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Impact of weather parameters on the spread of dengue cases in Dhaka

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Abstract

Introduction: Dengue cases have increased extremely in recent years because of globalization, easy movement, population growth and urbanization, and climate change. Presently, dengue causes hundreds of daily dengue incidences and tens of human deaths in Dhaka. In this study, the impacts of weather parameters on the spread of dengue cases have been investigated for the city.

Methods: The daily dengue cases and weather parameter values are collected for the city from public repositories. From these daily data, per-week average values were calculated to observe their weekly variations. Six different lagged week data have been generated by combining weekly average dengue cases with cumulative lagged weekly average weather parameters. Spearman rank correlation and quasi-Poisson generalized linear model have been applied in the lagged week data to assess the impacts of weather parameters on dengue cases.

Results: A significant positive association for relative humidity and a negative association for wind pressure have been observed with dengue incidence. Also, stronger estimates have been examined for more cumulative lagged week weather parameter values with dengue incidence. July to October might be the sensitive season for dengue in the city for higher values of relative humidity and lower values of wind pressure.

Conclusions: Dhaka is one of the most densely populated cities in the world. Also, the dengue incidence in the city has increased remarkably in the last several years. The findings observed in this study might help the city's decision-makers to initiate necessary steps before the dengue outbreak occurs.

Take-home message: July to October might be the sensitive season for dengue outbreaks in Dhaka due to higher relative humidity and lower wind pressure values. This finding might help the city's decision-makers to initiate necessary steps before the seasonal dengue outbreak occurs.

Keywords: Dengue; Dhaka; quasi-Poisson generalized linear model; Spearman rank correlation; weather parameter.

INTRODUCTION

Dengue is a viral disease transmitted to humans through an infected mosquito bite [1]. The disease does not spread from person to person. Instead, when a mosquito bites an infected patient, it becomes a carrier and transmits dengue to others through bites. The disease affects all age groups and is caused by four genetically related viruses (DENV-1 to 4) [2, 3]. The geographic spread of the dengue virus and the dengue incidence have amplified in the last 50 years because of globalization, the expansion of travel and trade, population growth and urbanization, and climate change [4]. After the COVID-19 pandemic, dengue has become the most threatening infectious disease in many countries worldwide. Most dengue cases are found in Southeast Asian and Western Pacific nations (i.e., tropical and sub-tropical regions) for favorable weather conditions for mosquito population expansion [5,6]. Dengue fever can seriously decrease the life expectancy of individuals re-infected by another serotype by producing severe illnesses, including dengue hemorrhagic fever and dengue shock syndrome [7]. Hence, it is necessary to understand the effects of weather parameters on the spread of dengue cases in these areas. This can be an early warning system for implementing prevention strategies for dengue outbreaks [8].

Dengue fever was first identified in Bangladesh in 1964 [9], and then in 2000, it showed a severe threat to public health, causing a pandemic [10]. Recently, the country observed dengue outbreaks in 2018 and 2019 [8]. After that, the dengue incidence was not seen as high, and then, in 2022, the dengue outbreak and fatalities increased due to the presence of four subtypes of dengue viruses [1]. Bangladesh is now experiencing its worst-ever dengue outbreak in history in 2023, with hospitals packed with a large number of dengue patients and the death toll rising. Dhaka witnessed the highest prevalence of daily dengue patients and fatalities (https://old.dghs.gov.bd/index.php/bd/home/5200-daily-dengue-status-report). The major dengue outbreak in the urban regions, especially in Dhaka, may be due to high population density, improper development, inadequate surveillance operations, denial of dengue defensive behavior, and climatic change [1]. Dengue is spreading to more metropolitan cities in Bangladesh. Several studies have examined the relationships between the spread of dengue cases and weather parameters, including those of Dhaka [11,12]. Some believed that weather parameters affected the spread of dengue cases, while others rejected the role of weather parameters in transmitting dengue cases [13]. Various models have been developed to find associations between dengue cases and weather parameters. For example, one study applied correlation analyses between per week average weather parameter values and weekly dengue cases in Malaysia and found temperature and rain as risk factors for dengue outbreaks. Then, these factors were used as input to machine learning models to evaluate the results [14]. In the study, the authors claimed to identify a new risk factor by combining the lagged average minimum temperature of 5 weeks with the current week and lagged cumulative rainfall for 2 weeks before the current week. Recently, one study applied a count regression approach on daily data to find an association of climate factors on dengue incidence in Dhaka, Bangladesh, and found positive correlations of maximum and minimum temperature, humidity, and wind speed, while negative correlations of rainfall and sunshine hours with the dengue incidence [15]. Another study developed a generalized linear model (GLM) to estimate annual dengue cases in Bangladesh based on monthly temperature, rainfall, and sunshine. It showed that temperature and precipitation affect dengue incidence depending on the time of year [8]. Several studies also stated that weather conditions can affect dengue incidence and mosquito abundance up to 5 months before the season starts [16-18]. All the studies mentioned above have used weather parameters like temperature, rain, humidity, wind speed, and/or sunshine to find associations with dengue cases. None of the above-mentioned studies have utilized weather parameters like cloud coverage or air pressure in their analyses. Only one study applied weather parameters, including air pressure, in their analyses in Thailand [19].

The daily dengue case data is a discrete count variable and often has a variance above expected in a Poisson distribution. Overdispersion (i.e., greater variability) occurs in the datasets. Previously, the best fit had been obtained by applying GLM with a quasi-Poisson regression on over-dispersed disease case data and meteorological variables [20,21]. This study aimed to estimate the relationship between dengue cases and weather parameters (maximum temperature, minimum temperature, wind speed, rain, relative humidity, cloud coverage, and air pressure) and then to identify the seasonal outbreaks for dengue incidence based on the data collected for the city of Dhaka. Also, the study aimed to identify the cumulative lagged effects of weather parameters on dengue cases. First, average weekly variations of dengue cases and weather parameters have been observed. Spearman rank correlation analyses have been performed, and finally, quasi-Poisson GLM has been applied to evaluate their associations. The relative humidity has been observed to have positive effects, while the wind pressure negatively affects the dengue incidence. July to October might be the seasonal dengue outbreak due to higher relative humidity and lower wind pressure. Also, more lagged week weather values have been found to have higher effects than less lagged week weather values. These observations might help the decision makers to initiate the pre-measures before the dengue outbreaks occur.

METHODS

Data collection

In this study, the impacts of weather parameters on the spread of dengue cases have been investigated for Dhaka (latitude: 23.810331, longitude: 90.412521), Bangladesh. The daily dengue case counts data have been collected from the daily press releases of the director general of health services in Dhaka, Bangladesh (https://old.dghs.gov.bd/index.php/bd/home/5200-daily-dengue-status-report). The daily dengue count data is available on the website from 27 August 2019 to 30 January 2020 and from 13 December 2021 to onwards. Hence, the daily dengue count data was collected for the two periods, from 27 August 2019 to 30 January 2020 and from 13 December 2021 to 29 October 2023. The website has no dengue press release information for 25-26 September 2019, 11 January 2023, 26 January 2023, and 16 February 2023. These data are filled with the average data sets for the previous seven days. Also, additional data were generated by taking averages of the data from the previous seven days at the end of the first period. This additional data has been used to calculate average weekly data. In total, data on daily dengue count was collected for 847 days. The weather data was collected from the World Weather website (https://www.worldweatheronline.com/). The daily weather data for Dhaka was obtained from historical weather information by searching for each date separately from the website. This data set contains maximum temperature in centigrade, minimum temperature in centigrade, wind speed in kilometers per hour, rain in millimeters, relative humidity in %, cloud coverage in %, and air pressure in millibars. Weather data, such as dengue case count data, have also been collected for the two periods. In addition, weather data from the previous thirty-five days was collected for both periods to generate the lag data set. The daily weather data has been collected for 917 days in total.

Statistical analysis

After collecting the daily dengue case counts and the weather parameter values, basic statistical operations (i.e., mean, standard deviation, minimum, median, and maximum) have been performed to observe the statistical characteristics of the data set over the periods. From the daily dengue count data, an average of per week data was calculated, comprising a total number of 121 weeks. Similarly, the per week average weather parameter values have been calculated, involving 131 weeks. The weekly average data sets have been generated to observe the weekly variations of dengue cases and the weather parameter values.

Lagged week data preparation

To examine the lagged effect of weather parameters on the transmission of dengue cases, six different lagged week data sets (i.e., week 0, week 1, week 2, week 3, week 4, and week 5) have been generated by using the per week average dengue cases and weather parameters. The lagged week data sets have been produced by combining the moving averages of the weather parameters with the dengue cases, as shown in the following -

$$LWD_n = Combine\ (DC_{current\ week}, \frac{\sum_{i=0}^{n} WP_i}{n+1})$$

Where *LWD* denotes the lagged week data, *DC* denotes the average weekly dengue cases, *WP* denotes the average weekly weather parameters, and *n* denotes the lagged week (*0* indicates the current week, *1* indicates lag week one, *2* indicates lag week two, and so on).

Correlation analysis between dengue cases and weather parameters

The average weekly dengue cases and weather parameter values do not follow the linearity (as shown in Figure 1). Hence, the Pearson correlation could not be the appropriate way to apply their correlation analyses. Instead, Spearman-rank correlation analyses were applied in this study to the dengue cases and the weather parameter values. Specifically, Spearman's rank correlation coefficient (*Rho*) has been used to understand the strength of relationships between the dengue cases and the weather parameters of all lagged data sets.

Quasi-Poisson GLM to assess impacts of weather parameters on dengue cases

In several previous studies of over-dispersed disease case data and meteorological variables, GLM with a quasi-Poisson regression was applied. Comparatively, better results were found than in other models [20-22]. Motivated by them, quasi-Poisson GLM has been applied to all six different lagged data sets in this study to assess the impacts of weather parameters on the spread of dengue cases.

RESULTS

Descriptive statistics of dengue cases and weather parameters

This study aims to observe the effects of weather parameters on the spread of dengue cases in Dhaka, Bangladesh. Table 1 shows the descriptive statistics of daily dengue cases and weather parameter values collected for the two periods combined. The maximum and minimum number of new dengue cases observed in a day were 1,327 and 0, respectively. The mean and median are 179.10 and 36, respectively, whereas a large standard deviation has been noted as 285.63 for daily dengue cases.

For the weather parameters, the highest and lowest values have been observed for maximum temperature as 46^0 C and 20^0 C, minimum temperature as 33^0 C and 11^0 C, wind speed as 30km/h and 4km/h, rain as 133.70mm and 0mm, relative humidity as 96% and 18%, cloud coverage as 100% and 0%, wind pressure as 1018 mb and 994 mb respectively. The mean and median for the weather parameter values have been observed as normal, and no major changes in the values of standard deviations have been seen.

Table 1. Descriptive statistics of dengue cases and weather parameters.

Statistics	*New daily cases (persons)*	*Maximum temperature (^0C)*	*Minimum temperature (^0C)*	*Wind speed (km/h)*	*Rain (mm)*	*Relative humidity (%)*	*Cloud coverage (%)*	*Wind Pressure (mb)*
Mean	179.10	31.85	22.56	11.62	5.56	60.73	35.31	1007.79
SD	285.63	4.46	4.65	4.71	12.20	16.65	29.57	5.00
Minimum	0.00	20.00	11.00	4.00	0.00	18.00	0.00	994.00
Median	36.00	32.00	24.00	10.00	0.20	63.00	36.00	1008.00
Maximum	1327.00	46.00	33.00	30.00	133.70	96.00	100.00	1018.00

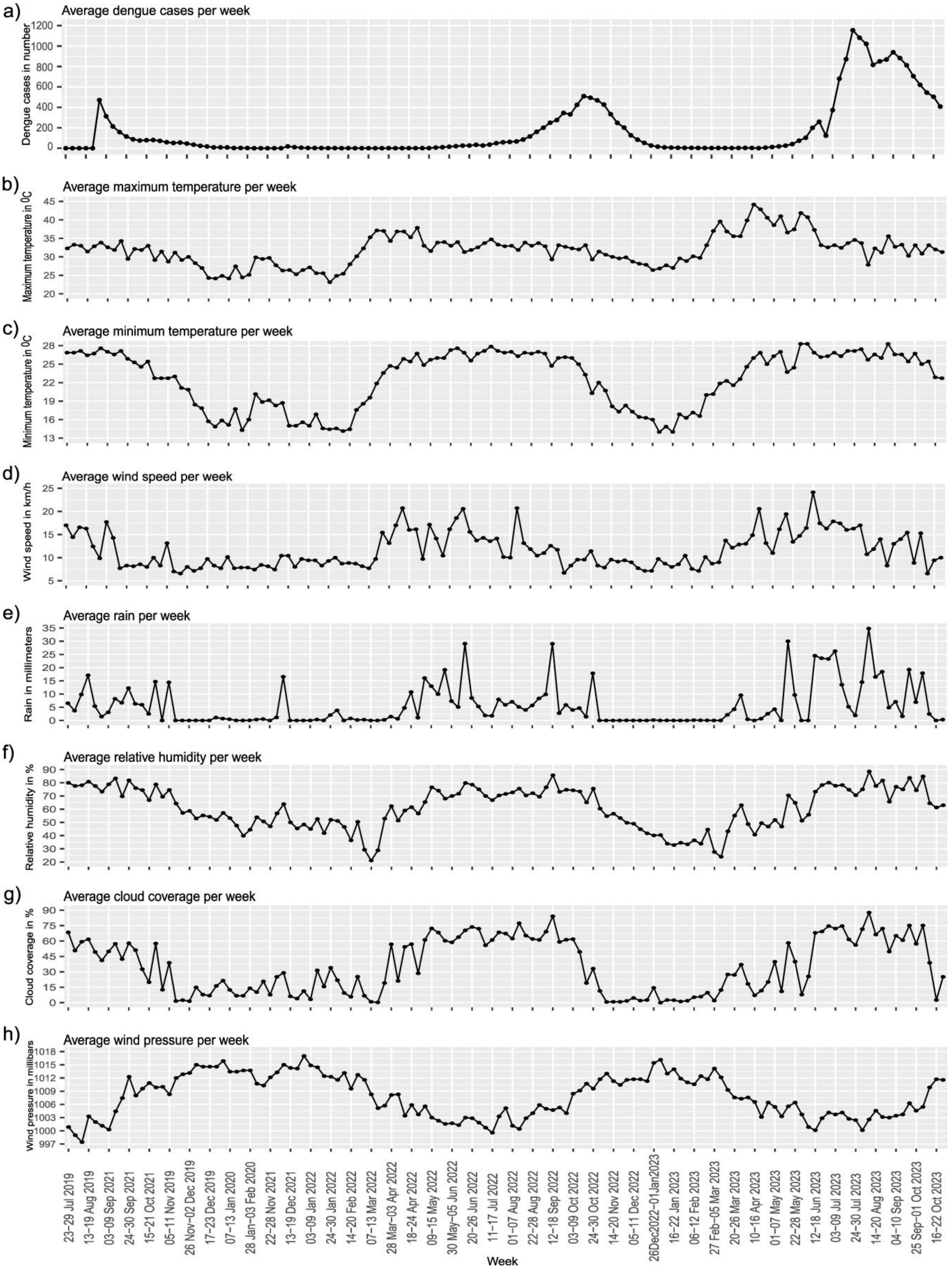
Note: SD = Standard deviation

Weekly variations of dengue cases and weather parameters

The weekly variations of the number of dengue cases and weather parameter values have been shown in Figure 1. The dengue cases of the first five weeks for each period (23 July 2019 to 26 August 2019 and 8 November 2021 to 12 December 2021) have been assigned as zero values and not used in any downstream analysis steps. However, their corresponding weather parameter values have been used to calculate the lagged week data sets. Comparatively higher values for average dengue cases have been observed from July to October, and lower values in the remaining period (Figure 1a). Also, comparatively higher values have been seen for average minimum temperature, wind speed, rain, relative humidity, and cloud coverage from the March to October period and lower values for the remaining period (Figure 1 c-g). Comparatively higher values have been examined for average maximum temperature from March to June and lower values from November to January (Figure 1b). The average wind pressure has been observed to have comparatively lower values from June to September and higher values in the remaining period (Figure 1h).

Similar patterns have been observed for dengue cases and weather parameters based on the pattern of the weekly variations of dengue cases and the minimum temperature, wind speed, rain, relative humidity, and cloud coverage. In contrast, dengue cases increased in July, and the weather parameters rose in March (Figure 1a, Figure 1 c-g). However, an opposite trend has been observed for maximum temperature and wind pressure with the dengue cases (Figure 1a, Figure 1b, Figure 1h).

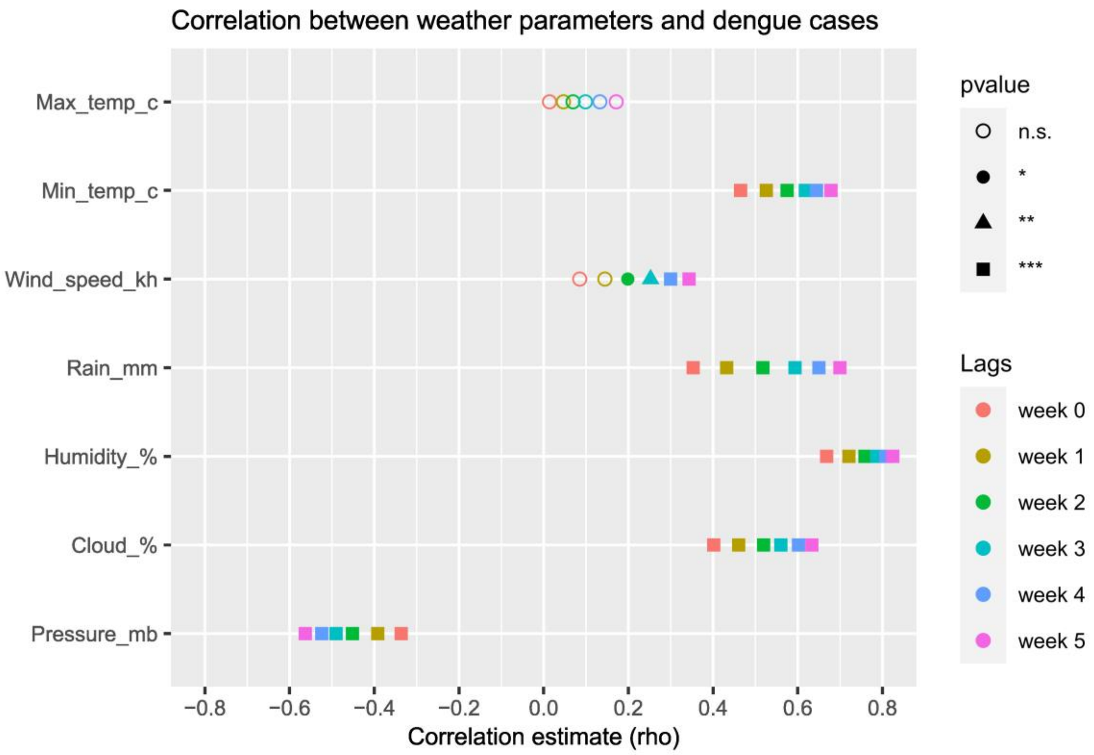
Figure 1. Average weekly variations of dengue cases and weather parameters: a) dengue cases, b) maximum temperature, c) minimum temperature, d) wind speed, e) rain, f) relative humidity, g) cloud coverage, and h) wind pressure.



Associations between dengue cases and weather parameters

After examining weekly average variations, Spearman rank correlation was applied between the dengue cases and weather parameters to find associations between them, as shown in Figure 2. Also, the effects of weather parameters on the spread of dengue cases have been observed at different cumulative average week lags (0-5 weeks). Significant positive correlations for minimum temperature, rain, relative humidity, and cloud coverage with the dengue cases have been observed. Wind pressure and dengue cases have shown a significant negative correlation. In both cases, comparatively higher values of the correlation estimates have been noted for larger lagged weeks than the smaller lagged weeks data sets. The wind speed has been examined to have a somewhat significant positive correlation with the dengue cases for the 5-3 lagged week data sets. On the other hand, no significant correlation has been observed between dengue cases and maximum temperature for any lagged week data sets.

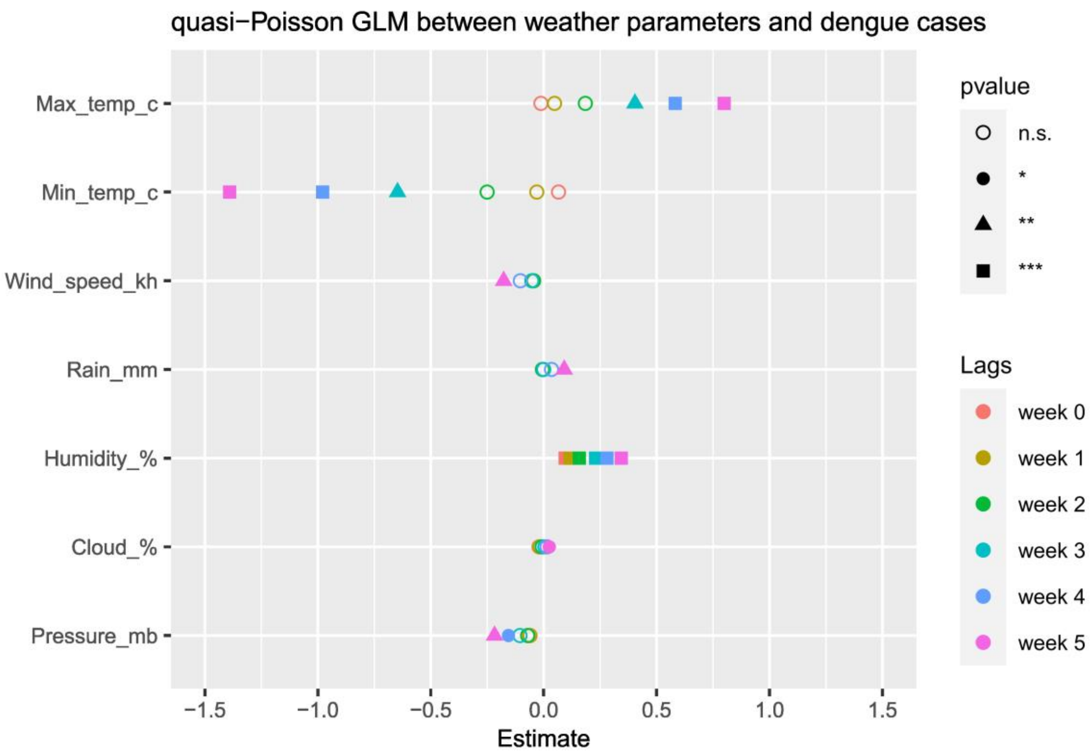
Figure 2. Spearman rank correlation between dengue cases and weather parameters.



Impacts of weather parameters on the spread of dengue cases

The impacts of weather parameters on the spread of dengue cases estimated by the model are displayed in Figure 3. Only relative humidity has been viewed to significantly affect the spread of dengue cases for all lagged week data sets, with comparatively stronger estimates for the more cumulative lagged weeks. The maximum temperature has been noted to have significant positive effects for the 5-3 lagged week data sets. In contrast, the remaining lagged week data sets have no significant effects on the spread of dengue cases. On the other hand, the minimum temperature has been seen to have substantial negative effects for the 5-3 lagged week data sets. In contrast, the remaining lagged week data sets of minimum temperature have no significant effects on the spread of dengue cases. The wind speed and pressure have been observed to negatively affect the spread of dengue cases for only the lagged week 5 data set. However, the rain has been seen to significantly positively affect the spread of dengue cases for only the lagged week 5 data set.

Figure 3. Quasi-Poisson generalized linear model output between dengue cases and weather parameters.



DISCUSSION

In the current study, the impacts of weather parameters on the spread of dengue cases have been investigated based on the per-week average data sets for Dhaka, Bangladesh. Dhaka is one of the most densely populated cities in the world. Also, the dengue incidence in the city has increased remarkably in the last several years. Moreover, the citywide daily dengue case data is available only for Dhaka on the website from where the data has been collected.

From both the correlation and model output, the relative humidity has been observed to have stable positive relations with dengue cases (Figure 2-3). However, the wind pressure has been examined to have negative relations with dengue cases (Figure 2, Figure 3). In both cases, comparatively stronger estimates have been noted for larger cumulative lagged week data sets (Figure 2, Figure 3). From the per-week average variation results, the dengue cases have been seen to have comparatively higher values from July to October (Figure 1a). The relative humidity has been observed to have higher values from March to October (Figure 1f). On the other hand, wind pressure was observed to have comparatively lower values from June to September (Figure 1h). These observations suggest that the July to October period might be the sensitive season for dengue cases due to higher relative humidity values and lower wind pressure values. A similar outcome has been stated for relative humidity in different studies worldwide and in Bangladesh [15,23]. A similar negative effect of wind pressure on the number of dengue cases has been observed in one study in Thailand [19]. Also, this study suggests that the cumulative more lagged week weather parameters may affect the spread of average dengue cases more than the less lagged week weather values. Different studies have observed comparable findings for lagged week weather parameter values with dengue incidence [24-26]. Although the remaining period has been observed to have several dengue cases and the remaining weather parameters have been seen to have some effects on the spread of dengue cases, more studies need to be conducted to reach a decision.

The results show changes in output have been observed for several weather parameter values on the spread of dengue cases in correlation and model analyses. These variations may have occurred because, in correlation analysis, the overdispersion zeros in the dengue case counts had not been addressed effectively; however, in model analysis, the quasi-

Poisson GLM handled the overdispersion zero values in the dengue case count efficiently. Also, different variants of dengue may have different rates of transmission. There is no information on the website where the data was collected about dengue variants. So, no variant data had been added to the manuscript. This may also be a reason for the alteration of the results of the analyses in the current study.

Several other factors can also influence the spread of dengue cases, including population density, social status of the city's people, awareness of the people, and so on. No such factors have been considered in the current study. Only weather parameters have been considered for the spread of dengue cases in the present analyses. Although some mentionable results have been observed from the current study, other factors need to be considered in combination with different weather conditions of different cities to make a concrete decision on the spread of dengue cases.

CONCLUSIONS

Based on the results of the analysis, this study suggests that weather parameters may specifically impact the spread of dengue cases. The relative humidity might positively affect the spread of dengue cases, whereas the wind pressure might be a negative effector for the transmission of dengue cases. Also, the more continuous cumulative lagged weak weather parameters might be the strong effector for the spread of dengue cases. Comparatively higher values of dengue cases have been observed from July to October in Dhaka. Similarly, relatively higher relative humidity values were observed in the city from March to October. On the other hand, comparatively lower wind pressure values have been observed from June to September in the city. Hence, considering the continuous cumulative lagged week weather parameter values, the July to October might be the sensitive season for dengue cases in Dhaka, Bangladesh. These outcomes might help the city's decision-makers to pay particular attention to a high volume of dengue patient management and raise public concern to fight against mosquito proliferation before the dengue outbreak occurs.

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Conflicts of Interest: The authors declare no conflict of interest.

Data Availability: Publicly available datasets have been analyzed in this study. These datasets can be found here: https://old.dghs.gov.bd/index.php/bd/home/5200-daily-dengue-status-report; https://www.worldweatheronline.com/. The processed data can be available on request (Email: hkj_cse@ru.ac.bd).

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