International Journal of Mosquito Research

ISSN: **2348-5906**
CODEN: **IJMRK2**
IJMR 2021; 8(2): 19-29

www.dipterajournal.com
Received: 07-01-2021
Accepted: 09-02-2021

Stavelin Abhinandithe K
Division of Medical Statistics, Faculty of Life Sciences, Department of Water & Health, JSSAHER, Mysuru, Karnataka, India

Madhu B
Department of Community Medicine, JSS Medical College, JSSAHER Mysuru, Karnataka, India

Dr. Balasumbramanian S
Director Research, JSSAHER, Mysuru, Karnataka, India

Sahana KS
Division of Medical Statistics, Faculty of Life Sciences, Department of Water & Health, JSSAHER, Mysuru, Karnataka, India

Corresponding Author:
Stavelin Abhinandithe K
Division of Medical Statistics, Faculty of Life Sciences, Department of Water & Health, JSSAHER, Mysuru, Karnataka, India

Negative binomial regression modeling to assess the influence of climatic factors on the dengue incidence during an epidemic in Mysore district

Stavelin Abhinandithe K, Madhu B, Dr. Balasumbramanian S and Sahana KS

Abstract
The geographical expansion of the outbreak of dengue has created a global interest in identifying the influential factors that cause the spread of the disease. The purpose of this research paper was to recognize by negative binomial models using climatic conditions from 2008 to 2019, the environmental factors associated with the incidence of dengue in the dengue epidemic region of Mysore, Karnataka**.** The occurrence of dengue was significantly influenced by the maximum temperature at lag 3 and the mean relative humidity without lag time or lag 0. The occurrence of dengue in the Mysore district of Karnataka was not strongly associated with rainfall. The dengue case Incidence Rate Ratio (IRR) increases by 1.242 percent for every one degree Celsius increase in maximum temperature at lag 3, and for every one degree increase in relative humidity, dengue incidence increases by 1.076 percent. The vector control and dengue management programme should be introduced at least three months in advance of the dengue epidemic season, taking into account the impact of maximum temperatures in previous months on the incidence of dengue.

Keywords: dengue, negative binomial model, maximum temperature, rainfall, relative humidity

1. Introduction

Dengue, which is considered to be the most common infectious disease in more than 100 countries around the world, transmitted to human through mosquito bite from infected Aedes species [1, 2]. Dengue, including both classical dengue fever and dengue hemorrhagic fever (DHF), is one of the significant causes of morbidity and mortality in India. There are four serotypes (DEN-1, DEN-2, DEN-3, and DEN-4) transmitted by the bite of infected Aedes mosquitoes, one of the most important arboviruses in the tropical and subtropical regions (World Health Organization, 2009) [3]. The risk of dengue fever has led to an unthinkable proportion in recent years, with an increase in the size of the "at-risk" human population [4]. India's dengue epidemiology was first documented in Madras in 1780, and the first dengue epidemic occurred in Calcutta in 1963; it was later reported in various parts of India. In most states in India, dengue is endemic and is also recognized to be one of the major causes of hospitalization. Many socio-demographic and climate factors have been linked to the global spread of the Dengue virus [5, 6]. Environment factors such as temperature, rainfall and humidity that make dengue a climate-sensitive disease are correlated with the vector life cycle, viral replication and host-vector interaction [7-13]. Any change in climatic factors could, therefore, be commendable for causing vulnerable changes in vector habitat expansion and prolongation of the distribution season. In order to predict the relationship between dengue incidences and climate conditions across the world, numerous studies have been carried out [14]. The effect of climatic variables and the subsequent lag periods on the incidence of dengue in the Mysore district were discussed in this paper. This study aims to offer insights to improve the plan for dengue control and thus to take steps before the lag time for the public sector.

2. Materials and Methods

2.1 Study Area and Climatic Conditions

Mysore is renowned for its heritage buildings and palaces, including Mysore Palace, and is an international place to visit, and for the festivities that take place during the Dasara festival, when the city receives many international tourists. The district of Mysore forms the southern part of Karnataka, with Tamil Nadu to its southeast, the district of Kodagu to its west, the district of Mandya to its north, the district of Hassan to its northwest, and the district of Bangalore to its northeast. It occupies a surface of 6854 sq. Km, which is 3.57 per cent of the total geographical area of the state. Despite remaining a cultural structure residing between 11 ° 30 'N to 12 ° 50' N latitudes and 75 ° 45 'E to 77 ° 45' E longitudes, Mysore district is a specific unit of territory.

2.2 Geographical Location and Area: A total geographical area of 6,76,382 hectares is occupied by the district, of which 62,851 hectares are forestland. As of 2011, Mysore City had an estimated population of 920,550, consisting of 461,042 men and 459,508 women, making it Karnataka's third most populous city.

2.3 Climatic Condition: Mysore has a tropical savanna climate (*Aw*) bordering on a hot semi-arid climate (*BSh*) under the Köppen climate classification. The city has Deccan forest area and it is located by two rivers: the Kaveri River that flows through the north of the city and the Kabini River, a tributary of the kaveri that lies to the south. Main seasons are summer from March to June, the monsoon season from July to November and winter from December to February [15]. The temperature Ranges from 39.4^0 to 46^0 F.

2.4 Data and Climatic Factors: Monthly dengue cases from 2008 to 2019 were collected from District Health office, Public sectors and government agencies, Mysore Karnataka. Monthly records of Maximum temperature (ºC), Minimum temperature (ºC), Mean temperature (ºC), Maximum rainfall (mm), and Minimum rainfall(mm), Mean rainfall(mm), Relative humidity (Maximum, Minimum and Mean)(%), Velocity daily mean (km) Vapor pressure (Maximum, Minimum, Daily mean) (%), Evaporation (Maximum, Minimum, Total, Daily) (mm) and Average sunshine were collected from the district between 2008 to 2019 from Indian Meteorological Department (IMD), India.

Table 1: Climatic variables, Variable label and Units of measurement

Sl. No	Climatic Variables	Variable Label	Units of measurements
1	Maximum temperature	TEMP MAX	ºC
2	Minimum temperature	TEMP MIN	ºC
3	Mean temperature	TEMP MEAN	ºC
4	Maximum rainfall	RAIN MAX	mm
5	Minimum rainfall	RAIN MIN	mm
6	Mean rainfall	RAIN MEAN	mm
7	Total rainfall during month	RAIN TOTAL	mm
8	Wind velocity daily mean	VELOCITY DAILY MEAN	Km/hr
9	Maximum relative humidity	RH MAX	%
10	Minimum relative humidity	RH MIN	%
11	Mean relative humidity	RH MEAN	%
12	Maximum vapor pressure	VP MAX	millibars
13	Minimum vapor pressure	VP MIN	millibars
14	Vapor pressure daily mean	VP DAILY MEAN	millibars
15	Maximum evaporation	EVA MAX	mm
16	Minimum evaporation	EVA MIN	mm
17	Total evaporation	EVA TOTAL	mm
18	Daily evaporation	EVA DAILY	mm
19	Average sunshine	AVG SUNSHINE	hours

2.5 Statistical analysis

Temperature (Maximum, Minimum, Mean), Rainfall (Maximum, Minimum, Total during month, Mean), Wind velocity daily mean, Relative humidity (Maximum, Minimum and Mean), Vapor pressure (Maximum, Minimum, Daily mean), Evaporation (Minimum, Maximum, Total, Daily), Average Sunshine were considered as predictor variables while dengue case was considered as response variable. Spearman correlation analysis was assessed between dengue cases and climatic factors to identify the most preceding months (lag period) on the occurrence of dengue. The predictor variable of 1 month earlier was considered lag 1 and the month corresponding to that of dengue case was lag 0. Lag period of one to 7 months were considered for preceding months.

Dengue cases were considered as count variable, this could fit either as Poisson or Negative binomial distribution. In Modeling Poisson regression model, one of the major assumptions is equality of the mean and variance. If this assumption is violated, an over dispersion problem can arise. In order to overcome the over dispersion, this study considered the generalization of Poisson model that is Negative Binomial regression model. However, dengue cases were over-dispersed that means variance greater than mean. Thus we considered negative binomial regression for dengue cases as a response variable which seemed to be appropriate for modeling.

$$P(y) = P(Y{=}y) = \frac{r(y+\frac{1}{\alpha})}{r(y+1)r(\frac{1}{\alpha})} \left(\frac{1}{1+\alpha\mu}\right)^{\frac{1}{\alpha}} \left(\frac{\alpha\mu}{1+\alpha\mu}\right)^{y}$$

Where μ >o is the mean of Y and α is the heterogeneity parameter. It can derive this parameterization as a Poisson-gamma mixture or alternately as the number of failures were the predicted variables, $X_1, X_2, \ldots, X_p$ are given, and the population regression coefficients $\beta_0, \beta_1, \beta_2, \beta_3, \ldots \beta_p$ are to be estimated [16]. The study used the maximum likelihood ratio statistics or commonly known as Deviance (D) statistics to test for the goodness of fitted model for Negative Binomial

model [16-19]. The best fit model was selected and interpreted. Similarly, incidence rate ratio (IRR) between dengue case and climatic factors was assessed to consider the relative risk of dengue incidence in relation to climatic factors. The statistical analyses were conducted using SPSS software version 22.
Maximum Likelihood method (MLE) was used for parameter estimation and negative binomial regression technique was used to analyze the MLE method. The general model was as followed;

$$\text{Log (DHF)} = a + b_1 X_1 + b_2X_2 + b_3X_3 + \ldots + b_kX_k$$
$$\text{DHF} = \exp\,[a + b_1 X_1 + b_2X_2 + b_3X_3 + \ldots + b_kX_k]$$
$$\text{DHF} = e^{a}\, e^{b_1 x_1} e^{b_2 x_2} e^{b_3 x_3} \ldots\, e^{b_k x_k}$$

Where DHF was number of dengue hemorrhagic fever cases, a, b_1, b_2, b_3,….. b_k were constants in model and X were independent variables [16, 18-19]

Significance test: In the current paper, the maximum likelihood ratio statistics or commonly known as deviance (D) statistics to test for the goodness of fitted model for negative binomial model. Deviance in the normal linear regression was similar to R^2 or coefficient of determination which was used to provide the descriptive information about the model fit and was calculated by

$$R^2 = \frac{\Sigma\,(\hat{y} - \bar{y})^2}{\Sigma\,(y - \bar{y})^2}$$

Where y was the observed value of y, $\hat{y}$ was the value of y predicted from the model and $\bar{y}$ is the mean value of y. The log likelihood ratio statistics (deviance) was introduced to check the appropriateness of a chosen response distribution when explanatory variables were added or excluded from the model. The deviance value was defined as:

$$\text{Deviance (D)} = 2\ \{\ \Sigma_i [y_i \ln\left(\frac{y_i}{\hat{\mu}_i}\right) - (y_i - \hat{\mu}_i)]\}$$

For a well fitted model with appropriate link function, error distribution and functional form, the expected value of residual deviance should approximately be equal to the number of degree of freedom regardless of the value of μ . In SPSS, we used to estimate the parameter by considering from mean deviance, the mean deviance close to 1 was the optimal model [20].
Residual analysis: In order to check for model fit, residual analysis is important as it can be thought of as the error associated with predicting or estimating outcomes using predictor variables [16, 28-19].

3. Results

During the 12 years period, a total of 2441 dengue cases have been reported with the smallest number being 0 per month and highest value of 232 cases per month. The mean is16.951, the variance is 1318.256. Since Variance was found to be greater mean, the data was considered to be over dispersed. In Figure 1, Yearly and monthly distribution of dengue cases showed a Seasonal pattern.

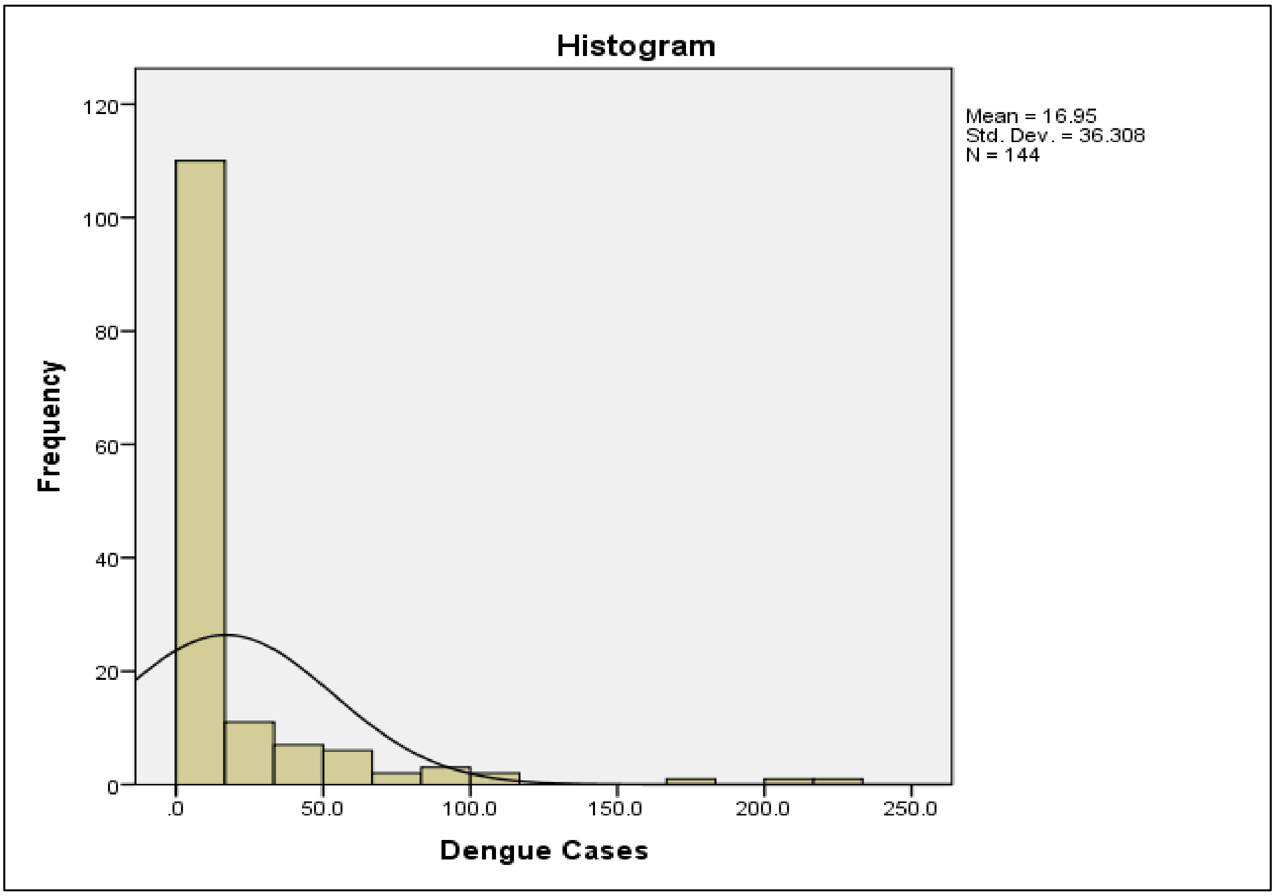

Fig 1: Yearly and monthly distribution of dengue cases of Mysore District.

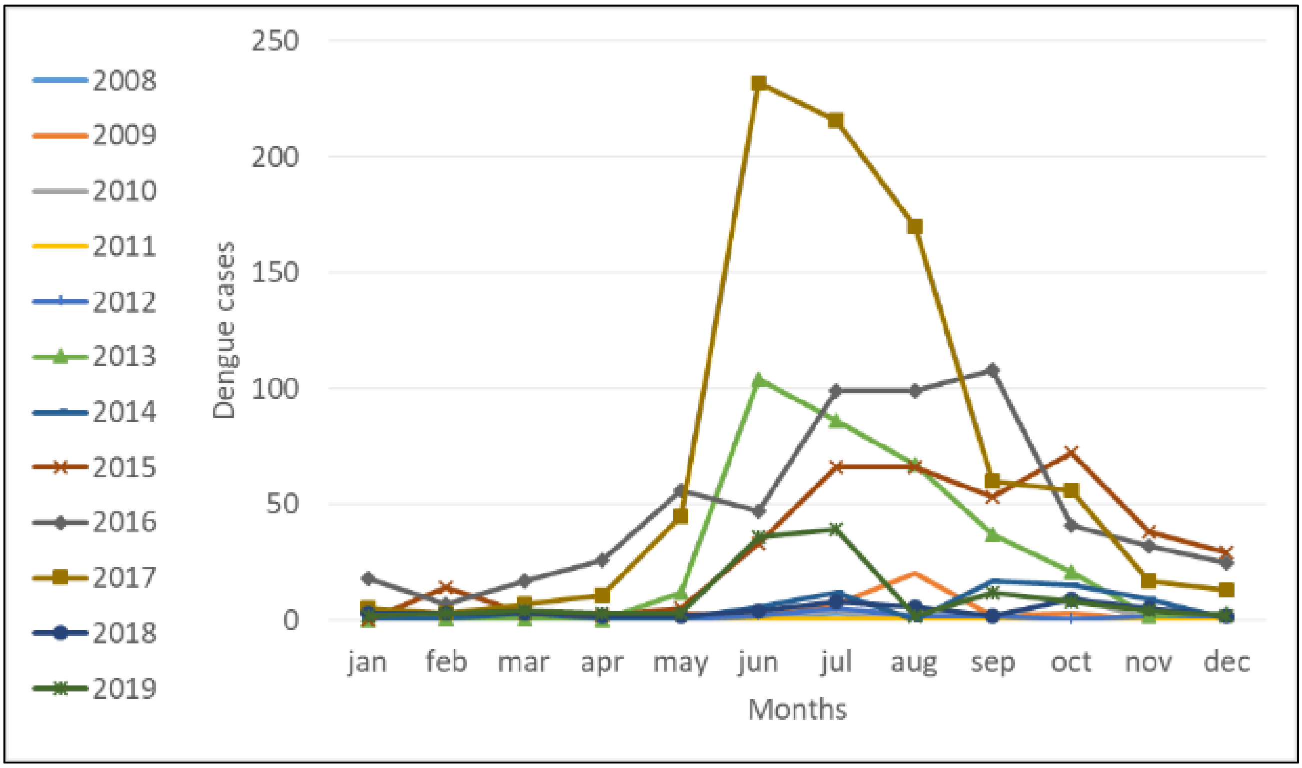

Fig 2: Yearly and Monthly distribution of dengue cases in Mysore district from 2008 to 2019

A clear seasonal pattern of dengue occurrence was observed with the cases more during the month of June-September. In 2015, 2016 and 2017, Mysore was considered to have a substantially increased incidence of dengue. The peak in dengue cases was observed in the year 2017, in the month of June with total of 232 cases and highest cases reported in the same year with around 835 (Figure 2). Mysore thus became a dengue endemic district of Karnataka.

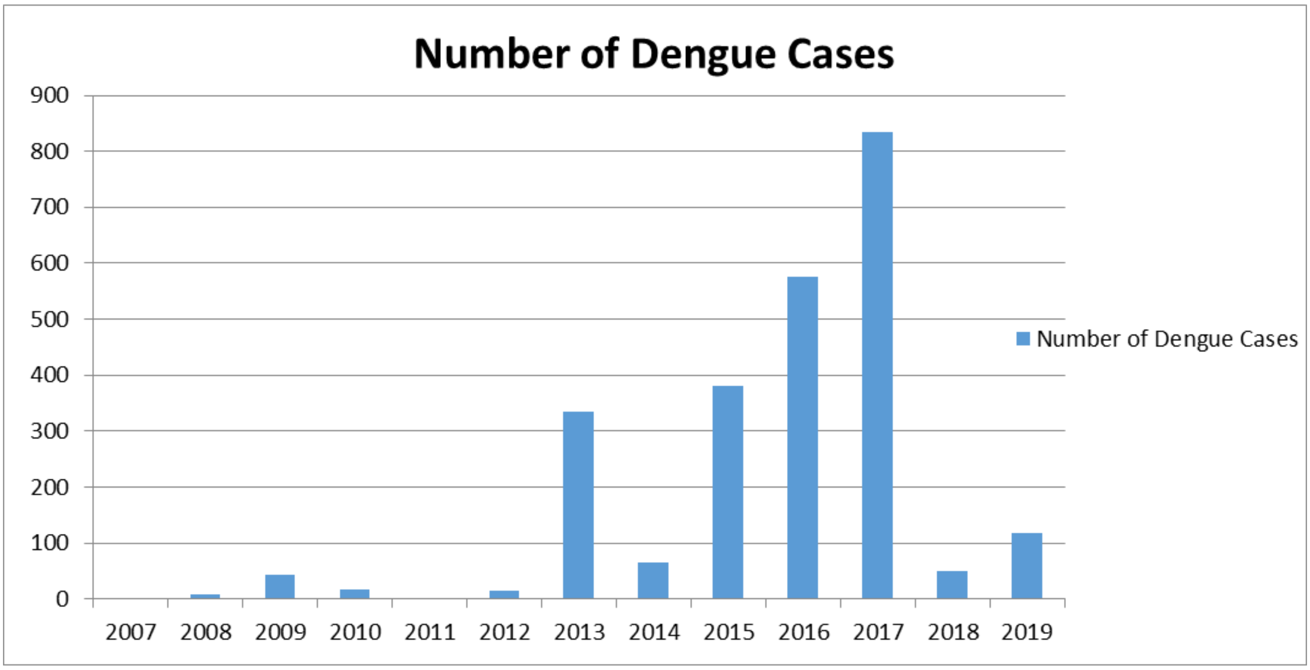

Fig 3: Dengue Cases by year from 2008 to 2019 in Mysore district.

Spearman correlation analysis showed temperature and relative humidity have some significant correlation with dengue cases. Maximum temperature was significantly correlated with dengue cases through lag 3-6 month with P value of (P<0.01) but not for the corresponding month with lag (0-2) month (Table 2). The effect of minimum temperature was significant through lag 1-3 with moderate correlation. Maximum rainfall was significant (P<0.01) but showed a negative correlation for lag 6 and lag 7. Minimum relative humidity showed significant (P<0.01) and moderate correlation at lag 0 and 1 and mean relative humidity showed significant through lag 0-2 month with moderate correlation at lag 0 month (r=0.457).

Table 2: Correlation analysis between dengue cases and climate factors with lag effects of 0-7 month's period

Climate variable	Lag month	Correlation	*P*-value
Maximum temperature	0	-0.111	0.184
	1	0.045	0.59
	2	0.188*	0.024
	3	0.250**	0.003
	4	0.320**	<0.0001
	5	0.321**	<0.0001
	6	0.281**	0.001
	7	0.128	0.125
Minimum temperature	0	0.174*	0.037
	1	0.305**	<0.0001
	2	0.324**	<0.0001
	3	0.283**	0.001
	4	0.137	0.101
	5	-0.01	0.91
	6	-0.116	0.166
	7	-0.206*	0.013
Mean temperature	0	0.058	0.488
	1	0.220**	0.008
	2	0.293**	<0.0001
	3	0.315**	<0.0001
	4	0.258**	0.002
	5	0.155	0.064
	6	0.017	0.838
	7	-0.081	0.336
Maximum Rainfall	0	0.115	0.17
	1	0.089	0.286
	2	0.042	0.619
	3	-0.158	0.059
	4	-0.253**	0.002
	5	-0.269**	0.001
	6	-0.337**	<0.0001
	7	-0.306**	<0.0001
Minimum Rainfall	0	0.184*	0.027
	1	0.094	0.263
	2	0.091	0.281
	3	-0.06	0.476
	4	-0.07	0.406
	5	-0.085	0.313
	6	-0.153	0.067
	7	-0.102	0.224
Mean Rainfall	0	0.116	0.166
	1	0.091	0.28
	2	0.043	0.61
	3	-0.158	0.059
	4	-0.245**	0.003
	5	-0.264**	0.001
	6	-0.336**	<0.0001
	7	-0.299**	<0.0001
Maximum Relative humidity	0	0.206*	0.013
	1	0.244**	0.003
	2	0.146	0.081
	3	0.081	0.337
	4	-0.025	0.765
	5	-0.059	0.483
	6	0.022	0.792
	7	-0.033	0.696
Minimum Relative humidity	0	0.404**	<0.0001
	1	0.335**	<0.0001
	2	-0.215**	0.01
	3	0.098	0.243
	4	0.035	0.676
	5	-0.054	0.521
	6	-0.073	0.384
	7	-0.069	0.411

Mean Relative humidity	0	0.457**	<0.0001
	1	0.413**	<0.0001
	2	0.271**	0.001
	3	0.178*	0.033
	4	0.064	0.447
	5	-0.049	0.559
	6	-0.042	0.614
	7	-0.033	0.696
EVA Max	0	-0.08	0.34
	1	-0.035	0.676
	2	-0.058	0.492
	3	-0.11	0.19
	4	-0.162	0.053
	5	-0.172**	0.039
	6	-0.306**	0
	7	-0.348**	0
EVA Min	0	0.004	0.958
	1	-0.003	0.973
	2	0.053	0.529
	3	0.131	0.117
	4	0.193*	0.202
	5	0.139	0.097
	6	0.155	0.064
	7	0.137	0.101
EVA Total	0	-0.210*	0.011
	1	-0.154	0.065
	2	-0.025	0.762
	3	0.045	0.589
	4	-0.029	0.732
	5	-0.018	0.832
	6	-0.076	0.366
	7	-0.202*	0.015
EVA daily	0	-0.217**	0.009
	1	-0.148	0.077
	2	-0.038	0.651
	3	0.052	0.534
	4	-0.017	0.838
	5	-0.002	0.981
	6	-0.064	0.446
	7	-0.199*	0.017
Rain total during month	0	0.188	0.099
	1	0.131	0.119
	2	0.113	0.179
	3	-0.116	0.166
	4	-0.241**	0.009
	5	-0.276**	0.001
	6	-0.342**	0
	7	-0.314**	0
Velocity Daily Mean	0	-0.01	0.905
	1	-0.09	0.285
	2	-0.029	0.733
	3	-0.104	0.214
	4	-0.200*	0.016
	5	-0.227**	0.006
	6	-0.205*	0.013
	7	-0.257**	0.002
VP max	0	0.369**	0
	1	0.338**	0
	2	0.320**	0
	3	0.324**	0
	4	0.323**	0
	5	0.243**	0.003
	6	0.179*	0.032
	7	0.146	0.082
VP min	0	0.446**	0
	1	0.424**	0
	2	0.355**	0

	3	0.250**	0.003
	4	0.1114	0.172
	5	-0.022	0.791
	6	-0.015	0.86
	7	-0.092	0.271
VP Daily mean	0	0.454**	0
	1	0.431**	0
	2	0.364**	0
	3	0.309**	0
	4	0.273**	0.001
	5	0.152	0.069
	6	0.119	0.177
	7	0.038	0.651
Average Sunshine	0	-0.284**	0.001
	1	-0.186*	0.027
	2	-0.097	0.253
	3	0.037	0.666
	4	0.224**	0.007
	5	0.258**	0.002
	6	0.308**	0
	7	0.302**	0

Negative binomial regression model was fitted for response variables on given predictor variables based on the fitting criteria. Both deviance test and omnibus test supported that eight models were well fitted to the data. The criteria of lowest value of AIC (or BIC) and mean deviance (-2LL/df) close to one were used to select a better model. The first model included all 56 predictor variables but none were significant under Wald Chi square test (P<0.05). Thus, it did not satisfy the condition those only significant predictors from the fitting of negative binomial regression of dengue case.

Table 3: Negative Binomial regression models of dengue cases

Negative binomial regression models of dengue cases								
Models	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Parameter	B	B	B	**B**	**B**	B	B	B
	(SE)	(SE)	(SE)	**(SE)**	**(SE)**	(SE)	(SE)	(SE)
(Intercept)	-72.904							
	12.2305							
Max Temp	0.063							
	0.1642							
Max Temp_1	0.324							
	0.2025							
Max Temp_2	0.043	0.197	0.157	0.121	0.103	0.202	0.102	
	0.2111	0.0806	0.0788	0.0672	0.0681	0.0802	0.0674	
Max Temp_3	0.1							0.217
	0.2116							0.066
Max Temp_4	0.15							
	0.1937							
Max Temp_5	0.158							
	0.2051							
Max Temp_6	0.111							
	0.1959							
Max Temp_7	0.137							
	0.1832							
Min Temp	0.209							
	0.1854							
Min Temp_1	0.006							
	0.2014							
Min Temp_2	-0.033	0.31	0.269	0.238	0.33	0.304	0.388	
	0.215	0.0951	0.1031	0.1062	0.092	0.0949	0.0876	
Min Temp_3	0.347							
	0.2168							
Min Temp_4	0.12							
	0.2193							
Min Temp_5	0.12							
	0.2238							
Min Temp_6	-0.237							
	0.222							
Min Temp_7	0.097							
	0.1967							
Max Rain	-0.012							

	0.0066							
Max Rain_1	-0.005							
	0.0069							
Max Rain_2	-0.001							
	0.0067							
Max Rain_3	-0.008							
	0.0068							
Max Rain_4	-0.002							
	0.0063							
Max Rain_5	-0.003							
	0.0068							
Max Rain_6	-0.007							
	0.0065							
Max Rain_7	-0.009							
	0.0065							
Min Rain	0.002	0.129		0.081	0.072	0.128	0.096	
	0.1082	0.1501		0.1252	0.1324	0.1495	0.1404	
Min Rain_1	-0.094							
	0.0963							
Min Rain_2	-0.015							
	0.1172							
Min Rain_3	-0.065							
	0.1068							
Min Rain_4	-0.046							
	0.0943							
Min Rain_5	-0.033							
	0.0923							
Min Rain_6	-0.074							
	0.1							
Min Rain_7	0.026							
	0.1015							
Velocity Daily Mean_6		0.002			0.004	0.002	0.001	
		0.0043			0.0052	0.0043	0.0043	
Max RH	0.027			0.09				
	0.0484			0.0436				
Max RH_1	0.057							
	0.0553							
Max RH_2	0.063							
	0.0516							
Max RH_3	-0.032							
	0.0547							
Max RH_4	-0.045							
	0.0493							
Max RH_5	0.012							
	0.0549							
Max RH_6	0.053							
	0.057							
Max RH_7	-0.082							
	0.0696							
Min RH	-0.029							
	0.0309							
Min RH_1	-0.039							
	0.0333							
Min RH_2	0.009							
	0.0324							
Min RH_3	-0.045							
	0.0386							
Min RH_4	-0.006							
	0.0354							
Min RH_5	0.003							
	0.0364							
Min RH_6	0.002							
	0.0425							
Min RH_7	-0.053							
	0.0549							
Mean RH	0.084		0.049	0.023	0.056			0.073
	0.0586		0.0228	0.025	0.0236			0.0176
Mean RH_1	0.066							
	0.0652							
Mean RH_2	-0.007							

	0.0583							
Mean RH_3	0.104							
	0.0727							
Mean RH_4	0.014							
	0.0697							
Mean RH_5	0.025							
	0.0743							
Mean RH_6	0.052							
	0.0813							
Mean RH_7	0.128							
	0.1047							
VP Max_1			-0.095					
			0.1663					
VP Max_2		-0.234			-0.049	-0.044		
		0.1906			0.0369	0.0355		
VP Max_3		0.021	0.004	-0.007	0.028	0.023	0.01	
		0.0368	0.0343	0.0341	0.0374	0.0369	0.038	
VP Min_1			-0.016					
			0.1683					
VP Min_2		-0.101				0.094		
		0.1988				0.0387		
VP Min_3		0.047	0.06	0.042	0.041	0.047	0.042	
		0.0331	0.0401	0.0323	0.0325	0.033	0.0335	
VP daily mean_1			0.094					
			0.3282					
VP daily mean_2		0.386		0.036			0.046	
		0.3832		0.0493			0.0448	

Table 4: Goodness of Fit foe verifying the suitability of the data.

Goodness of Fit[a]			
	Value	df	Value/df
Deviance	158.338	140	1.131
Scaled Deviance	158.338	140	
Pearson Chi-Square	158.785	140	1.134
Scaled Pearson Chi-Square	158.785	140	
Log Likelihood[b]	-460.867		
Dependent Variable: Dengue Cases			
Model: (Intercept), RHMEAN, TEMPMAX_3			

The deviance value divided by its degrees of freedom and the pearson chi-square value divided by its degrees of freedom were found to be 1.131 and 1.134 ≈ 1, respectively, suggesting that the data might be over dispersed. Which shows that Negative binomial regression model was suitable for data. The goodness of fit table

Table 5: Chi-Square value of likelihood ratio.

Omnibus Test[a]		
Likelihood Ratio Chi-Square	df	Sig.
38.531	2	0
Dependent Variable: Dengue Cases		
Model: (Intercept), RHMEAN, TEMPMAX_3		
a. Compares the fitted model against the intercept-only model.		

Table 5 shows omnibus test, from the p-value, it shows that the model was suitable for the data and was statistically significant at 0.05 level.

Table 6: Wald Chi-square test.

Tests of Model Effects			
Source	Type III		
	Wald Chi-Square	df	Sig.
(Intercept)	22.195	1	0
RHMEAN	17.043	1	0
TEMPMAX_3	10.793	1	0.001
Dependent Variable: Dengue Cases			
Model: (Intercept), RHMEAN, TEMPMAX_3			

Table 6 shows Wald Chi-Square test from the p-value it shows that the predictors were significant at 0.05 level.

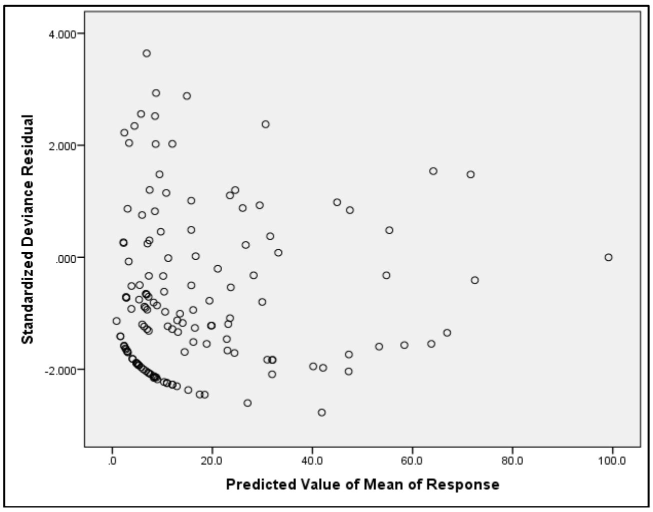

Fig 4: The relationship of the predictive value of the number of DHF cases with residuals.

Model 8 with two significant predictors (AIC= 929.733) was a better model.

Highly significant predictors in Model 8 under the Wald Chi square test ($P<0.05$) (Table 5) were Maximum temperature at lag 3 month (Temp Max_3) and Mean Relative humidity at lag 0 (RH Mean) . In order to make the interpretation simple, partial regression coefficients were expressed in the exponential form, i.e., exp (b_i). Exponential value greater than one indicated more effect of the predictor on the response variable and less than one indicated less effect, while one indicated no effect. Interpreting partial regression coefficients, the negative sign indicated a decrease in the response variable and the positive sign indicated an increase in the response variable per unit increase in a given predictor keeping the remaining predictors constant.

The variable Max Temp_3 has a coefficient of 0.217 which implies that for each one degree Celsius increase in Maximum temperature at lag 3 month, the expected log of dengue case increases by 0.217. Similarly, for Mean Relative humidity with a coefficient of 0.073, one degree increase in Mean Relative humidity of the corresponding month, the expected log of dengue cases increase by 0.073.

For Max temp_3 [exp (0.217) = 1.242] and RH Mean [exp (0.073) = 1.076] have values greater than one. This means Maximum temperature at lag 3 month and Mean Relative humidity at lag 0 have shown greater impact on dengue incidence. Among them, Mean Relative humidity at lag 0 was the most influential.

Similarly, the percent change in the incident rate ratio (IRR) of dengue cases was a 1.242%, and 1.076% increase for every unit increase in Max temp_3, Mean RH respectively, holding other predictors constant.

4. Discussion

Cases of dengue are affected by climatic factors such as temperature and relative humidity, which we observed with the aid of a correlation study of the response variable with these predictor variables, suggesting the effect of the climatic factors of the previous month, compared to other countries, at different lag times [14, 21-23]. The lag period of 1 to 7 months was chosen, taking into account the time for the adult Aedes spp. To grow from egg, extrinsic and intrinsic virus incubation period and time from the start of symptoms for patients to attend hospital [24].

Table 7: Negative binomial regression model of dengue cases (Model)

Parameter Estimates										
Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
			Lower	Upper	Wald Chi-Square	Df	Sig.		Lower	Upper
(Intercept)	-9.398	1.9947	-13.307	-5.488	22.195	1	0	8.29E-05	1.66E-06	0.004
RHMEAN	0.073	0.0176	0.038	0.107	17.043	1	0	1.076	1.039	1.113
TEMPMAX_3	0.217	0.066	0.088	0.346	10.793	1	0.001	1.242	1.091	1.414
(Scale)	1[a]									
(Negative binomial)	2.737	0.3466	2.136	3.508						
Dependent Variable: Dengue Cases										
Model: (Intercept), RHMEAN, TEMPMAX_3										
a. Fixed at the displayed value.										

In order to calculate the correlation between variables, the correlation analysis is known to be one way classification, but this does not resolve the co-effect of the other climate influences, so we implemented regression analysis in order to find the true association. However, in correlation analysis, rainfall was found to be correlated with dengue cases; it is not included in the regression analysis as a significant predictor [8]. The model that included rainfall showed a low coefficient value that could have less effect on the incidence of dengue in the district of Mysore. Although the effect of rainfall on the incidence of dengue has been compared to the population of vectors. Excess rainfall, however, may have a negative effect.

In the escalation of dengue cases at various lag times, temperature has played an important role. Maximum temperature effect at lag 3 plays a significant role, along with mean relative humidity. We noticed that the high incidence of dengue occurs in the months of June to August. This transition, along with vector adaptation and human behavior, may be related to climate change.

5. Conclusion

For dengue incidence in Mysore district, Karnataka, we identified temperature and relative humidity as possible or significant contributors in this analysis, with maximum temperature at lag 3 months and mean relative humidity at lag 0 being the most important factors influencing dengue incidence. We propose that the dengue containment vector control software would be more successful if implemented from March-April.

6. Limitations

Climate conditions are not the only indicator of vector-borne diseases, like dengue. The relation between socio-demographic components such as population growth, travel or migration rates, water storage habits and dengue incidence should also be considered. This study has been confined to a single district, so many districts covering different geographical regions should be examined in the future.

7. Abbreviations

AIC: Akaike's information criterion; BIC: Bayesian information criterion; IRR: incident rate ratio.

8. References

1. Bhatt S, Gething PW, Brady OJ, Messina JP, Farlow AW, Moyes CL *et al*. The global distribution and burden of dengue. Nature 2013;496(7446):504-7.
2. Brady OJ, Gething PW, Bhatt S, Messina JP, Brownstein JS, Hoen AG *et al*. Refining the global spatial limits of dengue virus transmission by evidence-based consensus. PLoS Negl Trop Dis. 2012;6(8):e1760.
3. Pun SB. Dengue: an emerging disease in Nepal. Journal of the Nepal Medical Association 2011;51(184).
4. Gupta N, Srivastava S, Jain A, Chaturvedi U. Dengue in India. The Indian journal of medical research 2012;136(3):373-90.
5. Pandey BD, Morita K, Santa Raj Khanal TT, Miyazaki I, Ogawa T, Inoue S *et al*. Dengue virus, Nepal. Emerging infectious diseases 2008;14(3):514.
6. Pandey BD, Rai SK, Morita K, Kurane I. First case of Dengue Virus infection in Nepal. Nepal Med coll J 2004;6:157-9.
7. Acharya BK, Cao C, Xu M, Khanal L, Naeem S, Pandit S. Present and future of dengue fever in Nepal: mapping
8. climatic suitability by ecological niche model. International journal of environmental research and public health 2018;15(2):187.
9. Barbazan P, Guiserix M, Boonyuan W, Tuntaprasart W, Pontier D, Gonzalez JP. Modelling the effect of temperature on transmission of dengue. Medical and veterinary entomology 2010;24(1):66-73.
10. Ehelepola ND, Ariyaratne K, Buddhadasa WM, Ratnayake S, Wickramasinghe M. A study of the correlation between dengue and weather in Kandy City, Sri Lanka (2003-2012) and lessons learned. Infectious diseases of poverty 2015;4(1):42.
11. Githeko AK, Lindsay SW, Confalonieri UE, Patz JA. Climate change and vector-borne diseases: a regional analysis. Bulletin of the World Health Organization. 2000;78:1136-47.
12. Gupta BP, Tuladhar R, Kurmi R, Manandhar KD. Dengue periodic outbreaks and epidemiological trends in Nepal. Annals of clinical microbiology and antimicrobials 2018;17(1):6.
13. Pang T, Mak TK, Gubler DJ. Prevention and control of dengue—the light at the end of the tunnel. The Lancet Infectious Diseases 2017;17(3):e79-87.
14. Morin CW, Comrie AC, Ernst K. Climate and dengue transmission: evidence and implications. Environmental health perspectives 2013;121(11-12):1264-72.
15. Wikipedia. Mysore. Available from: https://en.wikipedia.org/wiki/Mysore. [Accessed 01 November 2020].
16. Zwilling ML. Negative binomial regression. The Mathematica Journal. Dx.doi.org/10.3888/tmj. 2013,15-16.
17. Hilbe JM. Modeling count data. Cambridge University Press; 2014 Jul 21.
18. Naish S, Dale P, Mackenzie JS, McBride J, Mengersen K, Tong S. Climate change and dengue: a critical and systematic review of quantitative modelling approaches. BMC infectious diseases 2014;14(1):167.
19. Tuladhar R, Singh A, Varma A, Choudhary DK. Climatic factors influencing dengue incidence in an epidemic area of Nepal. BMC research notes 2019;12(1):1-7.
20. UCLA Academic Technology Services. (2012). SAS Annotated Output: negative binomial regression. Available Source: URL: UCLA Academic Technology Services, 2012
21. Choi Y, Tang CS, McIver L, Hashizume M, Chan V, Abeyasinghe RR *et al*. Effects of weather factors on dengue fever incidence and implications for interventions in Cambodia. BMC public health 2016;16(1):1-7.
22. Hii YL, Zhu H, Ng N, Ng LC, Rocklöv J. Forecast of dengue incidence using temperature and rainfall. PLoS Negl Trop Dis. 2012;6(11):e1908.
23. Karim MN, Munshi SU, Anwar N, Alam MS. Climatic factors influencing dengue cases in Dhaka city: a model for dengue prediction. The Indian journal of medical research 2012;136(1):32.
24. Chan M, Johansson MA. The incubation periods of dengue viruses. PloS one 2012;7(11):e50972.