Correlation between incidence of dengue and climatic factors in the Philippines: An ecological study

Ann Kashmer D. Yu, Sophia Isabel E. Ytienza, Airees Mae D. Yu, Vincent Christopher S. Yu, Keith Alexius K. Wangkay, Maria Antonia R. Wong, Marielle Alyanna B. Zamudio, Eljine Mae T. Zhang, Wally D. Yumul, Zakhira Maye R. Zipagan, Arianna Krystelle R. Yaranon, Jake Byron C. Zapanta, Gija B. Ysip, and Catherine Danielle Duque-Lee, MD, MMHA

Abstract

Introduction Dengue continues to be a major health concern in the Philippines. This study aimed to establish trends and correlations between the incidence of dengue and rainfall, humidity and temperature, respectively, in the different regions.

Methods Using 2018 records obtained from DOH and PAGASA, correlations were made between monthly measurements of climatic factors and the incidence of dengue using Pearson's r, while maps and interpolations were generated using quantum geographical information system software.

Results There was a significant positive but weak correlation between the incidence of dengue and rainfall (r = 0.379, 95% CI 0.255, 0.491; p < 0.001) and humidity (r = 0.215, 95% CI 0.080, 0.342; p = 0.002). There was a significant negative but weak correlation between the incidence of dengue and temperature (r = -0.145, 95% CI -0.277, -0.008; p = 0.039). A strong positive correlation was noted between the incidence of dengue, and rainfall and humidity, respectively, in several regions. Multiple regression indicates that rainfall, humidity and temperature are poor predictors of the incidence of dengue (R^2 = 0.1436, 0.0461 and 0.0209, respectively).

Conclusion This study showed overall a significant but weak correlation between an increased incidence of dengue and heavy rainfalls and high relative humidity, and a weak negative correlation for temperature. A high positive correlation of an increased incidence of dengue and heavy rainfalls and high relative humidity was observed in several regions.

Keywords: Dengue, rainfall, temperature, humidity, correlation

Dengue is a major public health concern mainly in tropical and subtropical parts of the world with two-fifths of the world's population at risk to its clinical manifestations and lethal complications. Reports indicate that there are about 50-100 million reported cases of this disease every year.[1] The Philippines as a tropical country has a high incidence of dengue. Recent studies have shown that climatic factors such as temperature, humidity, and rainfall influence the distribution of the incidence of dengue.[2] Despite the growing concern for the disease, there

* Presented in the 22nd Annual Research Forum, November 25, 2020 (online), UERMMMCI Research Institute for Health Sciences; recipient of the Dean Fernando S. Sanchez, Jr. Research and Publication Award

Correspondence:
Catherine Danielle Duque-Lee, MD, MMHA, Department of Preventive and Community Medicine, College of Medicine, University of the East Ramon Magsaysay Memorial Medical Center Inc., 64 Aurora Boulevard, Barangay Doña Imelda, Quezon City, PH 1113; e-mail: crduque-lee@uerm.edu.ph

have been limited local studies on the relationship between the number of dengue cases and these climatic factors.[3] Majority of the international studies have concluded that these climatic factors are related with the dengue case incidence while a significant minority have suggested otherwise.[4-6]

To contribute to the growing area of research on dengue, the researchers used the Quantum Geographic Information System (QGIS) as an innovative tool to develop alternative means in conducting epidemiological studies, to advance the knowledge and understanding among high-risk communities, and to encourage further promotion and implementation of laws and healthcare programs to raise awareness for dengue.[7] This is an analytic time-trend type of ecological study because the study is not only looking into dengue incidence over time in the different regions but it is also the ecological association between climatic changes over time and dengue incidence across the regions. This study aimed to establish a correlation between the incidence of dengue cases and the predisposing climatic factors observed across the regions.

The specific objectives of the study were to determine recorded monthly and annual climatic data per region and to determine recorded monthly and annual number of dengue cases in. The study then aimed to determine the correlation between these variables through linear regression. In addition, the study also aimed to create a geographical map using the QGIS software to illustrate patterns of correlation among the variables at a regional level of assessment.

Methods

This was an analytical time-trend type ecological study that determined relationship between the number of dengue cases and climatic factors temperature, relative humidity and average rainfall in the 17 regions of the country in 2018. The number of dengue cases per region was obtained from the Department of Health (DOH) database.[10] Information on the annual and monthly climatic readings were obtained from 51 out of 58 Surface Synoptic Stations of Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA).

The incidence of dengue was defined as the number of individual cases per 100,000 population, as recorded in the DOH database.[10] All the data on dengue cases retrieved from the DOH database were included in this study, including the regional and provincial data records of dengue cases and deaths. Data was available for all 17 regions. The climatic factors considered were temperature (°C), relative humidity (%) and average rainfall (mm/m^2). Information about the annual and monthly climatic readings were provided by the active stations of PAGASA. Among the 58 Surface Synoptic Stations (SYNOP) of PAGASA, 54 stations (93.1%) were active in 2018; the inactive stations were excluded.[9] Three more stations were excluded due to missing readings for either temperature or humidity. All 17 regions of the country were included in this study. The SYNOP is a representative station located in certain cities per region where all meteorological elements are measured at fixed observation times; collated data are submitted to the PAGASA Central Office.[11] The climatic records used in this study were from the PAGASA Central Office.

IBM SPSS Statistics software was utilized for statistical analyses with regards to the correlation between incidence of dengue and climatic factors. Pearson's correlation coefficient was used to measure the strength of association among variables, and the value of r determined the direction of the correlation. Results were interpreted as positively correlated if the value was in the positive range or towards +1; no relationship, if the value was 0; and negatively correlated if the value was in the negative range or towards -1. Multiple regression was used to assess the effectiveness of all climatic factors as predictors for the incidence of dengue cases. The Quantum Geographic Information System (QGIS) was used to create representative maps to provide information on correlations between the incidence of dengue and the climatic factors as a form of geospatial analysis. In order to visually appreciate possible correlations, an increasing magnitude of the independent variables were assigned with representative patterns using a 4 x 4 legend with two-dimensional axes (e.g., Figure 12).

This study was approved by the Ethics Review Committee of the UERMMMCI Research Institute for Health Sciences. Permission was obtained from the DOH and PAGASA for the retrieval and use of the data on dengue and climatic factors, respectively, in accordance with the Data Privacy Act.[12]

Results

Figure 1 shows that the Ilocos (Region I) and Cagayan (Region II) provinces, the Cordillera Autonomous Region (CAR) and MIMAROPA (Region IV-B) had the highest incidence of dengue in Luzon. Central Visayas (Region VII) and Northern Mindanao (Region X) had the highest incidence in the rest of the country. The Autonomous Region in Muslim Mindanao (ARMM) and the Bicol provinces (Region V) had the lowest incidence of dengue in the country. Figure 2 shows that the incidence of dengue was highest during the second half of the year. The peak for the Northern Luzon provinces (Region I, II and CAR) was July to October while the Zamboanga provinces and Northern Mindanao had a bimodal peak.

As shown in Figure 3, there was a wide variation in rainfall in the different regions. In 2018, the Ilocos provinces (Region I) had the highest mean rainfall at 956.72 mm/m^2 followed by CAR (815.39 mm/m^2) with a peak in August. Several regions had high levels of rainfall from June to September. Eastern

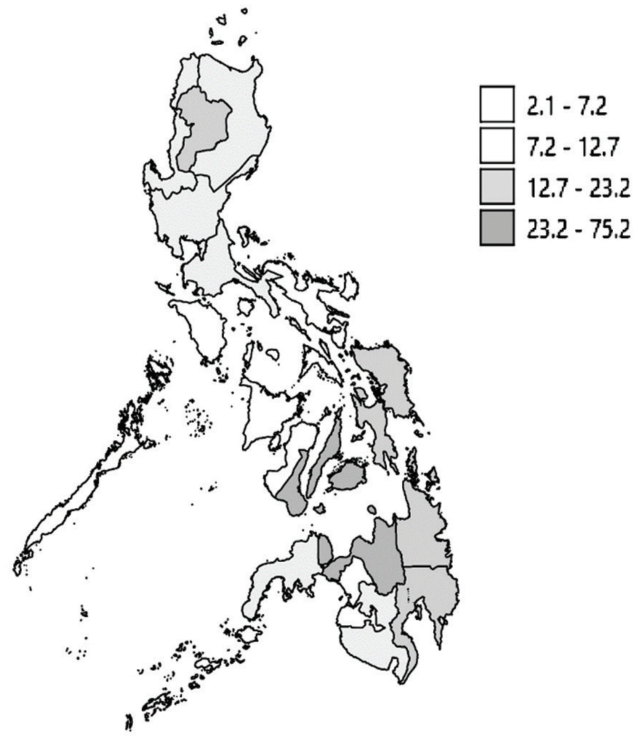

Figure 1. Regional incidence of dengue per 100,000 population

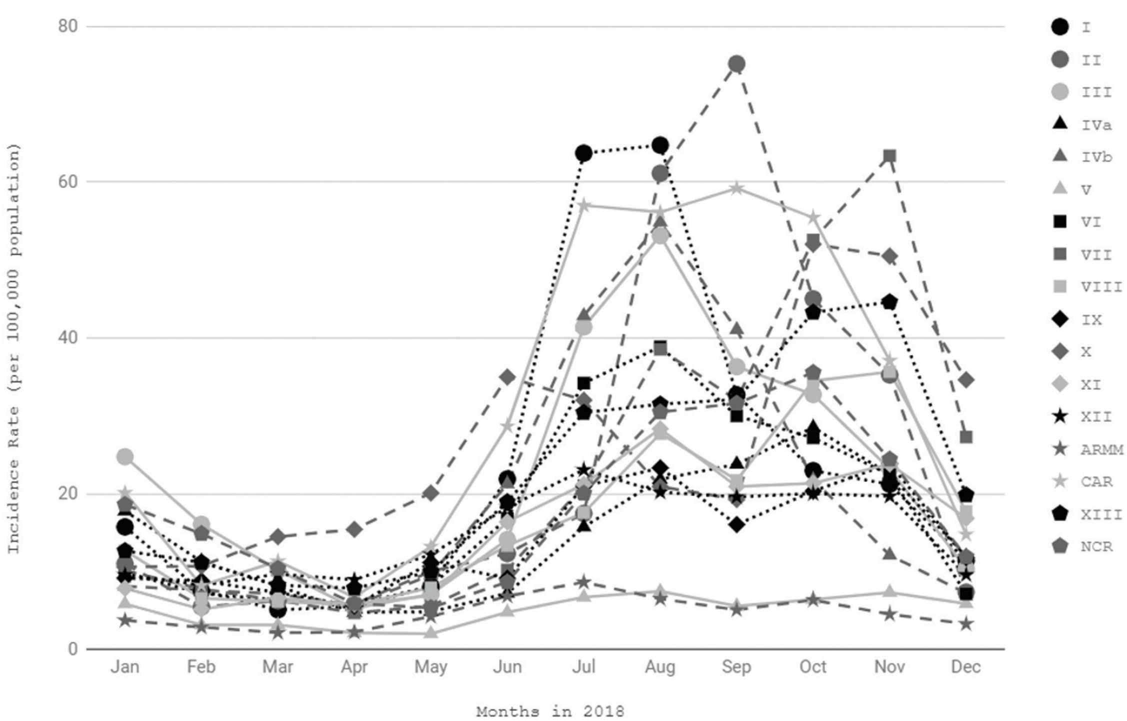

Figure 2. Monthly incidence of dengue in the Philippines by region.

Visayas (Region VIII) and the Bicol area (Region V) had their peak rainfall around December-January (768.33 and 696.44 mm/m^2, respectively). The mean relative humidity ranged from 60.5 to 88.7% and was highest in August, as shown in Figure 4. Region XII SOCCSKARGEN and ARMM had the lowest humidity. The mean temperature range was 24.4–29.8°C with a peak in May as seen in Figure 5. January was the coldest month of the year.

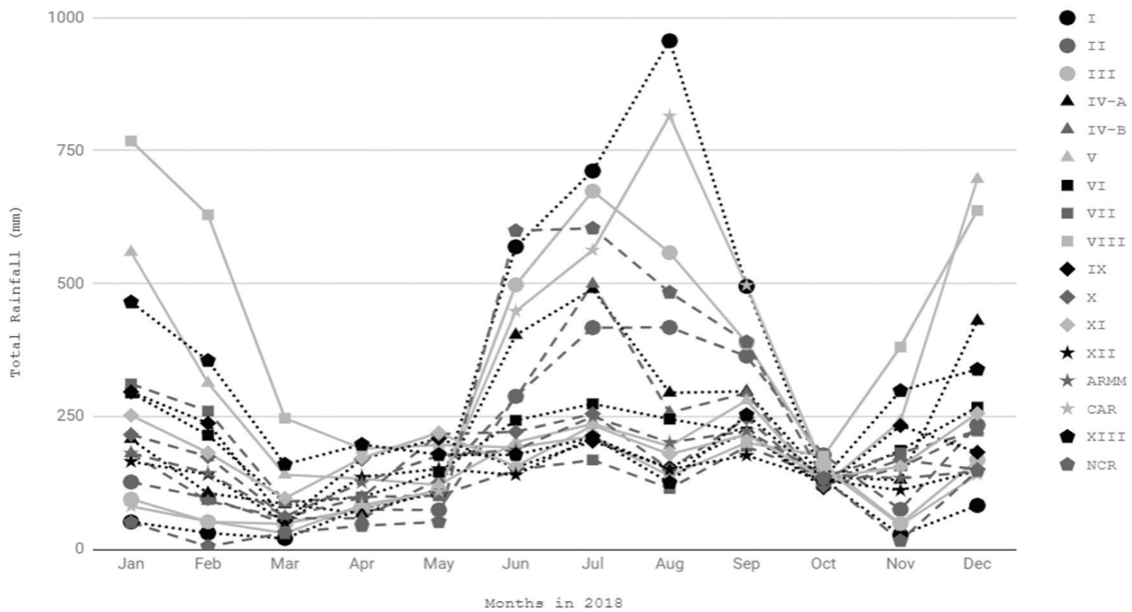

Figure 3. Monthly total rainfall (mm/m^2) in the Philippines by region.

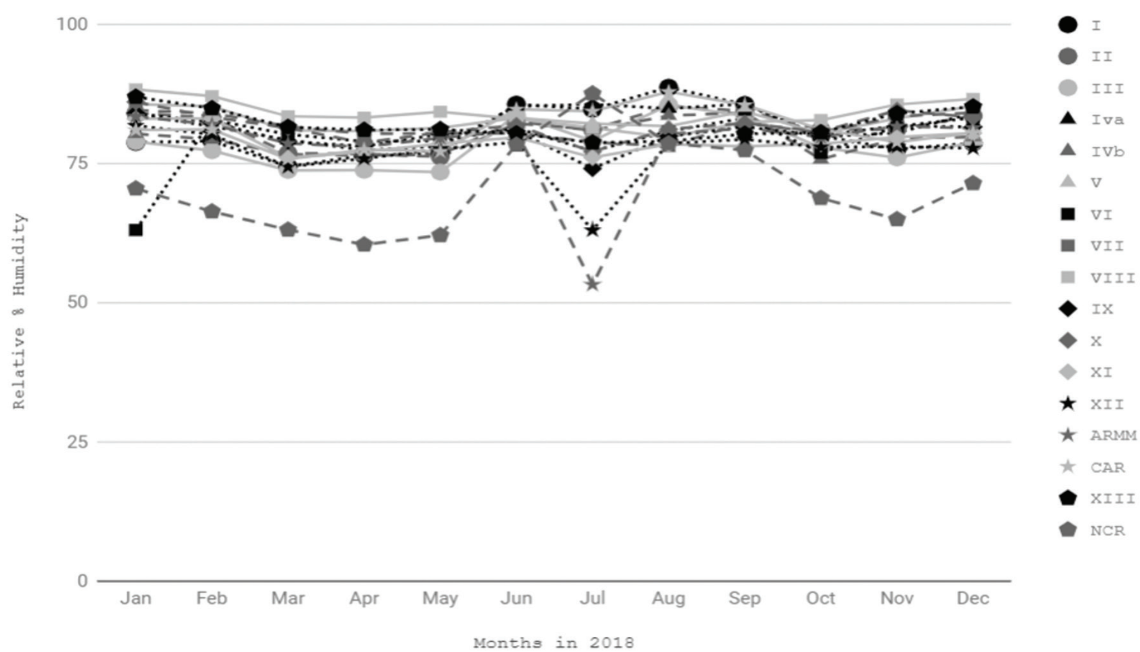

Figure 4. Monthly relative humidity (%) in the Philippines by region.

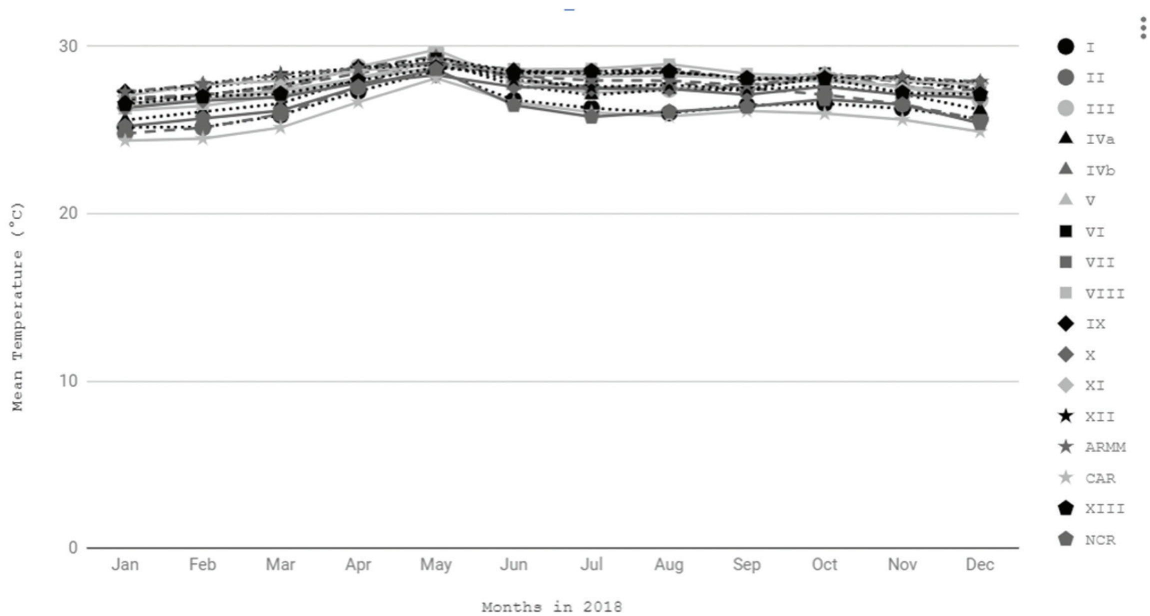

Figure 5. Monthly mean temperature (°C) in the Philippines by region.

As shown in Figure 6, the incidence of dengue paralleled the amount of rainfall for the previous month: an increase in rainfall in May was accompanied by an increase in dengue cases in June. As the rainfall increased from April to July, the incidence of dengue also increased from May to August. A similar pattern was observed for dengue and humidity, as seen in Figure 7, but not for dengue and temperature (Figure 8). Statistical analysis revealed a significant positive but weak correlation between the incidence of dengue and rainfall ($r = 0.379$, 95% CI 0.255, 0.491; $p < 0.001$) and humidity ($r = 0.215$, 95% CI 0.080, 0.342; $p = 0.002$). There was a significant negative but weak correlation between the incidence of dengue and temperature ($r = -0.145$, 95% CI -0.277, -0.008; $p = 0.039$) as seen in Table 1. A strong positive correlation was noted between the incidence of dengue, and rainfall and humidity, respectively, in the Northern Luzon regions, ARMM and Region IV-B. Multiple regression as shown in Figures 9 to 11 indicates that rainfall, humidity and temperature are poor predictors of the incidence of dengue ($R^2 = 0.1436$, 0.0461 and 0.0209, respectively).

Figure 12 depicts the incidence rate of dengue and rainfall through bivariate analysis in map form for July and March. The maps provide a representation of the degree of relationship between the compared variables. The pattern-legend indicated on each figure can be used as a guide to understand the magnitudes between dengue incidence and rainfall, simultaneously. The varying patterns arranged from left to right represent an increasing incidence of dengue while the patterns from top to bottom represent an increasing mean rainfall. The map for July shows the highest rainfall and incidence of dengue in the western part of Luzon, MIMAROPA, Western Visayas and Northern Mindanao.

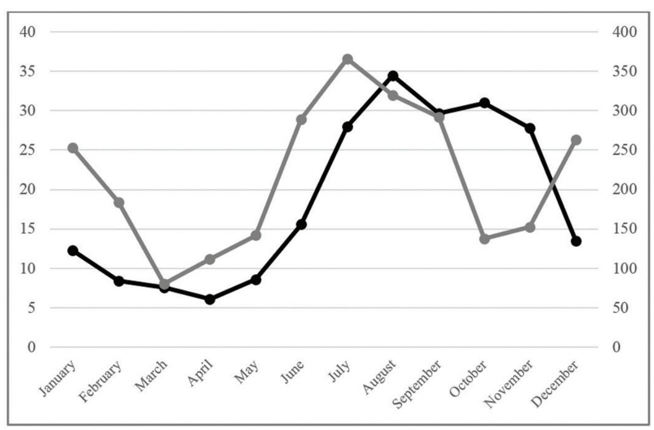

Figure 6. Mean incidence of dengue (black) vs rainfall (gray) by month (x-axis); left-hand y-axis is incidence per 100,000 population; right-hand y-axis is rainfall (mm/m^2)

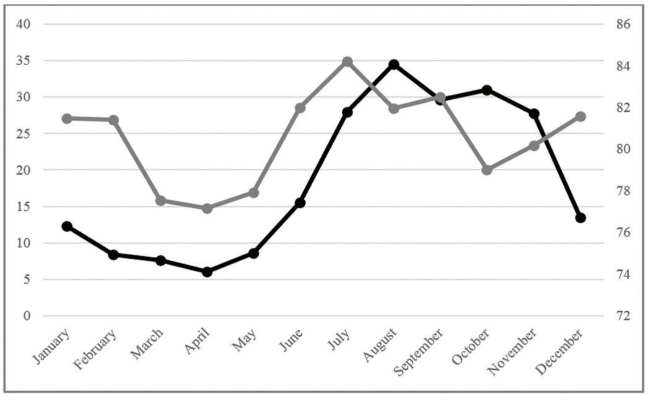

Figure 7. Mean incidence of dengue (black) vs humidity (gray) by month (x-axis); left-hand y-axis is incidence per 100,000 population; right-hand y-axis is relative humidity (%)

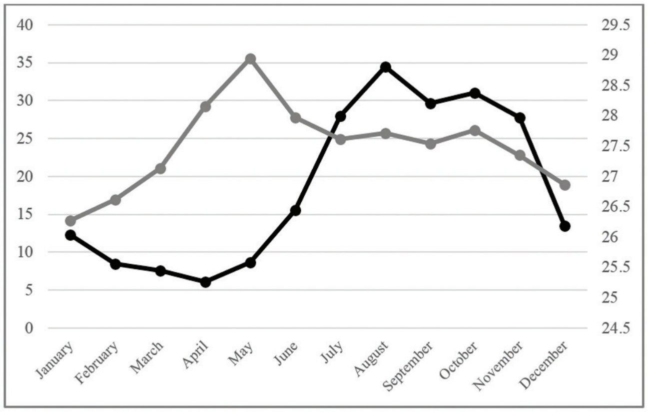

Figure 8. Mean incidence of dengue (black) vs temperature (gray) by month (x-axis); left-hand y-axis is incidence per 100,000 population; right-hand y-axis is temperature (oC)

Table 1. Correlation of incidence of dengue and climatic factors by region.

Region	Rainfall	Humidity	Temperature
Aggregate	0.379, 95% CI 0.255, 0.492, p < 0.001	0.215, 95% CI 0.080, 0.342, p = 0.002	-0.145, 95% CI -0.277, -0.008, p = 0.039
ARMM	0.753, 95% CI 0.315, 0.927, p = 0.005	-0.574, 95% CI -0.863, 0.000, p = 0.051	-0.094, 95% CI -0.634, 0.507, p = 0.772
CAR	0.730, 95% CI 0.269, 0.919, p = 0.007	0.733, 95% CI 0.275, 0.920, p = 0.007	0.120,95% CI -0.487, 0.649, p = 0.709
NCR	0.246, 95% CI -0.382, 0.718, p = 0.441	0.406, 95% CI -0.219, 0.795, p = 0.191	-0.280, 95% CI -0.736, 0.350, p = 0.378
Region I	0.900, 95% CI 0.674, 0.972, p < 0.001	0.830, 95% CI 0.489, 0.951, p = 0.001	-0.098, 95% CI -0.636, 0.504, p = 0.762
Region II	0.570, 95% CI -0.006, 0.862, p = 0.053	0.500, 95% CI -0.104, 0.834, p = 0.098	0.462, 95% CI -0.152, 0.819, p = 0.462
Region III	0.683, 95% CI 0.179, 0.903, p = 0.014	0.687, 95% CI 0.187, 0.904, p = 0.014	-0.319, 95% CI -0.755, 0.312, p = 0.311
Region IV-A	0.113, 95% CI -0.493, 0.645, p = 0.726	0.346, 95% CI -0.284, 0.768, p = 0.271	-0.193, 95% CI -0.690, 0.428, p = 0.547
Region IV-B	0.718, 95% CI 0.245, 0.915, p = 0.009	0.691, 95% CI 0.194, 0.906, p = 0.013	-0.119, 95% CI -0.649, 0.488, p = 0.713
Region V	0.286, 95% CI -0.344, 0.739, p = 0.367	0.188, 95% CI -0.433, 0.688, p = 0.559	-0.032, 95% CI -0.552, 0.595, p = 0.922
Region VI	0.314, 95% CI -0.317, 0.752, p = 0.321	0.104, 95% CI -0.500, 0.640, p = 0.749	0.271, 95% CI -0.359, 0.731, p = 0.394
Region VII	-0.001, 95% CI -0.573, 0.575, p = 0.997	-0.014, 95% CI -0.564, 0.583, p = 0.965	-0.005, 95% CI -0.571, 0.577, p = 0.987
Region VIII	-0.196, 95% CI -0.692, 0.426, p = 0.542	-0.272, 95% CI -0.732, 0.358, p = 0.392	0.237, 95% CI -0.390, 0.714, p = 0.458
Region IX	0.069, 95% CI -0.526, 0.618, p = 0.831	-0.203, 95% CI -0.696, 0.420, p = 0.527	0.064, 95% CI -0.529, 0.615, p = 0.843
Region X	0.000, 95% CI -0.574, 0.574, p = 0.999	-0.054, 95% CI -0.609, 0.537, p = 0.869	0.240, 95% CI -0.387, 0.715, p = 0.453
Region XI	0.009, 95% CI -0.567, 0.580, p = 0.979	-0.222, 95% CI -0.706, 0.405, p = 0.488	0.100, 95% CI -0.503, 0.736, p = 0.757
Region XII	-0.495, 95% CI -0.832, 0.110, p = 0.102	-0.057, 95% CI -0.611, 0.534, p = 0.859	-0.265, 95% CI -0.728, 0.364, p = 0.405
Region XIII	-0.785, 95% CI -0.937, -0.384, p = 0.002	-0.895, 95% CI -0.970, -0.660, p < 0.001	0.230, 95% CI -0.396, 0.710, p = 0.472

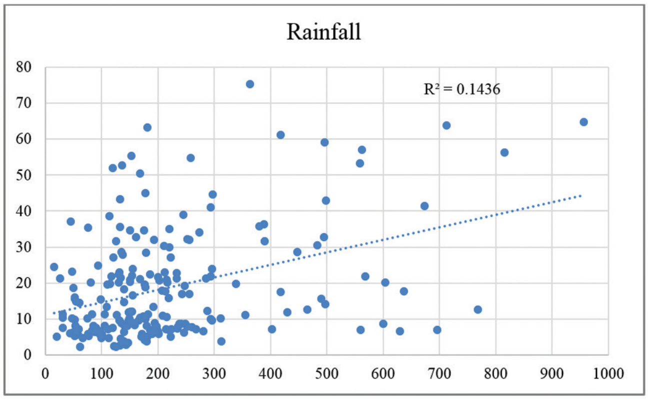

Figure 9. Correlation of incidence of dengue per 100,000 population and rainfall (mm/m^2)

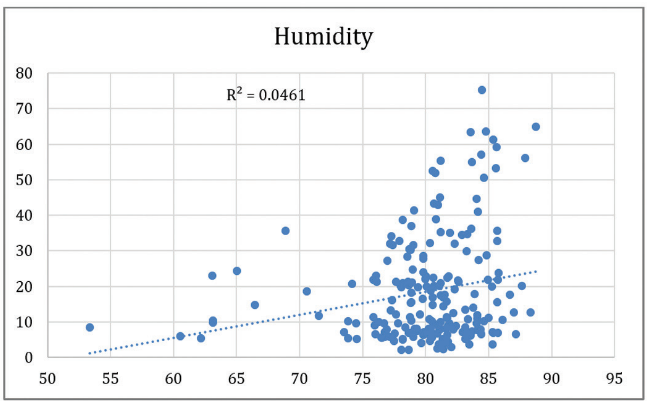

Figure 10. Correlation of incidence of dengue per 100,000 population and relative humidity (%)

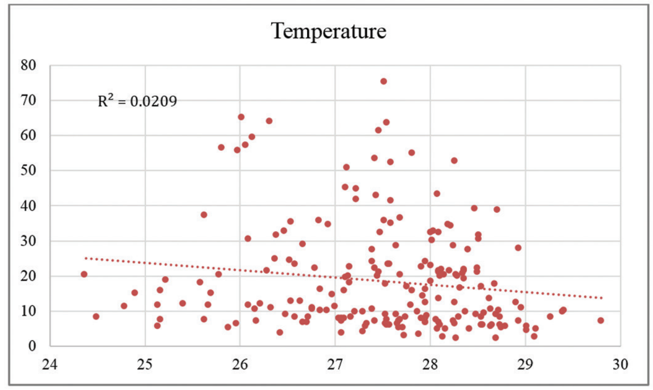

Figure 11. Correlation of incidence of dengue per 100,000 population with temperature (°C)

Discussion

The incidence of dengue—being a mosquito-borne disease —is expected to be dependent on the life cycle of its vector, Aedes. As previously mentioned, rainfall, humidity, and temperature are expected to contribute to the progression of its life cycle. This study observed an increasing incidence of dengue cases during the typical rainy season in the Philippines (June to September) but not from October to December. The results showed a weak correlation between the incidence of dengue with heavy rainfall and high relative humidity, respectively. However,

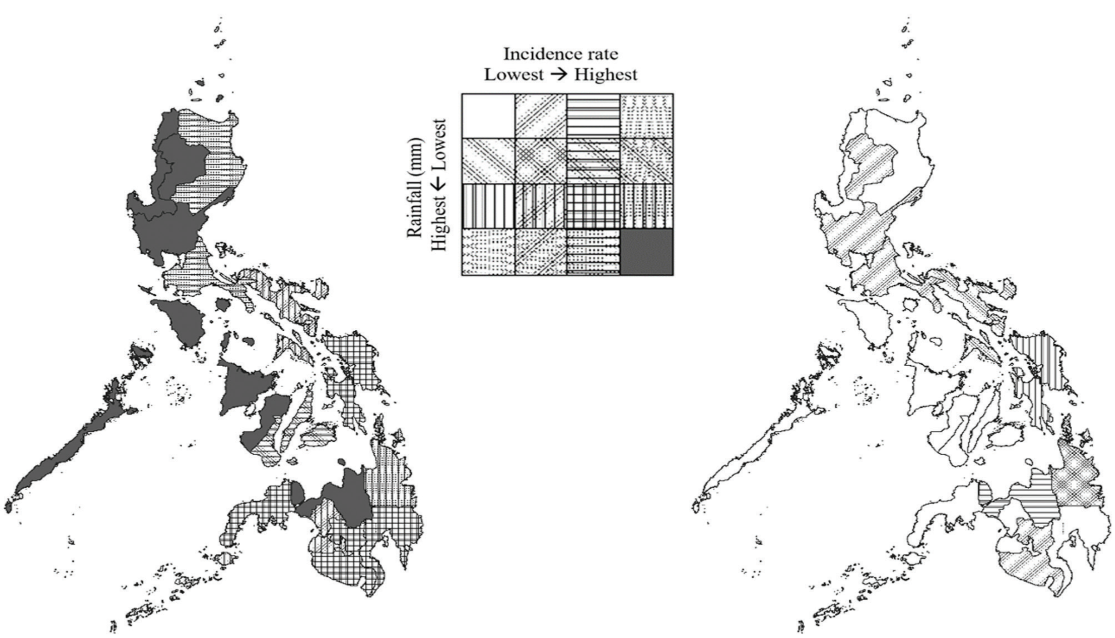

Figure 12. QGIS map showing rainfall and incidence of dengue in the different regions in July (left) and March (right)

the negative correlation between the incidence of dengue and temperature is not in accordance with most studies in Southeast Asia which reported that a higher temperature resulted in an increased population growth of *Aedes aegypti* and the transmission of the dengue virus.[14] A possible explanation for the findings is that both mosquito vectors of *Aedes aegypti* and *Aedes albopictus* are found here in the Philippines with the former breeding in both indoors and outdoors, and the latter breeding mostly in outdoors and is more adaptable to changes in temperature.[15] Hence, it may be that some regions may have more of *Aedes albopictus* resulting in the less significant impact of temperature on the incidence of dengue compared with the regions having less of the vector. However, no available literature has been published on which specific regions in the Philippines have *Aedes albopictus* as the more predominant specie and hence, such assumptions are difficult to ascertain. It is also possible that the recorded range of temperature in this study may have had no effect on the vectors as this may be the ideal functioning range in terms of *Aedes albopictus*' biology.

The results are consistent with studies which observed that heavy rainfall led to an increased transmission of dengue virus as it created abundant outdoor breeding places, but are not in consonance with studies concluding that heavy rainfall led to reduced survival of the mosquito, translating into a lower incidence of dengue.[16,17] In addition, the results showed a lag period between the increased rainfall and higher relative humidity, and dengue incidence, where the increase in rainfall and humidity preceded the rise in incidence (Figures 6 & 7). This may be attributed to the lag phase of the vectors' growth cycle after the appearance of a favorable breeding environment. This might also explain a weaker correlation than expected with dengue incidence versus the climatic factors on a monthly basis.

This study showed strong correlation of the increased incidence of dengue with heavy rainfall and higher relative humidity, respectively, in Regions I, III, IV-B and CAR, and a strong negative correlation in Region XIII. The different finding in Region XIII is difficult to ascertain given only the information of its climatic factors. As mentioned, negative correlations for humidity and rainfall were noted in parts of the Visayas and Mindanao, indicating that there may be a common factor in these regions that may explain the data. It may be helpful to see the correlations of the same variables in previous years to determine if a similar trend will be observed as the present study was limited to a one-year observation period.

The maps produced from QGIS mapping software provided a visual representation of the correlations observed allowing an instant visual identification and demarcation of regions at risk of having a high incidence of dengue cases. There were several limitations in this study such as the number of active PAGASA stations per province and the dengue serotype classifications. Confounding factors such as population density, topographical differences, health policies and education among the regions may have resulted in current findings. Differences in the biology and perhaps even adaptations of the mosquito-vectors may have altered the expected results, specifically for temperature. Given the seasonal variation in the incidence of dengue, a time-series analysis rather than multiple regression would have shown a more precise relationship between dengue and the climatic factors studied

This study showed that overall, there is a significant but weak positive correlation between an increased incidence of dengue, and heavy rainfall and high relative humidity, respectively, and a weak negative correlation for temperature. Strong positive correlations for both heavy rainfall and higher relative humidity were observed in Regions I, III, IV-B, and CAR, and a weak negative correlation was observed in Region XIII. Rainfall, humidity and temperature are poor predictors of dengue. The reader is advised to exercise caution in interpreting the results in this study so as to not to commit the fallacy of ecological interference, given that the aggregation of dengue incidence and climatic factors at a regional level would result in the loss or concealment of certain details of information which can only be observed at the provincial or city/municipality level.

Acknowledgements

The authors are very thankful to Mr. Ben Hur S. Pintor, a QGIS software expert from BNHR IT Solution, for rendering them time and effort in training and helping them learn about the QGIS mapping software. All his teachings, advice and reminders brought them to a higher learning experience. They also acknowledge the Department of Health and the Philippine Atmospheric, Geophysical and Astronomical Services Administration which were accommodating and responsive in providing them the necessary information needed for their study.

References

1. Longo DL, Fauci AS, Kasper DL, Hauser SL, Jameson J, Loscalzo J. eds. Harrison's Principles of Internal Medicine. 19th ed. New York, NY: McGraw-Hill; 2015.
2. Edillo F, Roble N, Otero N. The key breeding sites by pupal survey for dengue mosquito vectors, Aedes aegypti (Linnaeus) and Aedes albopictus (Skuse), in Guba, Cebu City, Philippines. SEA J Trop Med PH 2012; 43(6): 1365-74.
3. Bravo L, Roque VG, Brett J, Dizon R, L'Azou M. Epidemiology of dengue disease in the Philippines (2000–2011): A systematic literature review [Internet]. PLoS Negl Trop Dis 2014; 8(11): e3027. Available from: https://doi.org/10.1371/journal.pntd.0003027
4. Morin CW, Comrie AC, Ernst K. Climate and dengue transmission: Evidence and implications. Environ Health Perspect. 2013; 121(11-12): 1264–72. doi: 10.1289/ehp.1306556
5. Alto BW, Bettinardi D. Temperature and dengue virus infection in mosquitoes: independent effects on the immature and adult stages [Internet]. Am J Trop Med Hyg. 2013 Mar 6; 88(3): 497–505. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/ PMC3592531/.
6. Louis VR, Phalkey R, Horstick O, Ratanawong P, Wilder-Smith A, Tozan Y, Dambach P. Modeling tools for dengue risk mapping - a systematic review. Int J Health Geogr 2014; 13: 50. doi: 10.1186/1476-072X-13-50
7. Sia Su GL. Correlation of climatic factors and dengue incidence in Metro Manila, Philippines [Internet]. Ambio. 2008 Jun; 37(4): 292–4. Available from: http://doi.-org/10.1579/00447447(2008)37[292:COCFAD]2.0.CO;2
8. Climate of the Philippines [Internet]. Philippine Atmospheric, Geophysical and Astronomical Services Administration. [cited 2020 Nov 1]. Available from: http://bagong.pagasa.dost.gov.ph/information/climate-philippines
9. Mandate/Mission/Vision/Values/Functions. Citizen's Charter [Internet]. Philippine Atmospheric, Geophysical and Astronomical Services Administration. [cited 2020 Nov 1]. Available from: https://pubfiles.pagasa.dost.gov.ph/pagasaweb/files/PAGASA_Citizen's_Charter_signed_copy.pdf
10. Dengue [Internet]. Republic of the Philippines Department of Health. [cited 2019 Oct 08]. Available from: https://www.doh.gov.ph/Health-Advisory/Dengue
11. Field Station Categories [Internet]. Philippine Atmospheric, Geophysical and Astronomical Services Administration. [cited 2020 Nov 1]. Available from: http://bagong.pagasa.dost. gov.ph/information/field-station-categories
12. Republic Act 10173 – Data Privacy Act of 2012 [Internet]. National Privacy Commission. [cited 2019 Oct 08]. Available from: https://privacy.gov.ph/data-privacy-act/
13. Lai YH. The climatic factors affecting dengue fever outbreaks in southern Taiwan: an application of symbolic data analysis. Biomed Eng Online 2018; 17(Suppl 2): 148. doi: 10.1186/s12938-018-0575-4
14. Comparison on Dengue Vectors [Internet]. Centers for Disease Control and Prevention. [cited 2019 Oct 26] Available from: https://www.cdc.gov/dengue/resources/30jan2012/comparisondenguevectors.pdf
15. Bhatt S, Gething PW, Brady OJ, et al. The global distribution and burden of dengue. Nature. 2013 Apr 25; 496(7446): 504-7. doi: 10.1038/nature12060. Epub 2013 Apr 7.
16. Alshehri MSA. Dengue fever outburst and its relationship with climatic factors. World Appl Sci J 2013; 22(4): 506–15. doi: 10.5829/idosi.wasj.2013.22.04.443
17. Sociodemographic data [Internet]. Commission on Population and Development. [cited 2019 Oct 29] Available from: http://popcom.gov.ph/?fbclid=IwAR1LfiV7iyLb2C1SXjiQTEMPVuoMUyo1v70832ThpIjae_yOhbF_dZI1mm4