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A Correlation Study between Dengue Incidence and Climatological Factors in the Philippines

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Abstract

Dengue is a viral mosquito-borne infection transmitted primarily by the *Aedes* mosquitoes. It is one of the several emerging tropical diseases which progressively spread geographically to virtually all tropical countries like the Philippines. Recent climate changes related to global warming have increased the potential risk of dengue outbreaks in the world. In this paper, we study and investigate temperature and precipitation as climatological factors affecting dengue incidence in the Philippines from the year 2015 to 2018. Monthly dengue cases and climate data were gathered for the said study period. A correlation and wavelet coherence analyses were performed to determine a relationship between dengue incidence and climatological factors in the Philippines. Results show that the amount of rainfall is strongly correlated to the increase of dengue cases in the country as compared to the temperature. Evidence shows that dengue incidence in the Philippines mostly occur during the rainy season. Thus, intensified surveillance and control of mosquitoes during the rainy season are recommended.

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1 Introduction

"Throughout human history, infectious diseases have caused debilitation and premature death to large portions of the human population, leading to serious social-economic concerns" [1]. "One of the most important infectious diseases is dengue, a major international public health concern with more than 55% of the world population at risk of acquiring the infection" [2]. "Dengue is a viral mosquito- borne infection transmitted by the *Aedes* mosquitoes" [3,4]. It is one of the several emerging tropical diseases which progressively spread geographically to virtually all tropical countries, like the Philippines [5]. "it is transmitted primarily by the bite of infected female mosquitoes *aedes aegypti*, but it also has been associated with other species such as *ae. Albopictus*, *ae. Polynesiensis*, and *ae. Scutellaris"* [6**]**.

"Dengue transmission requires four necessary conditions: susceptible humans, abundant vector, virus introduction, and conducive environment, like climate. Climate factors such as temperature, rainfall, and humidity influence the life stages of female adult *Aedes* mosquitoes" [7-11]. "In particular, the temperature has a strong influence on dengue transmission and the *Aedes* mosquito population" [8,10]. "In addition, rainfall provides plenty of breeding sites for mosquito vectors such as puddles, while humidity affects the adult mosquitoes' survival and biting frequency" [12]. "The amount of rainfall may affect the larval population size [11], and the rainfall pattern has a certain effect on the larval density" [13]. "Climate change impact factors are relevant to the mosquito population. Dengue incidences in Thailand, Taiwan, Singapore, and Brazil are associated with seasonal patterns in temperature, relative humidity, and rainfall" [14,15]. "Statistical approaches have revealed that these seasonal patterns play a significant role in dengue transmission" [8,16,17]. Therefore, the study about dengue incidence and climate factors in the Philippines from the year 2015 to 2018 was investigated to know the relationship of both variables.

2 Materials and Methods

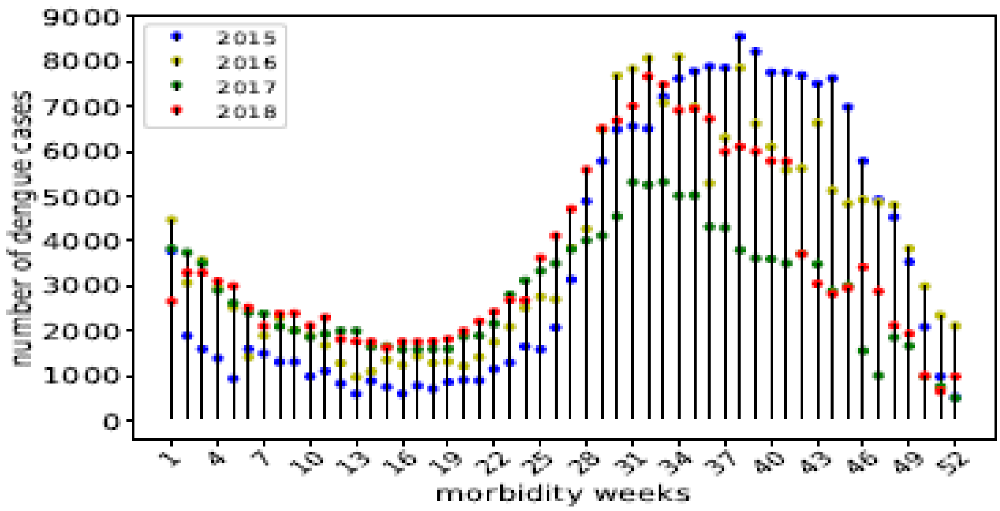
In this section, we present some relevant data informations needed in the study. These data include the weekly morbidity cases and monthly dengue incidence in the Philippines for the year 2015 to 2018, and the average monthly temperature and precipitation for the same study period. These data are requested through the Philippines' Freedom of Information (FOI) website [18] and can be accessed in [19].

2.1 Philippine epidemiological data

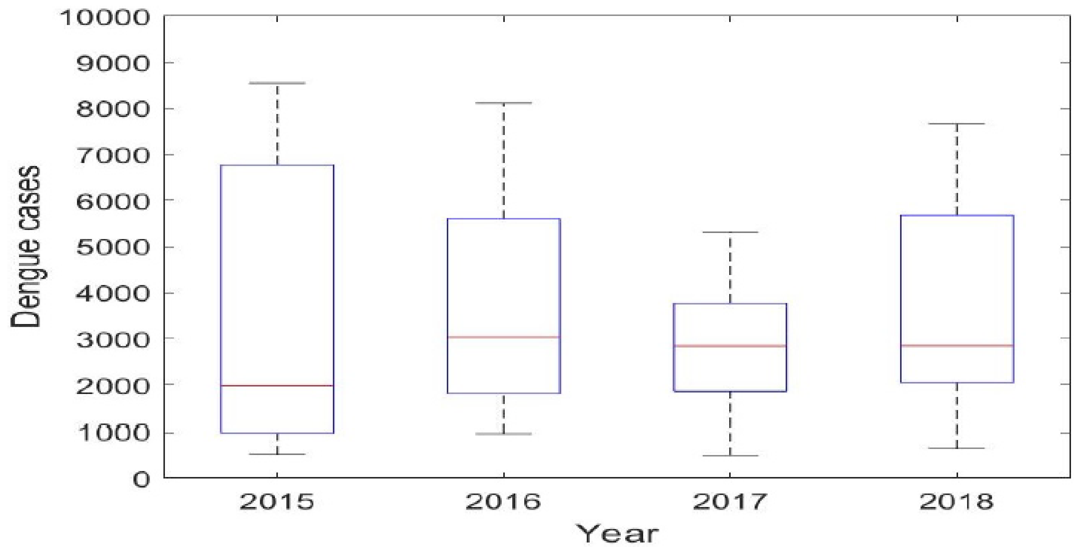
"Dengue cases by morbidity week in the Philippines for the year 2015 to 2018 were gathered. Data for these periods were requested from the Epidemiology Bureau, Public Health Surveillance Division of the Department of Health, Philippines" [20]. "The information was collected from the Philippine Integrated Disease Surveillance and Response System (PIDSR) National Database. For instance, Fig. 1 (a) depicts the reported dengue cases by morbidity week in the Philippines for the year 2015 to 2018 according to the data" given in [20-22]. The graph shows a decreasing trend of reported dengue cases during the first 16 weeks. Observe that for the four years, data show increasing pattern of dengue cases from the second week (around week 16), attaining a peak on the third quarter (around week 38), and decreasing towards the end of the year. Meanwhile, Fig. 1 (b) shows the annual distribution of dengue cases in the Philippines for the same study period. Dengue cases decreased from 198,273 cases in 2015 to 188,944 cases in 2016. The lowest number of dengue cases among the study period was recorded around the year 2017 with 148,480 cases, then gradually increases towards 2018 with 184,198 cases.

2.2 Philippine climatological data

Philippine climatological data for the same time period were next gathered from the Philippines' weather bureau PAGASA [23]. These data are archives of weather-related information collected from the 10 PAGASA Doppler radar stations and 44 PAGASA field offices all over the Philippines. These data are disseminated in various forms of media including on its official website. They are quality controlled and then archived in electronic databases. These archived datasets are made machine- readable to maximize their potential use, which also made them vulnerable for data mishandling, abuse, and exploitation [24]. Fig. 2 shows the graph of the average monthly temperature and precipitation for the year 2015 to 2018 based on the Philippine climatological data provided by [23]. The figure shows that the highest monthly average temperature recorded within the study period was 29.37˚C in the 20th week of 2016 around the month of May, which is the second hottest month of the year after April, followed by 29.02˚C in the same week and the same month of 2018. Meanwhile, the lowest monthly average temperature recorded was 25.27˚C in the 2nd week of 2015 around the month of January. The same figure shows that between the study period from 2015 to 2018, the highest average monthly precipitation recorded was 426.905 mm in the 25th week of 2016 around the monsoon month of June, while the smallest average monthly precipitation was 39.9916 mm in the 12th week of 2015 around the summer month of March.



(a) Philippine dengue cases by morbidity week for the year 2015−2018



(b) Annual distribution of Philippine dengue cases for the year 2015−2018

Fig. 1. (a) The reported Philippine dengue cases by morbidity week for the year 2015−2018. (b) The annual distribution of Philippine dengue cases for the year 2015−2018

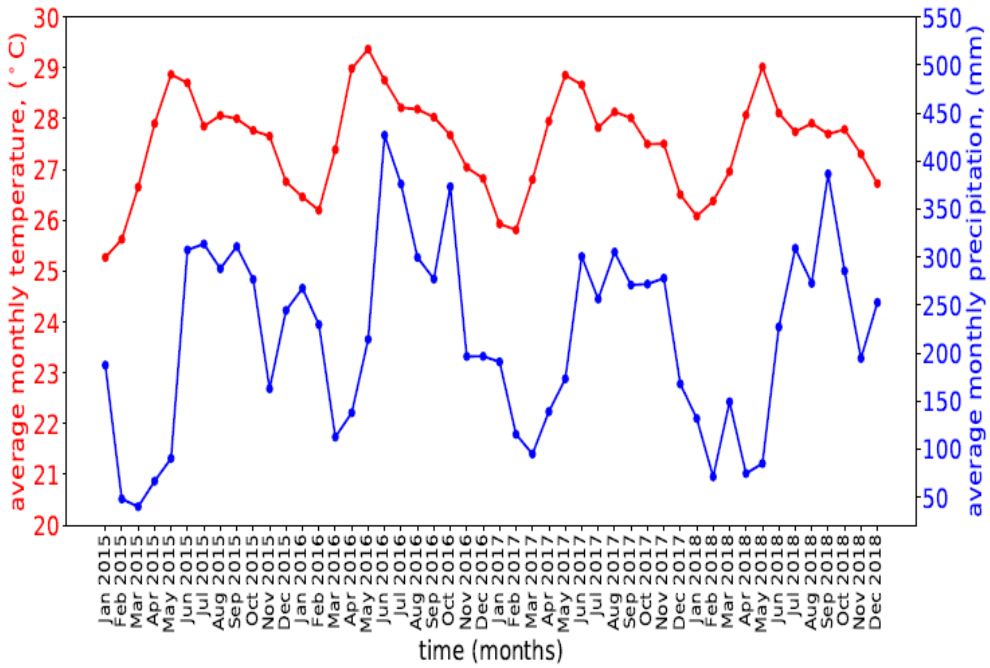


Fig. 2. The Philippine climatological data: average monthly temperature (red) and precipitation (blue) for the year 2015−2018

3 Results and Discussion

3.1 Seasonal variation of dengue incidence and climate factors

“Dengue disease has risen in an alarming state in the Philippines in recent years. Data from the Philippines’ Department of Health (DOH) reported an estimated suspected dengue cases of 84,085 in the country from January 1st to August 6th of 2016, which is 15.8% higher compared to the same period of last year in 2015 with only 72,627 reported cases, out of this, 372 resulted to death” [12]. “This alarming rate is partly due to several factors such as climatic condition, rapid urbanization, increasing population, and poor mosquito surveillance and control system, which all contributed to the increasing number of dengue cases in the country” [25,20]. In particular, Fig. 3 shows the dynamics of the number of dengue cases in the Philippines for the year 2015 2018 against the temperature and precipitation, respectively. The figure shows that the number of dengue cases decreases on relatively lower and higher temperatures which coincides during the colder and summer months of January to May, and increases on moderate temperatures which is around June to November. This is due to the fact that during the colder and summer months, the number of disease-carrying mosquitoes decreases due to increasing mosquitoes mortality rate. The same figure shows that the number of dengue cases also decreases during the dry season which is around the months of January to May, and increases during the rainy season which is around the months of June to November. This is because at dry season, droughts are commonly experienced in the country resulting to the drying of the breeding grounds of mosquitoes, while the rainy season promotes mosquito breeding. Meanwhile, a decrease on the number of dengue cases in the country is observed during the later part of the year. The main reason to this is the fact that at this time period in the Philippines, temperatures usually drop due to northeast monsoons which are experienced in the country as a cool northeast wind characterized by below moderate temperatures with little rainfall. In effect, mosquitoes less multiply during this time period in the country resulting to the decrease of their population.

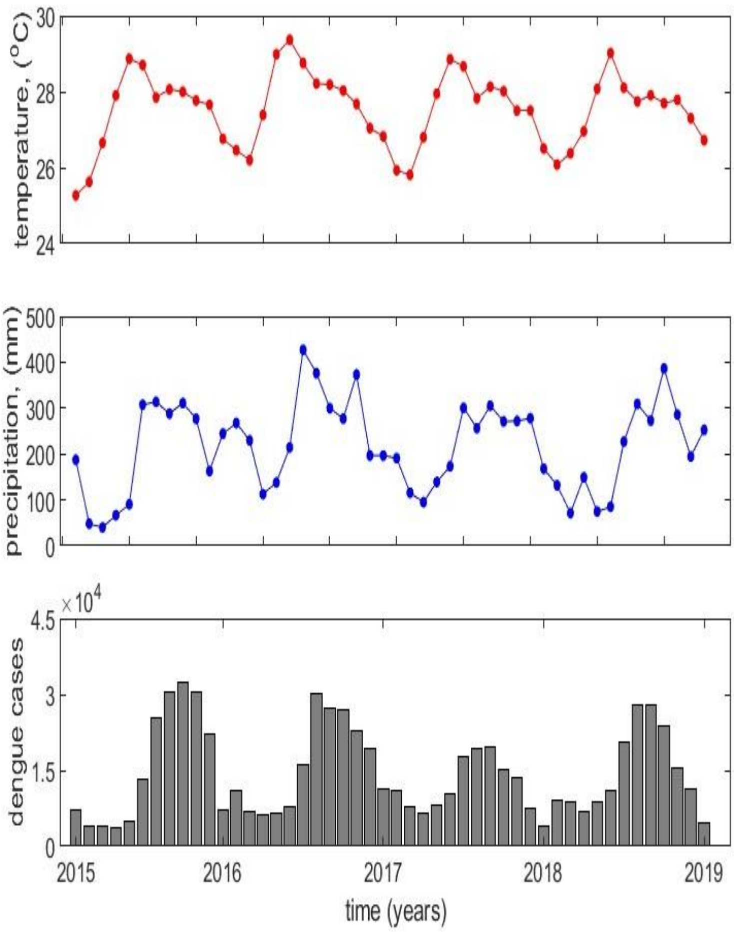


Fig. 3. Seasonal variation of the monthly dengue cases and the monthly average temperature and precipitation in the Philippines for the year 2015−2018

3.2 Correlation analysis

To investigate the result in Section 3.1, we compute the correlation between the monthly dengue cases and the monthly average temperature and precipitation for the year 2015 2018. This correlation is commonly used to measure the strength of an association between two variables. As the value of the correlation coefficient approaches 1, the relationship between the two variables becomes stronger, and the directions of the relationship are sign (+) and sign ( ), which indicate a positive and negative relationship, respectively. We carry out three measures of non-parametric rank correlations: Spearman's ρ, Kendall's τ , and Pearson's **p** rank correlation coefficients given by equatioins (3.1), (3.2), and (3.3), respectively.

$$\rho = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}} \tag{3.1}$$

$$\tau = \frac{C - D}{C + D} \tag{3.2}$$

$$\mathbf{p} = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \tag{3.3}$$

Where, *C* is the number of concordant pairs and *D* is the number of discordant pairs. We then compute the associated correlation coeffiecients using Matlab's (R2021b version) built-in spearmanr rank, kendalltau rank and pearsonp rank correlation functions. Fig. 4 shows the correlation matrix plot between the number of dengue cases and the temperature, and the number of dengue cases and precipitation, respectively, together with the Spearman (green), Kendall (red) and Pearson (black) correlation coefficients. The figure shows that both the monthly average temperature and precipitation, and the number of dengue cases exhibit positive relationship for the aforementioned years. However, of the two climatological factors, the average monthly precipitation and the number of dengue cases exhibits more positive correlation than the monthly average temperature and the number of dengue cases. Therefore, precipitaion contributes more on the occurence of dengue disease in the Philippines as compared to the temperature. Thus, intensified surveillance and control of mosquitoes during the rainy season are recommended.

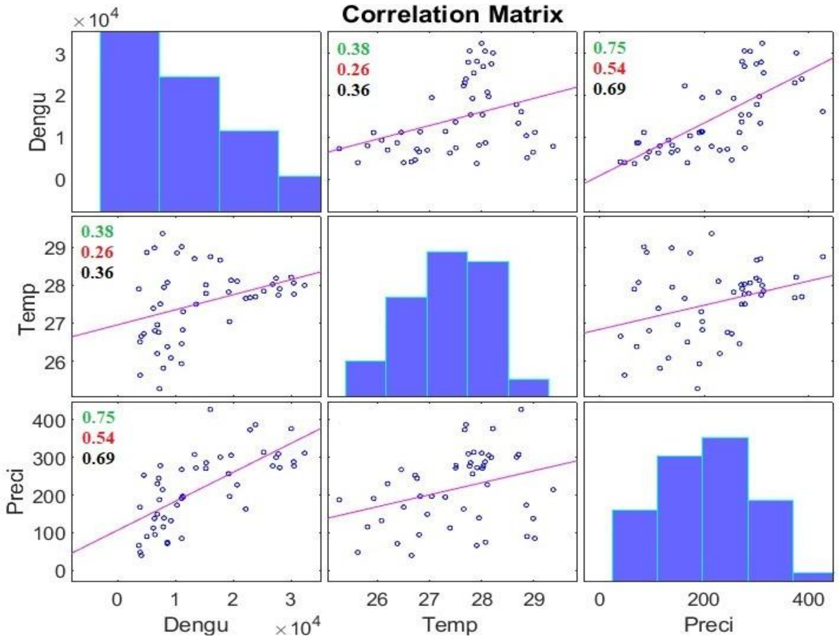


Fig. 4. Correlation matrix between the monthly dengue cases and the monthly average temperature and precipitation in the Philippines for the year 2015−2018

3.3 Wavelet coherence analysis

"Wavelet coherence analysis is a wavelet approach that extracts the time and frequency of a time series and it is the most efficient method in studying non-stationary data which transforms a time series into a wave" [26,27]. "It is also used to determine whether the presence of a particular periodic frequency at a given time in dengue incidences corresponded to the presence of the same periodic frequency at the same time in the given meteorological variables" [28].

We now use wavelet coherence analysis to detect changes in the periodicity between the number of dengue cases and local meteorological variables, namely, average temperature and precipitation. In Fig. 5, the coherence between the number of dengue cases and the local meteorological variables varied at different periods and the periodicity of the signals were different through time. The cone of influence (COI) shows the edge effects that became significant at different periodicities. Colors indicate the strength of the coherence, with red areas are highly significant at the 95% level against red noise, and blue areas are not significant at all. For the number of dengue cases and the average temperature, there were significant periodicities detected in the 1−3-month band in the year 2017, 5−6-month and 8−12-month bands between the year 2015−2017 (Fig. 5). Likewise, for the number of dengue cases and the average precipitation, wavelet analysis showed a significant 5−7-month periodicity band between the year 2015−2016 and an 8−12-month periodicity band between the year 2015−2017. There were also some mild periodicities detected at 2−3-month band periods that appear in an occasional pattern (Fig. 6).

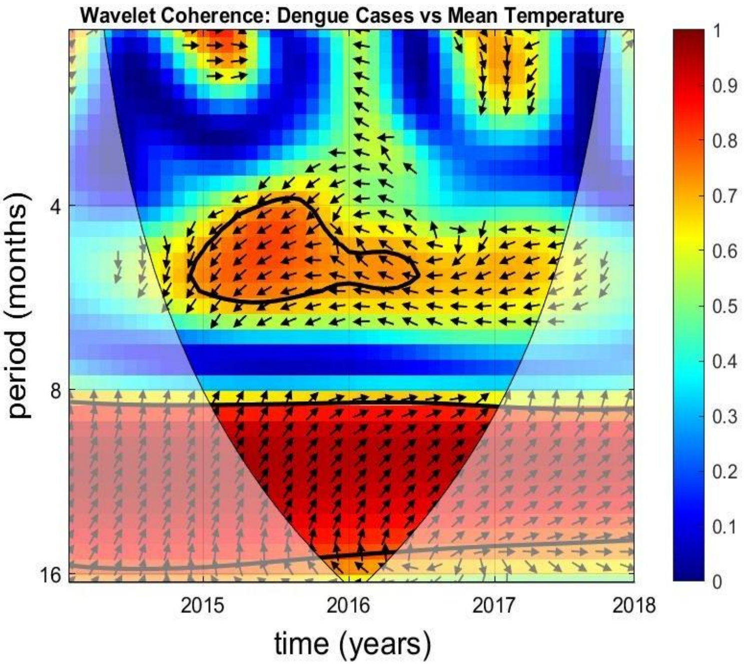


Fig. 5. Wavelet coherence analysis between the number of dengue cases and the average temperature (°C)

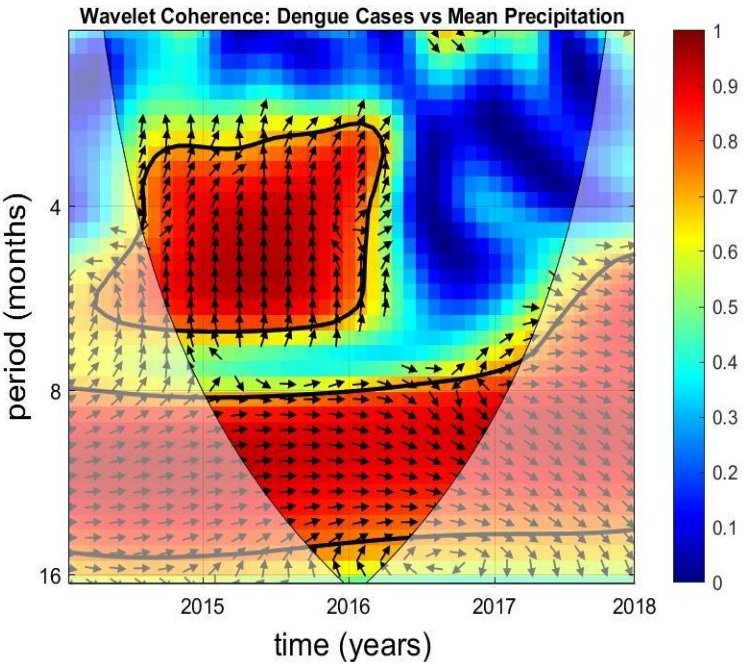


Fig. 6. Wavelet coherence analysis between the number of dengue cases and the average precipitation (mm)

Directions of the arrows indicate the degree to which the number of dengue cases and the local meteorological variables are in phase. In Fig. 5, the average temperature is leading against the number of dengue cases in the 1−3-month band, 5−6-month band, and 8−12-month band as depicted by the right-down, left-down and right-up arrows. That is, an increase in the number of dengue cases was observed first before an increase in temperature in the aforementioned periodicity bands. Meanwhile, Fig. 6 shows that in the 5−7-month periodicity band, the number of dengue cases is lagging against the average precipitation by one fourth of the cycle at that period as depicted by the up arrows. The same figure shows that in the 8−12-month periodicity band, the number of dengue cases and the average precipitation are perfectly in phase as depicted by the right arrows. Hence, the increase on the number of dengue cases are largely attributed to the increase on the average amount of rainfall at the aforementioned months.

4 Conclusion

Climate plays a significant role in the dynamics of dengue disease transmission. It affects the lifecycle and biting behavior of mosquitoes. In this study, we investigated the correlation between dengue cases and climatological factors in the Philippines from the year 2015 to 2018. The presented paper is relevant, because the fight against the dengue epidemic is not removed from the agenda of the Philippines, as it is for many countries with a humid and hot climate. The epidemic modeling methodology in this work is based on the correlation approach in combination with wavelet analysis. This methodology has became normative for modeling epidemics, the source of which is the mosquito factor, as evidenced by the articles of authors from Vietnam, Indonesia, Sri Lanka and other tropical countries. Therefore, the obtained results, such as the positive correlation between the level of diseases and the average monthly temperature and the level of precipitation look completely natural and do not raise doubts about their reliability. However, on the other hand, this kind of connection is common knowledge. More interesting is the result of the simulation, according to which the level of precipitation has a more significant effect on the level of diseases than the average monthly temperature. As the results show, risks were particularly higher in climatological events with high amount of rainfall. Thus, intensified surveillance and preventive measures during the rainy season must be introduced to local communities in order to deal with the mitigation of dengue cases in the country.

On the basis of wavelet analysis, results showed the seasonal cyclist of the dynamics of dengue diseases. Disease surveillance and control of mosquitoes including the use of a machine learning- based methodology which is capable of providing forecast estimates of dengue prediction in the country, the creation of diagnostic centers that will facilitate the disease surveillance, and an integrated approach that combines environmental management, chemical control, and biological methods in the control of mosquitoes [29] must be implemented. Hence, the observed wavelet analysis of these climatological variables can be integrated into these disease surveillance and vector control measures to enhance dengue prediction for better vector control and management in the future. Thus, the transmission of dengue fever brought about by the mosquitoes can be reduced.

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Competing Interests

Authors have declared that no competing interests exist.

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