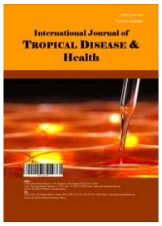


International Journal of TROPICAL DISEASE & Health

40(3): 1-19, 2019; Article no.IJTDH.53701
ISSN: 2278–1005, NLM ID: 101632866

Impact of Climatic Factors on Dengue Incidences in Eastern Province, Sri Lanka

K. A. N. K. Karunarathna[1*] and J. Sriranganesan[1]

[1]*Department of Mathematics, Faculty of Science, Eastern University, Sri Lanka.*

Authors' contributions

This work was carried out in collaboration between both authors. Author KANKK designed the study, performed the statistical analysis and wrote the protocol. Both authors wrote the first draft of the manuscript. Author JS managed data collection and the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJTDH/2019/v40i330228
Editor(s):
(1) Dr. Thomas I. Nathaniel, Department of Biomedical Sciences, School of Medicine -Greenville, University of South Carolina, Greenville, USA.
Reviewers:
(1) Meer Ahmad Mydin Meera, Meer Ahmad Health-Care Consultancy, Malaysia.
(2) Kabbale Fredrick George, Makerere University, Uganda.
Complete Peer review History: http://www.sdiarticle4.com/review-history/53701

Original Research Article

Received 25 November 2019
Accepted 01 February 2020
Published 11 February 2020

ABSTRACT

Introduction: Health sector is one of the most important sectors of any country. Many aspects such as diseases, health practices, and institutions are associated with health. Among different infectious diseases, dengue has become a major health issue for human in most tropical and subtropical regions. It is a viral disease originated and spread from mosquito and it is in several forms. Since, this seriously affects human life, taking necessary measures, including policies, rules, regulation and best practices to bring this menace into a minimum level, is essential. Such actions require proper background about the disease including factors that this disease depends on. Several factors may be associated with dengue fever and climatic variables take a greater place. Effect of these variables may vary from area to area.

Aims: This study aimed to investigate the impact of climatic variables for progression of dengue disease in the Eastern Province of Sri Lanka, which is consisted of three districts: Batticaloa; Trincomalee and Ampara.

Study Design: Number of dengue incidences and climatic variables such as rainfall, temperature, number of rainy days, day time humidity, night-time humidity, number of sunny days, and UV Index were obtained for each month in the period from 2009 to 2017 from Meteorology Department and

**Corresponding author: Email: nkkarunarathna@gmail.com;*

statistical abstracts of Sri Lanka. Analysis was carried out by using the statistical techniques: correlation analysis; regression analysis; principle component analysis and a graphical technique, contour maps.

Results: Only a few climatic factors affect dengue incidences in these three districts. However, no any regular pattern could be observed. Impact of each climatic factor varies from district to district. In Batticaloa district, a number of rainy days and day time humidity affect dengue incidences negatively and positively respectively meanwhile wind speed positively affects dengue incidences in Ampara district. No any climatic variables in Trincomalee district show a relationship with dengue incidences in the district. In general, moderate humidity creates a favourable situation for the spread of dengue disease irrespective of districts. Heavy rainfall does not show a relation with dengue incidences as people believe.

Conclusion: It is difficult to investigate the impact of each climatic factor alone on dengue incidences because there are inter correlated. Number of dengue incidences may depend on many other variables such as population density, geographical location, health practices, personal health status, knowledge, policies of different institutes and organizations. It is essential to incorporate these sorts of variables also to have a proper understanding of the dengue disease and its spread.

Keywords: Dengue; climatic factors; infectious disease; epidemic disease; mosquitoes.

1. INTRODUCTION

Dengue is a most rapidly spreading mosquito-borne viral disease in human as a major public health problem in many tropical and subtropical regions of the world. It is an infectious disease transmitted to human mainly through the bites of infected female mosquitoes *Aedes aegypti* and *Aedes albopictus*. It is caused by a flavivirus with four distinct but closely related serotypes (DENV 1, DENV 2, DENV 3 and DENV 4) [1]. This disease is classified into three forms. Dengue Fever (DF) which is the flu-like illness. Dengue Heamorrhagic Fever (DHF) is more severe and associated with loss of appetite, vomiting, high fever, headache and bleeding diathesis. Dengue Shock Syndrome (DSS) which reflect a high level of disease severity requiring intensive medical care [2].

The World Health Organization (WHO) estimates that 3.9 billion people, in 128 countries, are at risk of infection with dengue viruses. Not less than 500,000 people with severe dengue in every year are admitted to hospitals with a mortality rate of 2.5% every year [2].

Dengue is a serious public health problem in most of the administrative districts in Sri Lanka. The first serologically confirmed dengue incidence in Sri Lanka was in 1962 [3]. The first island-wide outbreak was reported in 1965 [4]. Both *Aedes aegypti* and *Aedes albopictus* are widespread in Sri Lanka [5] and all four serotypes have been circulating in the country for more than three decades [6]. *Aedes aegypti* is the primary dengue vector in most endemic countries and a highly domesticated urban mosquito that lives close to human residences where they develop as adults [7]. The adult mosquitoes prefer to rest indoors and may feed daylight hours and on low sunshine day if they are indoors [8]. It prefers to feed on humans, and breed in natural and artificial man-made water containers as its larval habitat. Human-blood is both a protein source for egg development and energy for flight [9]. *Aedes albopictus* also contributes to dengue transmission, but serves as a vector primarily in rural areas [10] and have outdoor larval habitat. *Aedes aegypti* is a daytime feeder and its peak biting periods are early in the morning and before dusk in the evening. *Aedes aegypti* will often feed on several persons during a single blood meal and may transmit dengue virus to multiple persons in a short time [8].

During the past few months, an increasing trend in the number of dengue incidences has been reported in Sri Lanka. In the year 2018, 51569 dengue incidences and from January to November 2019, 80776 dengue incidences were reported to the Epidemiology Unit of the Ministry of Health, Nutrition and Indigenous Medicine. Sri Lanka experienced its largest dengue epidemic in 2017. In 2017, 186101 dengue incidences were reported to the Epidemiology Unit of the Ministry of Health of Sri Lanka with over 320 deaths. The highest numbers of dengue incidences were reported during the month of June, 2017. According to the WHO, this is a 4.3 fold higher than the average number of incidences for the same period between 2010 and 2016.

Unplanned urbanization, globalization, climate change and increasing population growth are important factors affecting dengue that may facilitate the global spread of dengue [11]. Further, global warming can extend the disease transmission season and decrease the duration of the female mosquito's gonotrophic cycle [9]. Climatic factors affect directly and indirectly the disease spreading, mosquito breeding and establishment [12]. Heavy monsoon rains, public failure to clear rain-soaked garbage, standing water pools and other potential breeding grounds for mosquito larvae are characteristic of the higher number of incidences reported in urban and suburban areas [13]. In recent decades, dengue has been expanding globally due to climate change.

Sri Lanka is located between 5º55′ and 9º51′ North latitude and between 79º42′ and 81º53′ East longitude [14]. Due to the geographic location of Sri Lanka the climate could be characterized as tropical. Climate factors play an important role in local and global transmission of dengue. Sri Lanka ranked as fourth in 2016 [15] and second in 2017 [16] highest climate risk country in the world. Rainfall, temperature, humidity, number of rainy day, number of sunshine days and wind are the most important meteorological factors in spreading dengue virus. Rainfall in Sri Lanka has multiple origins. Monsoonal, Convectional and depressional rain account for a major part of the annual rainfall. Monsoon rain occurs two periods, namely, the South–West from May to September and North-East from December to February, and is responsible for nearly 55% of the annual precipitation [17]. Convectional rain occurs during the first inter-monsoon period from March to April, mainly in the afternoon or evening and is likely to be experienced anywhere over the Island. Depressional rain also occurs during the second inter-monsoon from October to November.

Rainfall contributes to create and maintain breeding sites for mosquitoes. Historical data shows that there were always two peaks of dengue incidence in Sri Lanka. One during South-West monsoons and another during North-East monsoons. Analysis of the data on the present outbreak showed the incidence of dengue was high in Eastern province and districts adjoining to Western province. Especially with the commencement of the North-Eastern monsoons, there was a risk of dengue outbreaks in more districts [18]. Rainfall affects reproduction of vectors and vector abundance [19]. However heavy rainfall may flush out larvae and pupae from outdoor containers and may reduce the lifespan of the mosquitoes. A certain number of rainy days is generally favorable for mosquito development.

Fig. 1. Map of Sri Lanka (Eastern province has been colored)

The average annual temperature of the country ranges from 26ºC to 28ºC and average level of humidity ranges from 60 to 90% during the different seasons in different regions of the country and changes with rainfall. Higher temperature may reduce the extrinsic incubation period of the dengue virus, egg development time and increase the biting rate of the mosquitoes. Humidity affects flights and host seeking behaviour and lifespan of mosquitoes and mosquito reproduction. High humidity is associated with increased feeding activity, survival and development of eggs in *Aedes aegypti*. Humidity and wind directly affect evaporation rates of mosquito breeding sites. A certain number of rainy days is generally favourable for mosquito development [19]. Moreover, the daily minimum temperature and an increase in the rainfall from the previous month were associated with an increase in the larval abundance [20]. There is a combined contribution of temperature and humidity on dengue outbreaks generated by the feeding activity, survival and development of mosquitoes [21].

In 2017, the second greatest number of dengue-related mortalities had been recorded in Eastern province [22]. The Eastern coastal districts Batticaloa, Trincomalee and Ampara lie in the dry zone of Sri Lanka. Batticaloa and Trincomalee are badly affected by dengue in recent years [18]. A seasonal shift in the density of the two *Aedes* species has been observed in Batticaloa. *Aedes aegypti* tends to predominate during the pre-monsoon season and *Aedes albopictus* during the monsoon season. Since the monsoon rain in Batticaloa district from October to December, the density of *Aedes mosqutoes* increases during this period and a positive association between rainfall and *Aedes* density has been observed [5].

Numerous studies have been done around the world to relate dengue incidence and climate factors [19]. Weerartne et al. conducted *Aedes* egg survey and larval survey in Kandy and Kurunegala districts of Sri Lanka. They presented no positive association between the abundance of *Aedes* eggs and larval density indices with the number of dengue incidences in Kandy [23]. Also there was a positive relationship between the number of *Aedes* eggs and rainfall and humidity but not with temperature. Dharshini et al. also conducted *Aedes* egg survey and larval survey in Batticaloa district of Sri Lanka [5]. They observed a positive association between rainfall and *Aedes* density.

Liyanage et al. pointed that both rainfall and temperature are significantly associated with risk of dengue in the Kalutara district of Sri Lanka [24]. Also they described a strong relationship between the oceanic El Nino index to weather patterns and to dengue at a longer latency time. They used distributed lag non-linear model and hierarchical analysis to estimate the overall relationship between weather and dengue. Sirisena et al. generated an auto regressive integrated moving average (ARIMA) model to predict the future outbreak in 12 districts of Sri Lanka [25]. They used GIS methodology to map and evaluate the spatial and temporal distribution of dengue and elucidated the association of geographical and climatic risk factors with dengue incidence. Ehelepola et al. have obtained a result that large diurnal temperature ranges were negatively correlated with dengue transmission in Colombo district of Sri Lanka [26]. Similar studies with different climate factors (temperature and humidity) were done by them in Kandy [27]. Also the rainfall, temperature, humidity, hours of sunshine and wind were correlated with the dengue incidence using the wavelet time series analysis [28]. Sun et al. found an association of dengue incidence and local climate factors for 12 districts of Sri Lanka and the correlations are different for different districts [29]. Moreover they found an ARIMA models for each districts to predict future trends of dengue incidence. Prakash et al. did a study in Sri Lanka: Seven districts of Sri Lanka were randomly selected across all climatic zones for this study [30]. They concluded that the incidence of dengue have shown an increasing trend from 2006 to 2015 in almost all the districts and there is a statistically significant difference between average incidences between years. They constructed Poisson Regression model (Log –linear) to identify the relationships between temperature, rainfall and dengue incidence in all districts together. Sirisena et al. explained the importance of effective vector control programmes to reduce the dengue related morbidity and mortality in Sri Lanka [6]. Also they explained about the virus, changes in the epidemiology, role of climatic factors in spread of dengue virus and the prevention of dengue. Edirisinghe revealed that the rainfall factors play a vital role in the spread of the disease in Colombo district of Sri Lanka but relatively low relationship were identified between rain and the spreading of the disease in other part of the country [31].

Chakravarti et al. designed a relationship of dengue infection with climatic factors in India. They found that highlighted rainfall, temperature and relative humidity as a major and important factors for dengue outbreak [32]. Promprou et al. indicated that the climate factors may play a part in the transmission cycles of DHF and the relative importance of these climate factors varied with geographical areas in Southern Thailand [19]. They found that relative humidity had a positive association with transmission of DHF on the Andaman sea side but a slightly negative association on the Gulf of Thailand side. Step wise regression technique was used to fit the statistical model. Tuladhar et al. analyzed the importance of environmental factors influencing dengue incidence in Chitwan district of Nepal by negative binomial model [33]. They found that temperature and relative humidity were significantly affected dengue incidence but rainfall was not associated with dengue incidence. Lai analyzed the climate factors affecting dengue fever outbreaks in Southern Taiwan [34]. The result indicated that temperature is significantly correlated with dengue fever incidence but rainfall and sunshine were both negatively correlated with the transmission of dengue fever. Zhang et al. assessed the epidemic characteristics of dengue in Chao-Shan area of China and the effect of seasonal climate variation on the dynamics of dengue [35]. They included mean temperature, mean rainfall and mean relative humidity for the wavelet analysis for time series of notification of dengue.

Most of climate studies on dengue have been done in the central province and Western province of Sri Lanka [23,24,26], where the climate differs significantly from that of the Eastern province of Sri Lanka. Only few studies have been done on the relationship between climate and dengue incidences in Batticaloa [5] and those studies were limited to data which were collected from only Batticaloa district in the Eastern Province of Sri Lanka. The objective of this study is to identify the impact of climatic factors on the density (in terms of number) of dengue incidences in the Eastern province of Sri Lanka, which has three districts Batticaloa, Trincomalee and Amapra.

2. MATERIALS AND METHODS

The objective of this study was to find the relationship between number of dengue incidences in Eastern province which was obtained from the Epidemiology Unit of the Ministry of Health, Nutrition and Indigenous Medicine and some climatic factors which data were available for. Monthly data from year 2009 to year 2017 were obtained from the statistical abstracts of Department of Census and Statistics, Sri Lanka. Number of dengue incidences, rainfall (mm), temperature (ºC), number of rainy days, day time and night time humidity (percentage of water particles in air), wind speed (kmh^{-1}), number of sunny days in each month in the considered period were recorded.

For this kind of analysis, different statistical methods could be used. Promprou, Jaroensutasinee and Jaroensutasinee in 2005, have used step wise regression technique [19] meanwhile Poisson regression has been used by Prakash et al. to model number of dengue incidences [30]. Further, Promprou, Jaroensutasinee and Jaroensutasinee in 2005, have used negative binomial model for representing number of dengue incidences [19]. The wavelet time series analysis has been used by Ehelepola and Ariyaratne in 2015 to model number of dengue incidences [27].

This analysis was carried out by using several statistical techniques including a graphical representation. First, the correlation analysis was used to identify the linear relationships of variables. Pearson's product moment correlation coefficient was used as the measure of linear relationship. The relationship of number of dengue incidences with other climatic factors was given the priority than the relationship among climatic factors. Further, regression model was also used to identify the impact of each climatic variable on number of dengue incidences. Contour maps were produced for identified pairs of climatic variables that were identified from regression analysis and identified impacts of those factors. Since, some of climatic variables considered for the regression analysis show multicollinearity, principle component analysis also was performed to produce some independent predictors with climatic factors, and regression analysis of dengue incidences was performed with principle components. In the analysis, the first three principle components were used for the regression analysis since they could cover more than 80% of total variation. Minitab 14 version was used for the analysis meanwhile analysis was carried out separately for each district. Some graphs were produced in Excel.

3. RESULTS AND DISCUSSION

An overview of the status of dengue incidences in all districts is given in the first part of this section while the results of the analysis are discussed separately for each district in the second part.

Total number of dengue incidences in each district in each year throughout the period considered, is given in the Table 1 while it is illustrated in Fig. 1. Extreme numbers of dengue incidences have been found in 2017 from all these districts compared to other years in this period. Batticaloa district shows the highest number of dengue incidences in year 2017 while the minimum number of dengue incidences has been reported from Ampara district.

During the period from 2009 to 2017, a total of 13412 dengue incidences have been reported from Batticaloa district which was the highest among these three districts. In other years, except 2017, numbers of dengue incidences are within 534 to 1693 and the highest number of incidences, 5600, in 2017, is also from Batticaloa.

The minimum total of 8487 dengue incidences was recorded by Trincomalee district during the entire period with a range from 168 to 661 in the period 2009-2016. In 2017, a peak value, 5008, of dengue incidences was reported in Trincomalee district.

In Ampara, a total of 9350 incidences have been reported from 2009 to 2017 with the highest number of dengue incidences in year 2017, which was 4080. In Ampara district, dengue incidences are in the range from 284 and 1240 during the period from 2009 to 2016.

Figure 2 clearly shows that during the period from 2009 to 2017, numbers of dengue incidences in Batticaloa are higher compared with other two in which the minimum is shown by Trincomalee except in 2013 and 2016. However, in 2013 and 2016, Ampara has recorded the highest total incidences.

Other results of the analysis that was carried out separately for each district are discussed district wise below.

3.1 Results of Batticaloa District

Number of dengue incidences that have been recorded in each month during the period considered are illustrated by Fig. 3. Overall, two phases can be observed in this graph. The first phase is from 2009 to 2015 and then the second is from 2016 to 2017. Within the first phase, except in few months, number of dengue incidence in a month is below 100. Only around five occasions, it has exceeded 200. However, incidences in months in the second phase, from 2016 to 2017, are higher along that period. On average, it can be observed that the minimum incidences are in the months around October and the higher incidences are seem to be around December and adjacent months.

Figure 4 illustrates how each climatic factor, along with dengue incidences, has distributed, on average, within a period of year. Among the climatic variables in Batticaloa, rainfall shows a higher variation within the year. Rainfall, on avarage, increases from September to December and then decreases upto March. During the period from March to September, district gets less rainfall than 100 mm. In June and July, it becomes the mininmum. Average number of dengue incidences also show a fluctuation within the year. From September to April, an increasing trend can be observed while it gradually drops down till September in which the minimum can be seen.

Monthly average night time humidity in Batticaloa district varies in the range nearly from 75 to 90. In the period from June to September, it is below 80. The average day time humidity, which shows a pattern similar to average night time humidity within the year, vary with a minimum of 60 and maximum of 80, and also lower values are during the period from May to October. It is clear that average temperature is in the range from 25 to 30, with a slight increment in the middle of the year. The special pattern, an opposite trend, can be observed in average number of rainy days and sunny days. The least average number of rainy days per month within the period considered is about 10 meanwhile average value of UV index per month is below 10 throughout the year.

Table 1. Number of dengue incidences in each district

Year	Number of dengue incidences		
	Batticaloa	Trincomalee	Ampara
2009	534	189	389
2010	1250	987	774
2011	1693	177	284
2012	717	168	557
2013	556	207	746
2014	970	661	675
2015	1474	587	605
2016	612	503	1240
2017	5606	5008	4080
Total	13412	8487	9350

Table 2. Correlations between number of dengue incidences and climatic variables

Rainfall	Temperature	Rainy days	Humidity day	Humidity night	Wind speed	Sunny days	UV Index
-0.068 (*P*=.48)	-0.095 (*P*=.32)	-0.195 (*P*=.04)	0.198 (*P*=.04)	0.140 (*P*=.15)	0.158 (*P*=.10)	0.168 (*P*=.08)	0.039 (*P*=.68)

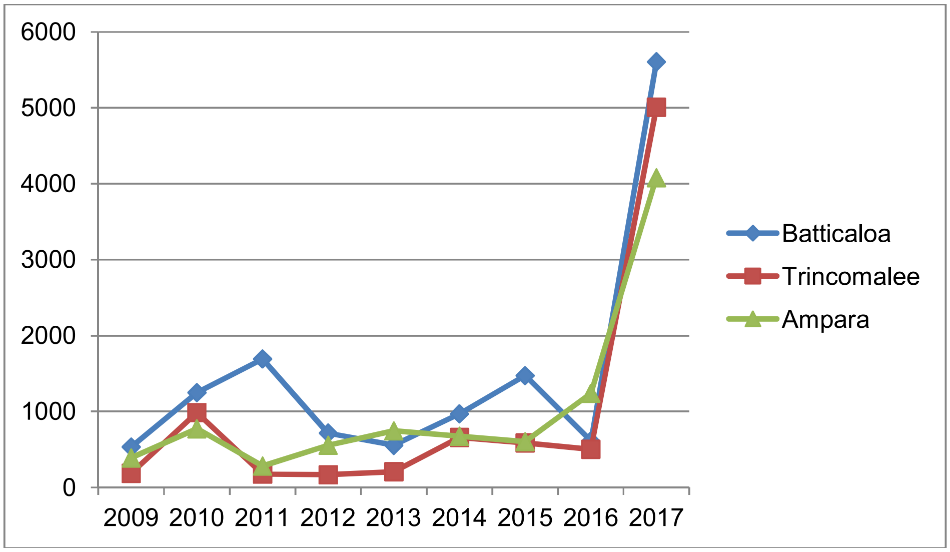


Fig. 2. Distribution of dengue incidences of each district in the period from 2009 to 2017

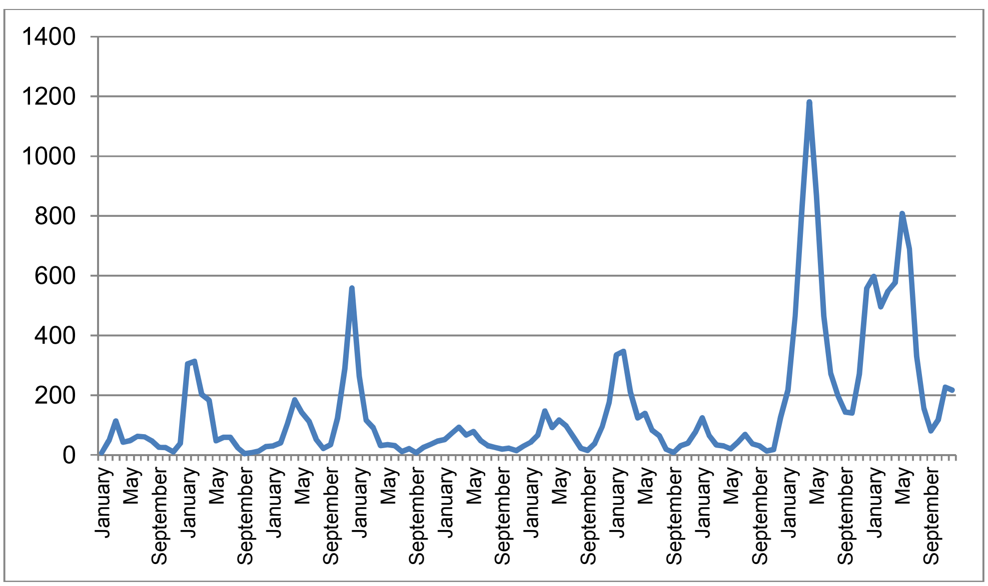


Fig. 3. Distribution of dengue incidences over the period

Measures for linear relationships, the Pearson's correlation coefficients between number of dengue incidences and climatic variables in Batticaloa district are given in the Table 2 with corresponding *P*-values within the brackets. Number of dengue incidences is negatively correlated with number of rainy days and positively correlated with day time humidity. Meanwhile, other climatic variables in Batticaloa district do not show significant relationships with number of dengue incidences. It can be observed that most of climatic variables are inter correlated.

Number of dengue incidences was modeled by a multiple linear regression model with all climatic variables. Since, all climatic variables, except day time humidity, were not significant, a simple linear regression model was fitted again only with day time humidity. Details of the fitted model are given in Table 3 and Table 4. *P*-value indicates that regression model is significant.

Details regarding the significant of factor are in the Table 4. Day time humidity is highly significant.

Contour plots for dengue incidences for some selected pairs of climatic variables are given in Fig. 5. The plot under Fig. 5a clearly indicates that density of dengue incidences is higher when day time and night time humidity are moderate. It is indicated by the Fig. 5b that low rainy days and middle humidity in the range from 20 to 50 bring higher density of dengue incidences. Furthermore, according to the Fig. 5c, number of rainy days and night humidity do not contribute much for higher number of dengue incidences.

The results of principle component analysis are given in Table 5 and Table 6. Values in the second row of the Table 5 represent the variance, as a proportion of the total variance, of each principle component and the cumulative proportion of the total variance of climatic variables are in the last row. The first three principle components can explain 80.7% of total variance. Table 5 represents the contribution of each climatic factor for each principle components.

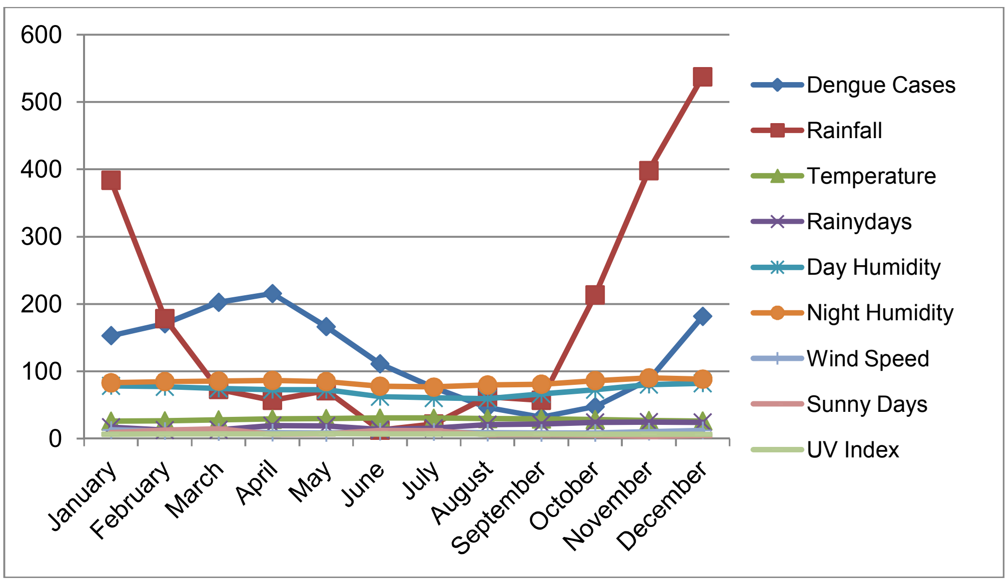


Fig. 4. Distribution of climatic variables and dengue incidences within a year

Table 3. ANOVA table of regression model with day time humidity

Source	DF	SS	MS	F	*P*
Regression	1	1724991	1724991	52.13	0.000
Residual error	105	3474315	33089		
Total	106	5199306			

DF: Degree of freedom; SS: sum of square of error; MS: mean square of error; F: F table value; P- P value

Table 4. Significance of predictor in the regression model

Predictor	Coef	SE Coef	T	*P*
Humidity day	1.76	0.24	7.22	0.000

Coef: coefficient; SE coef: Standard error of coefficient; T: t table value; P-P value

Table 5. Details of principle component analysis

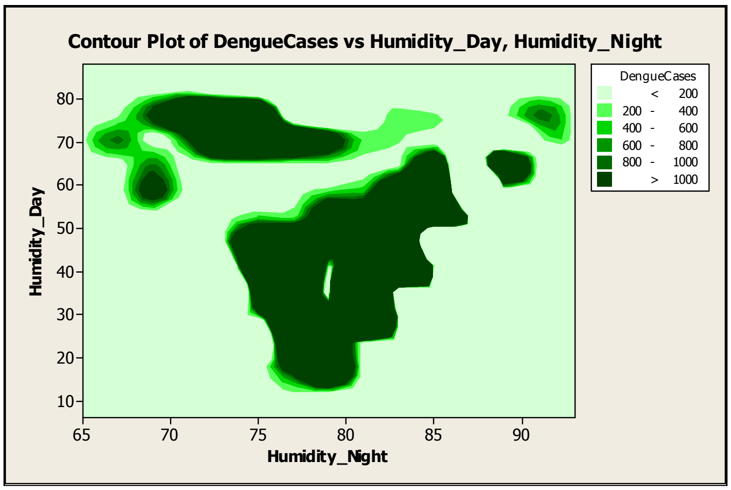
Eigen value	3.641	1.8253	0.9898	0.6532	0.3873	0.2649	0.1825	0.056
Proportion	0.455	0.228	0.124	0.082	0.048	0.033	0.023	0.007
Cumulative	0.455	0.683	0.807	0.889	0.937	0.970	0.993	1.000

Proportion: variance as a proportion of total variance; cumulative: cumulative proportion

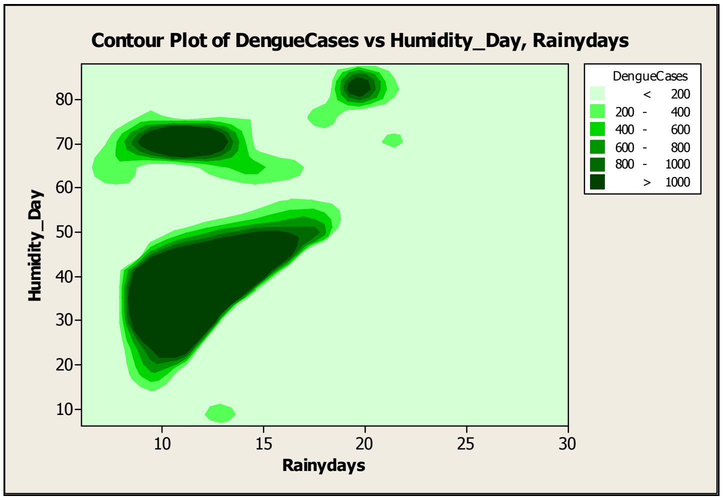
Table 6. Coefficient of principle components

Variable	PC1	PC2	PC3
Rainfall	-0.419	-0.115	0.029
Temperature	0.414	0.359	-0.112
Rainy days	-0.363	0.481	-0.173
Humidity day	-0.423	-0.122	0.355
Humidity night	-0.413	0.085	0.227
Wind speed	-0.170	-0.573	-0.169
Sunny days	0.336	-0.495	0.190
UV index	0.174	0.176	0.845

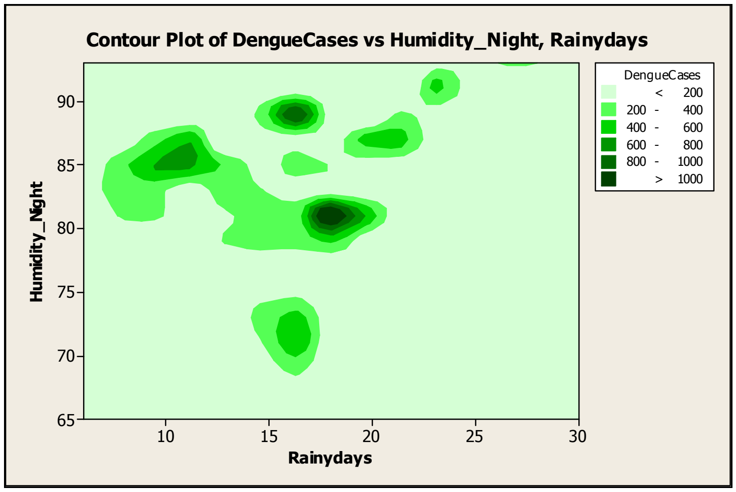
PC1: principle component 1; PC2: principle component 2; PC3: principle component 3



(a)



(b)



(c)

Fig. 5. Contour maps of dengue incidences for some pairs of climatic variables

Rainfall, rainy days, day time and night time humidity, and wind speed negatively contribute to the first principle component while other variables do have positive effect. The second principle component is negatively affected by the variables rainfall, day time humidity, wind speed and number of sunny days and other show positive contribution.

Results of the regression model fitted with first three principle components are given in Table 7 and Table 8. *P*-value in the Table 7 indicates that model is significant at 5% significance level. Except the second principle component other two principle components including the intercept are significant at 5% significance level according the *P*-values in the Table 8. Rainfall, number of rainy days, day time humidity have higher contribution for the first principle component and the second principle component is most highly contributed by UV Index.

3.2 Results of Trincomalee District

Distribution of dengue incidences in each month in the period considered is given by Fig. 6. In this district also, two phases, in terms of number of dengue incidences, can be observed during. In the first phase, that is 2009-2016, numbers of dengue incidences are below 100 in almost all months, except in seven months. They are January (233), February (283), March (145) in 2010, April (115) in 2014, January (131) in 2015 and January (102), December (132) in 2016. In year 2017, it varies from 70 in October to 2114 in March.

The distribution pattern of dengue incidences, per month, on average, in Trincomalee district is given in Fig. 7 with pattern of all other climatic variables. Average monthly dengue incidences during the period from January to April is higher, than 50 incidences, compared to the rest of period of the year. Further, it is apparent that a decreasing trend is during the period April to October and increasing pattern is from October to April. March shows the on average per month highest dengue incidences of about 380 in Trincomalee district. That is due to a single value, 2114, in March 2017. Except this figure, average number of incidences much more less than it appears now. It is probably about 50.

In Trincomalee district, on average rainfall per month, is below 400 mm. In general, an increasing trend in average rainfall per month is in the period from June to December and then it declines upto June. Night time humidity is higher than that of day time. Monthly average night time humidity is in the range from 75 to nearly 85. During the period from May to September, average humidity is just below 80. Monthly average day time humidity, which is always less than night time, decreases from around 75 to 60 during from January to July. Then, it moves up till 80 in the rest part of the year. Average monthly temperature shows an increasing trend from January to June and then downward trend upto December. Anyhow average monthly temperature is within 25 to 30. Average number of sunny days is little below 15. Average monthly wind speed has exceeded 20 in the period from

June to August, but below 25. Value less than 10, but nearly close values, are in each month for UV index.

Pearson's correlation coefficients for each pair of climatic variables and dengue incidences are given in the Table 9. Those climatic variables show positive as well as negative relationships with number of dengue incidences. However, no any factor shows a significant relationship with dengue incidences except relationships among climatic variables itself.

Results of the regression model fitted for the dengue incidences by climatic variables are given in Table 9 and Table 10. According to *P*-values, it is clear that no any factor is significant at 5% significance level.

Contour plots of dengue incidences produced for certain pairs of climatic variables are given in Fig. 8. These plots exhibit that higher density of dengue incidences reported when moderate day time and night time humidity are available. Fig. 8b shows moderate wind speed and low night humidity as well as higher night humidity and low wind speed create a favorable environment for dengue incidences.

Details of principle components of climatic variables of Trincomalee district are given in the Table 11. Eigen values, proportion of variance that represented by each principle component, and cumulative proportions of variance are given in the Table. It is clear that first three principle components represent more than 80% of total variance. Hence, in fitting the regression model, only first three components were used.

Rainfall, number of rainy days, day time humidity and night time humidity are positively related with the first principle component analysis while other variables negatively contribute to it. Except UV index, all other variables are having equal contribution in size. The second principle component is positively affected by rainfall, day time humidity, wind speed and sunny days. Anyhow, wind speed shows the least contribution while day time humidity also shows a lower coefficient. A positive contribution is shown by rainfall, temperature, rainy days, and wind speed to the third principle component analysis. UV index shows the highest negative contribution for the third principle component while rainfall shows the least.

Table 7. ANOVA table of the regression model with principle components

Source	**DF**	**SS**	**MS**	**F**	***P***
Regression	3	490182	163394	5.45	0.002
Residual Error	104	3118307	29984		
Total	107	3608488			

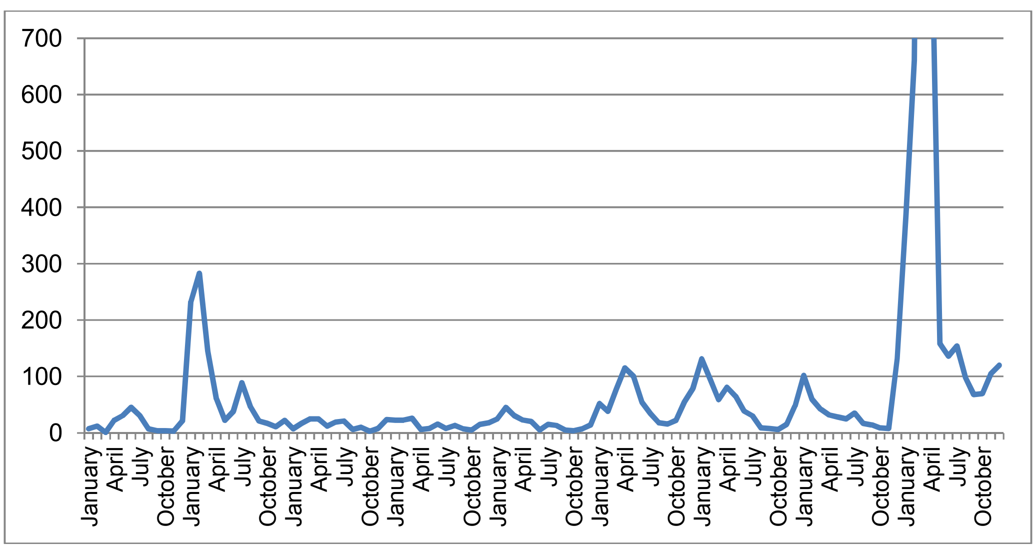


Fig. 6. Distribution of dengue incidence in Trincomalee district

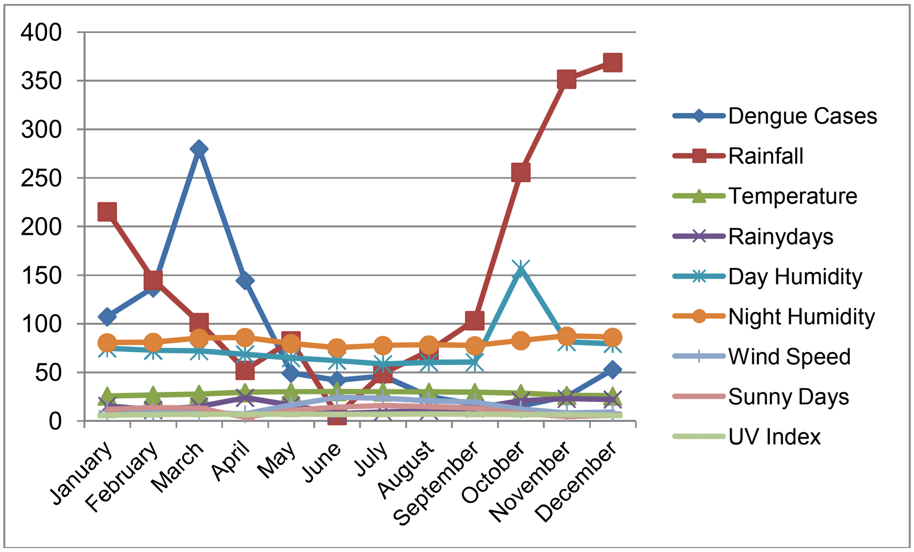


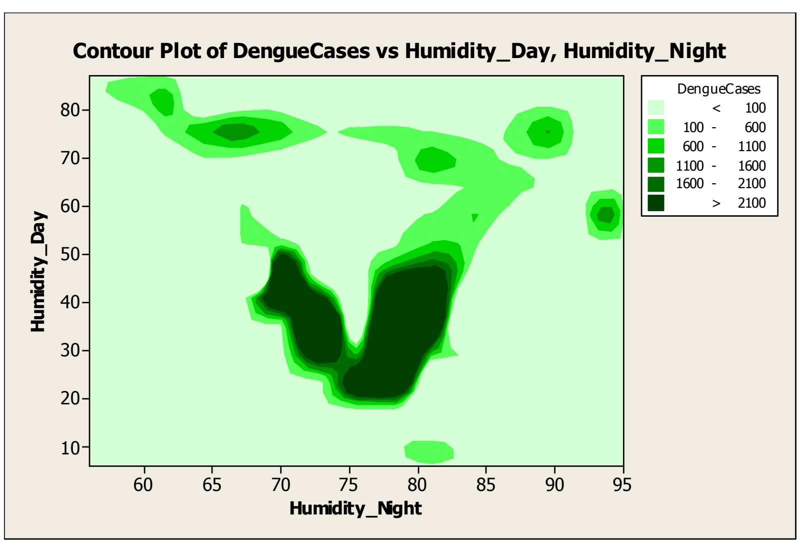
Fig. 7. Distribution of each climatic variables and dengue incidences in Trincomalee district

Table 8. Significance of the principle components in regression model

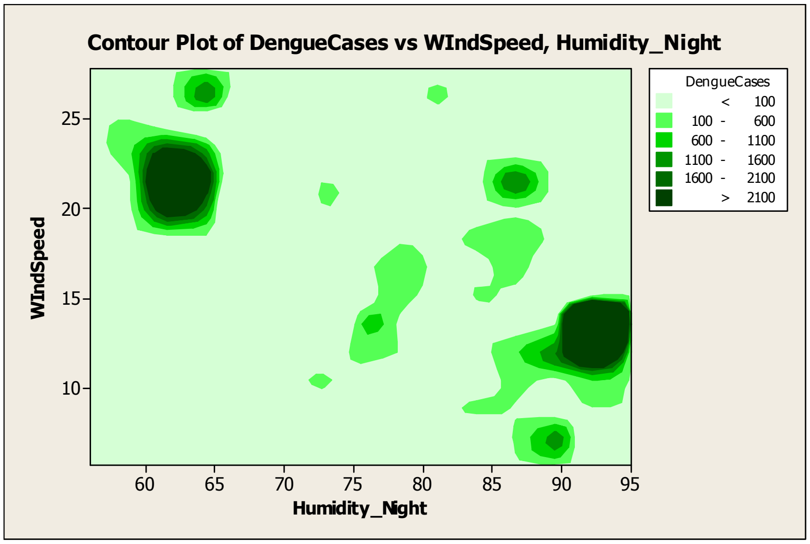
Predictor	**Coef**	**SE Coef**	**T**	***P***
Constant	-536.40	228.90	-2.34	0.02
PC1	1.96	0.67	2.90	0.005
PC2	-1.46	2.72	-0.54	0.59
PC3	18.51	5.26	3.52	0.001

Table 9. Correlations between number of dengue incidences and climatic variables

Rainfall	**Temperature**	**Rainy days**	**Humidity day**	**Humidity night**	**Wind speed**	**Sunny days**	**UV index**
-0.045 (P=.64)	-0.044 (P=.65)	-0.004 (P=.96)	0.066 (P=.49)	0.1 (P=.31)	-0.154 (P=.11)	0.017 (P=.86)	0.022 (P=.82)



(a) Day humidity Vs night humidity



(b) Wind speed Vs night humidity

Fig. 8. Contour plots for some selected variables

Results of the regression model fitted with these principle components are given in the Table 13 and Table 14. Figures (*P*-values) in these two tables imply that no any principle component is significant. This indirectly indicates that status of dengue incidences do not depend on climatic variables.

3.3 Results of Ampara District

Distribution of dengue incidences in Ampara district is illustrated by Fig. 9. Number of dengue incidences in Ampara district is well below 50 except in a few occasions. During the time closer to January in several years, number has gone beyond 100. The special matter is that in every month of 2017, numbers of dengue incidences are higher than 100 and below nearly 650.

Average number of dengue incidences per month does not exceed 175, meanwhile it shows the minimum of nearly 50 during the period from April to October. Monthly average rainfall also shows almost similar pattern of dengue incidences, where it goes upto 350. From January to June, it gradually decreases and then increases upto December. In this district, monthly average day time humidity comes down from 90 to around 75 during the period from January to September. Again it starts to increase till its' maximum. In Ampara district too, monthly average temperature is between 25 and 30 approximately. During the middle part of the year, temperature is in high level. Throughout the year, average monthly wind speed is below 25 whereas low averages are indicated from February to October. Average number of rainy days in Ampara district is less than 20 in the first part of the year upto August. Thereafter, it increase to maximum of 25 in December. An opposite pattern is shown by the average number of sunny days. In general, UV index remains almost the same level all the year around.

Table 15 shows that among all climatic variables considered, only wind speed shows a significant positive correlation of size 0.36. However, other climatic variables are having inter relationship among them self.

The results of the regression model fitted with climatic variables are given in the Table 16. Its *P* -value is 0.00 which is less than significance level. This indicates that the model is significant at 5% significance level.

Significance of each factor in the regression model is given in the Table 17. It is clear that only wind speed show a relationship with number of dengue incidences in Ampara district.

The contour map produced for slightly significant variables are given in the Fig. 11. This plot indicates that density of dengue incidences is higher when wind speed and number of sunny days are lower.

Table 10. ANOVA table for regression model

Source	DF	SS	MS	F	*P*
Regression	8	343548	42944	0.760	0.642
Residual Error	94	5341441	56824		
Total	102	5684989			

Table 11. Details of principle components

Eigen value	4.518	1.189	0.717	0.575	0.448	0.315	0.173	0.064
Proportion	0.565	0.149	0.090	0.072	0.056	0.039	0.022	0.008
Cumulative	0.565	0.713	0.803	0.875	0.931	0.970	0.992	1.000

Table 12. Coefficients of first three principle components

Variable	PC1	PC2	PC3
Rainfall	0.345	0.205	0.140
Temperature	-0.349	-0.466	0.215
Rainy Days	0.398	-0.393	0.264
Humidity Day	0.352	0.170	-0.340
Humidity Night	0.355	-0.256	-0.342
Wind Speed	-0.399	0.035	0.331
Sunny Days	-0.354	0.470	-0.389
UV Index	-0.258	-0.520	-0.610

Table 13. ANOVA table for regression model

Source	DF	SS	MS	F	*P*
Regression	3	223453	74484	1.420	0.243
Residual Error	104	5473281	52628		
Total	107	5696734			

Table 14. Significance of principle components in regression model

Predictor	Coef	SE Coef	T	*P*
Constant	-269.00	180.20	-1.49	0.139
PC1	2.06	1.36	1.52	0.133
PC2	0.05	2.62	0.02	0.986
PC3	-6.62	3.54	-1.87	0.064

Table 15. Correlations between number of dengue incidences and climatic variables

Rainfall	Temperature	Rainy Days	Humidity day	Humidity night	Wind speed	Sunny days	UV Index
0.135 (*P*=.17)	-0.184 (*P*=.06)	-0.110 (*P*=.25)	0.144 (*P*=.14)	0.112 (*P*=.25)	0.360 (*P*=.00)	0.067 (*P*=.49)	-0.115 (*P*=.24)

Table 16. ANOVA table of regression model by climatic variables

Source	DF	SS	MS	F	*P*
Regression	1	925669	925669	72.03	0.00
Residual Error	107	1375031	12851		
Total	108	2300700			

Table 17. Significance of climatic variables in regression model

Predictor	Coef	SE Coef	T	*P*	VIF
Wind Speed	8.975	1.058	8.49	0.01	0.000

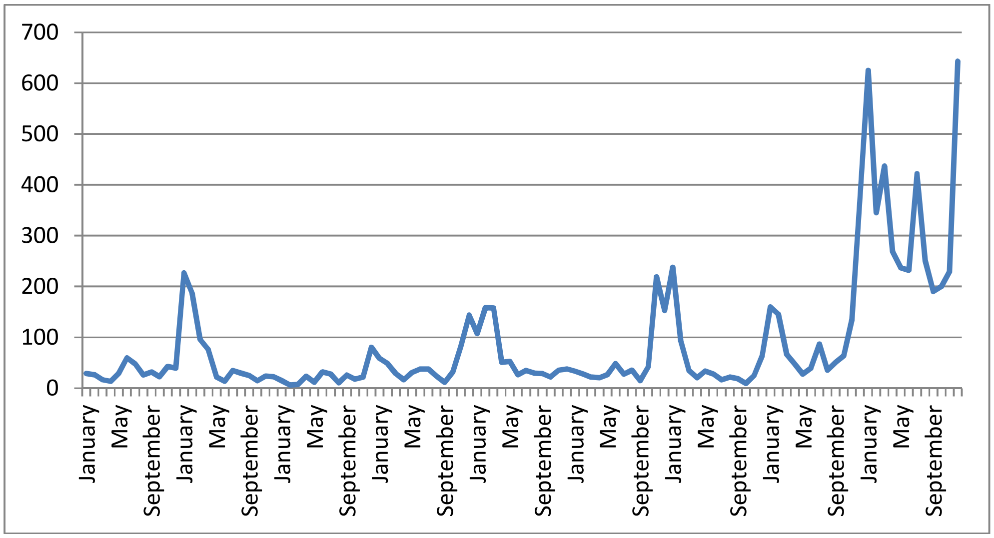


Fig. 9. Distribution of dengue incidences in Ampara district

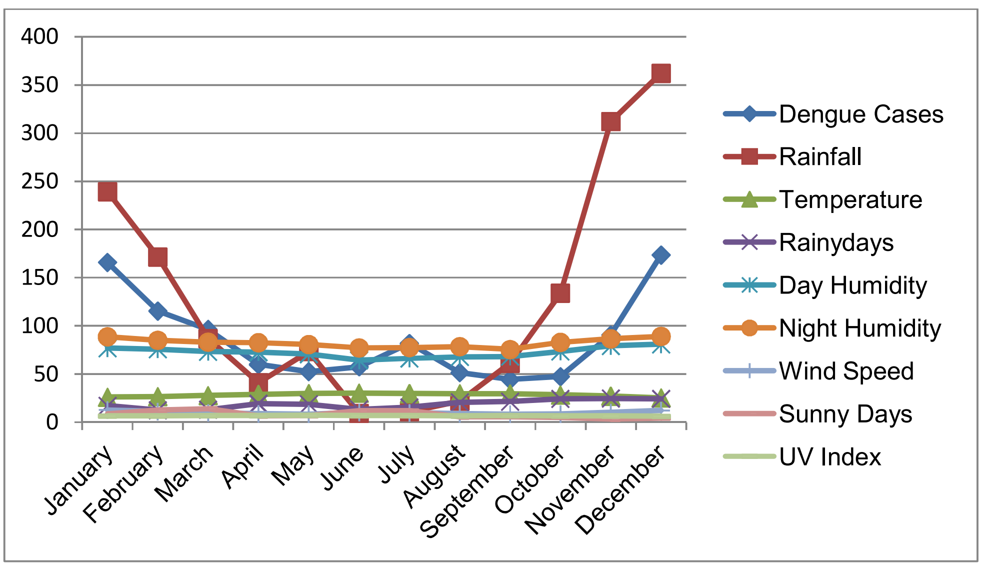


Fig. 10. Distribution of each climatic variables and dengue incidences in Ampara district

Table 18. Details of principle components

Eigen value	3.880	1.843	0.821	0.599	0.379	0.285	0.1319	0.060
Proportion	0.485	0.230	0.103	0.075	0.047	0.036	0.016	0.008
Cumulative	0.485	0.715	0.818	0.893	0.940	0.976	0.992	1.000

Details of the principle components obtained for climatic variables of Ampara district are given in the Table 18. Cumulative proportions of variance imply that first three principle components cover more than 80% of total variation of climatic variables. Therefore, only three principle components were used.

P-value in the Table 19 indicates that the regression model fitted with three principle components is significant at 5% significance level.

Details about the significance of each principle component in the regression model are given in the Table 20. Only the second principle component is significantly affects the number of dengue incidences.

Contribution of each climatic factor for each principle component is given in the Table 21. Each climatic factor contributes differently for each principle component. In case of the second principle component, number of sunny days and wind speed negatively give higher contribution meanwhile number of rainy days and rainfall contribute positively for the second principle component. This indicates dengue incidences is negatively correlated with number of sunny days and wind speed, while it is positively related with rainfall and number of rainy days.

Table 19. ANOVA table of regression model of principle components

Source	DF	SS	MS	F	*P*
Regression	3	121461	40487	3.07	0.03
Residual Error	104	1369772	13171		
Total	107	1491232			

Table 20. Significance of principle components in regression model

Predictor	Coef	SE Coef	T	*P*
Constant	-23.74	61.65	-0.39	0.70
PC1	-6.22	4.01	-1.55	0.12
PC2	-7.75	3.07	-2.52	0.01
PC3	13.44	8.47	1.59	0.11

Table 21. Coefficients of principle component analysis

Variable	PC1	PC2	PC3
Rainfall	-0.439	-0.055	-0.234
Temperature	0.405	0.248	0.124
Rainy Days	-0.300	0.569	0.052
Humidity Day	-0.473	-0.041	-0.150
Humidity Night	-0.384	-0.096	-0.080
Wind Speed	-0.229	-0.493	-0.018
Sunny Days	0.272	-0.580	-0.068
UV Index	0.238	0.144	-0.945

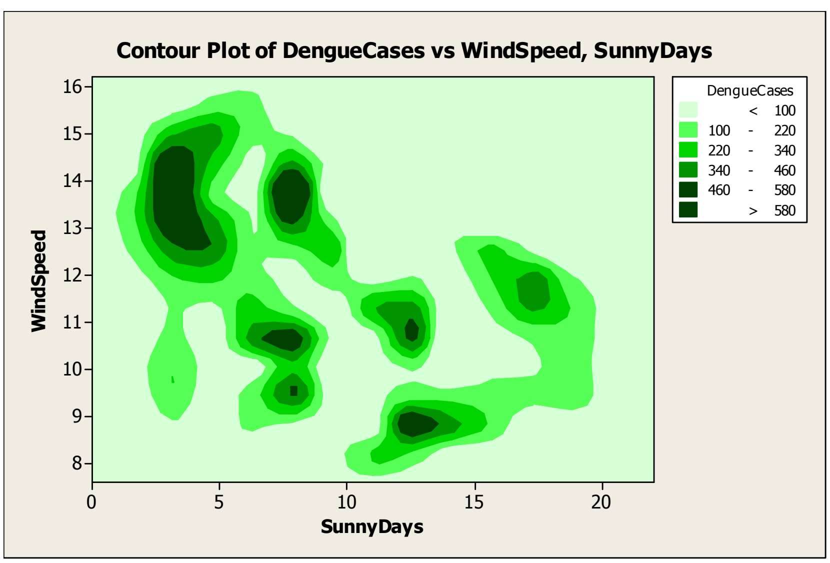


Fig. 11. Contour map of dengue incidences against wind speed and sunny days

4. CONCLUSION

According to the results of this study, it is clear that impacts of climatic variables on dengue incidences differ from district to district. Climatic variables in Trincomalee district do not show any relationship with dengue incidences whereas some relationships between climatic variables and dengue incidences can be observed in Batticaloa and Ampara district. In 2015, Ehelepola and Ariyaratne in 2015 also have stated that correlations between some climatic factors and dengue incidences are different for different districts [27].

In Batticaloa district, number of rainy days negatively affects dengue incidences while day time humidity shows a positive relationship with the dengue incidences. Promprou, Jaroensutasinee, Jaroensutasinee in 2005 also have confirmed that high humidity increases feeding activity, survival and development of eggs and raining for a few number days creates a favorable situation for mosquito spread [19].

The wind speed in Ampara district is positively correlated with dengue incidence in the district. Ehelepola and Ariyaratne in 2015 [27] also have found that wind is related with the dengue incidences. In contrast, climatic variables in Trincomalee district do not provide evidence for a relationship with dengue incidences recorded within the district.

People's general view is that heavy rainfall is the reason for past spread of dengue disease. However, in this study, such a result could not be observed. In contrast, Gubler in 2011 [20], Dharshini et al. in 2011 [5] and Liyanage, Tissera, Sewe, Quam and Amarasinghe in 2016, [24] have discovered a relationship between rainfall and mosquito density.

In this study, several statistical techniques were used for the analysis. It could be observed that results of all techniques are not the same. For instance, in Batticaloa district, correlation analysis shows only two significant factors (number of rainy days and day time humidity), while only one factor (day time humidity), is identified by regression analysis. This may be due to the inter relationships exist among all climatic variables.

Furthermore, it is apparent that only climatic variables are not enough to explaining the variation in dengue incidences. District is a large area. Climatic status of the district is not uniform throughout the district meanwhile number of dengue incidences recorded is also not equally distributed. This inadequate representation of reality by data also may be one of the reasons why these variables are unable to represent a reasonable amount of variation in dengue incidences.

Above all, there may be many other types of factors such as geographical changes, population density, health practices of dwellers, policies of government institutes such as municipal council, and private organizations. For a better understanding, all these sort of variables should be taken into consideration in further researching.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. WHO: Dengue Guidelines for Diagnosis, Treatment, Prevention and Control; World Health Organization: Geneva, Switzerland. 2009;1–14.
2. World Health Organization (WHO). Available:https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue
3. Vitarana T, Jeyakuru W, Withane N. Historical account of dengue haemorrhagic fever in Sri Lanka. Dengue Bulletin. 1997;21:117.
4. Messer WB, Vitarana UT, Sivananthan K, Elvtigala J, Preethimala LD, Ramesh R, Withana N, Gubler DJ, De Silva AM. Epidemiology of dengue in Sri Lanka before and after the emergence of epidemic dengue hemorrhagic fever. Am. J. Trop. Med. Hyg. 2002;66:765–773.
5. Dharshini S, Vinobaba M, Jude PJ, Karunaratne SH, Surendran SN. Prevalence and insecticide susceptibility of dengue vectors in the district of Batticaloa in Eastern Sri Lanka. Trop Med Health. 2011;39(2):47–52. DOI:10.2149/tmh.2010-19

6. Sirisena PDNN, Noordeen F. Evolution of dengue in Sri Lanka-changes in the virus, vector and climate. Int. J. of Infect. Dis. 2014;19:6-12.
7. World Health Organization. Available:http://www.who.int/denguecontrol/mosquito/en
8. Gubler DJ. Dengue and dengue hemorrhagic. Clin Microbiol Rev. 1998; 11(3):480-496.
9. Weaver SC, Reisen WK. Present and future arboviral threats. Antiviral Re. 2010; 85(2):328. DOI:10.1016/j.antiviral.2009.10.008
10. Gratz NG. Critical review of the vector status of Aedes albopictus. Med. Vet. Entomol. 2004;18:215–227.
11. WHO Report: Global strategy for dengue prevention and control 2012-2020. Available:https://www.who.int/denguecontrol/9789241504034/en
12. Gubler DJ, Reiter P, Ebi K, Yap W, Nasci R, Patz J. Climate variability and change in the United States: Potential impacts on vector and rodent borne diseases. Env Health Pers. 2001;109:223. DOI:10.1289/ehp.109-1240669
13. World Health Organization (WHO). Available:https://www.who.int/csr/don/19-july-2017-dengue-sri-lanka/en/
14. Annual Health Statistics 2017 Sri Lanka. 2019;1. Available:https://www.health.gov.lk/moh.final/English/others .php?pid=110
15. Eckstein D, Kunzel V, Schafer L. Global climate risk index 2018 Who suffers most from extreme weather events? Weather-related loss events in 2016 and 1997 to 2016. Germanwatch e.V.; 2017. Available:www.germanwatch.org/de/1438
16. Eckstein D, Hutfils ML, Winges M. Global climate risk index 2019. Who suffers most from extreme weather events? Weather-related loss events in 2017 and 1998 to 2017. Germanwatch e.V.; 2017. Available:www.germanwatch.org/en/cri
17. Statistical Abstract; 2018. Available:www.statistics.gov.lk/abstract2018/index.asp
18. International Federation of Red Cross and Red Crescent Societies; 2018. Available:https://reliefweb.int/report/Sri-Lanka/Sri-Lanka-dengue-dref-final-report-MDRLK007dfr.pdf
19. Promprou S, Jaroensutasinee M, Jaroensutasinee K. Climatic factors affecting dengue haemorrhagic fever incidence in Southern Thailand. Dengue Bulletin. 2005;29:41-48.
20. Gubler DJ. Dengue. Urbanization and globalization: The unholy trinity of the 21st century. Tropical Medicine and Health. 2011;39:3–11.
21. Nagao Y, Thavara U, Chitnumsup P, Tawatsin A, Chansang C, Campbell-Lendrum D. Climatic and social risk factors for *Aedes* infestation in rural Thailand. Trop Med Int Health. 2003;8(7): 650-659.
22. Ali S, Khan AW, Taylor-Robinson AW, Adnan M, Malik S, Gul S, The unprecedented magnitude of the 2017 dengue outbreak in Sri Lanka provides lessons for future mosquito-borne infection control and prevention. Infection, Disease & Health. 2018;23(2):114-120. Available:https://doi.org/10.1016/j.idh.2018.02.004
23. Weeraratne TC, Perera MDB, Mansoor MACM, Karunaratne SHPP. Prevalence and breeding habitats of the dengue vectors Aedes aegypti and Aedes albopictus (Diptera: Culicidae) in the semi-urban areas of two different climatic zones in Sri Lanka. Int J Trop Insect Sci. 2013; 33:216–26.
24. Liyanage P, Tissera H, Sewe M, Quam M, Amarasinghe A. A spatial hierarchical analysis of the temporal influences of the El Niño-Southern oscillation and weather on dengue in Kalutara District, Sri Lanka. International Journal of Environmental Research and Public Health. 2016;13(11): 1087. DOI: 10.3390/ijerph13111087
25. Sirisena P, Noordeen F, Kurukulasuriya H, Romesh TA, Fernando L. Effect of climatic factors and population density on the distribution of dengue in Sri Lanka: A GIS based evaluation for prediction of outbreaks. PLoS One. 2017;12(1): e0166806. DOI:10.1371/journal.pone.0166806
26. Ehelepola ND, Ariyaratne K. The correlation between dengue incidence and diurnal ranges of temperature of Colombo district, Sri Lanka 2005-2014. Glob Health Action. 2016;9:32267. Available:https:/dx.doi.org/10.3402/gha.v9.32267
27. Ehelepola NDB, Ariyaratne K. The inter relationship between dengue incidence and diurnal ranges of temperature and humidity in a Sri Lankan city and its

potential applications. Glob Health Action. 2015;8;29359.
28. Ehelepola NDB, Ariyaratne K, Buddhadasa WMNP, Ratnayake S, Wickramasinghe M. A study of the correlation between dengue and weather in Kandy City, Sri Lanka (2003-2012) and lessons learned. Infect Dis Poverty. 2015;4:42. DOI: 10.1186/s13104-019-4185-4
29. Sun W, Xue L, Xie X. Spatial-temporal distribution of dengue and climate characteristics for two clusters in Sri Lanka from 2012 to 2016. Sci Rep. 2017; 12884. DOI: 10.1038/s41598-017-13163-z
30. Prakash TGSL, Ranasinghe DMSHK, Karunadasa IGSSK. Dengue prevalence as an evidence of climate change in Sri Lanka. International Journal of Multi-disciplinary Studies. 2018;5(2):23–30.
31. Edirisinghe G. Contribution of rainfall patterns for increased dengue epidemic in Sri Lanka. American Scientific Research Journal for Engineering, Technology and Science. 2017;35:1.
32. Chakravarti A, Kumaria R. Eco-epidemiological analysis of dengue infection during an outbreak of dengue fever, India. Virology J. 2005;2:32.
33. Tuladhar R, Singh A, Varma A, Choudhary DK. Climatic factors influencing dengue incidence in an epidemic area of Nepal. BMC Res Notes. 2019;12:131. Available:https:/doi.org/10.1186/s13104-019-4185-4
34. Lai Y. The climatic factors affecting dengue fever outbreaks in southern Taiwan: An application of symbolic data analysis. Bio Med Eng online. 2018;17(2): 148. Available:https://doi.org/10.1186/s12938-018-0575-4
35. Zhang Q, Chen Y, Fu Y, Liu T, Zang Q, Gue P, et al. Epidemiology of dengue and the effect of seasonal climate variation on its dynamics: a spatio-temporal descriptive analysis in the Chao-Shan area on China's southeastern coast. BMJ Open. 2019; 9:e024197. DOI: 10.1136/bmjopen-2018-024197

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/53701