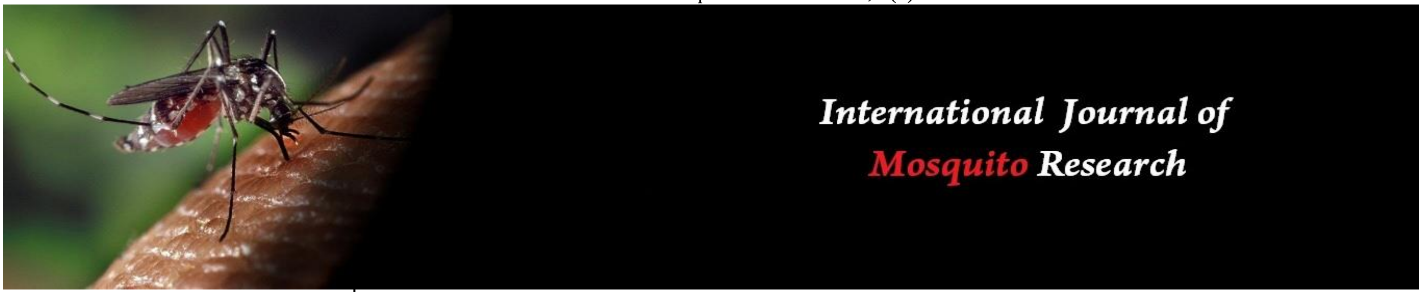

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Muhammad Ilyas
Mathematical Science Research centre Federal Urdu University of Arts, Science and Technology, Karachi, Pakistan

Shaheen Abbas
Mathematical Science Research centre Federal Urdu University of Arts, Science and Technology, Karachi, Pakistan

Sehar Afshan Naz
Lab of Molecular Microbiology and Medical Mycology Department of Microbiology Federal Urdu University of Arts, Science and Technology, Karachi, Pakistan

Mustansir Abbas
Lab of Molecular Microbiology and Medical Mycology Department of Microbiology Federal Urdu University of Arts, Science and Technology, Karachi, Pakistan

Correspondence
Shaheen Abbas
Mathematical Science Research centre Federal Urdu University of Arts, Science and Technology, Karachi, Pakistan

The impact of climatic influence on dengue infectious disease in Karachi, Pakistan

Muhammad Ilyas, Shaheen Abbas, Sehar Afshan Naz and Mustansir Abbas

Abstract
Dengue fever, a viral infection caused by bite of an infected Aedes mosquito, has become a major concern for health authorities all over the world mostly in the tropical countries. This study is conducted to evaluate climatic influence on the outbreaks of dengue fever in Karachi city of Pakistan. The descriptive statistics and trend analysis are employed to investigate the impact of climatic variables in dengue fever outbreaks during the period of January 2001-December 2016. Time series plots are observed high in dengue incidences during the months of September to November, as well as kurtosis value for dengue (27.765 >3) suggested leptokurtic and increasing flattened tail for dengue with influence of climatic parameters. Trend analysis is used to fit dengue fever as a function of temperature, rainfall and ENSO 3.4 index respectively. The results stated that the months of September to November are peaked seasonal months for dengue outbreaks.

Keywords: Dengue fever, EI Nino southern oscillation (ENSO) 3.4 index, Land surface mean temperature, Rainfalls, Trend analysis

1. Introduction
Dengue fever has been considered as one of the important vector borne viral infection responsible for morbidity and mortality in large number of population particularly in urban areas of tropical and subtropical countries every year [1]. The clinical understanding of this infection can be limited to non-democratic or self-dengue fever for Spartan life in threatening dengue hemorrhagic fever or dengue shock syndrome. This infection is caused by virus of the genus flavivirus belonging to Flaviviridae family which is transmitted in human mainly by bite of infected mosquitoes *Aedes aegypti or Aedes albopictus* [1, 2]. There is thirty times rise in the incidence of dengue infectious over the past 50 years. Tropics are the highest risk areas; particularly Asia, where 70% of all dengue outbreaks occur and the India alone contribute 34% of the total cases [1, 3].

There are many factors contributes in overwhelming increase in the prevalence of dengue infection. Among them, globalization, demographic changes, trade, climatic changes, global warming etc. are mainly responsible for the spread of the main vectors i.e. Aedes mosquitoes of this viral disease. The *Aedes aegypti* was originally belong to Africa while Age. Albopictus was Asian but due to global trade and frequent travelling, these mosquitoes also expanded their range rapidly. They have been disseminated to faraway regions through global shipping, particularly trade of used rubber tires where they used to lay their eggs [2]. Infected travelers also play an important role in transmission of this virus in different parts of world.

An elevated risk of dengue endemicity is also strongly associated with climatic change. The association of climatic parameters and dengue fever has been deliberated in the first decade of the 20th century as few researchers of that time tried to establish the correlation between the climate parameters and the dengue fever [4]. The metrological parameters such as temperature, precipitation (rainfall), humidity, and ENSO index have been linked with survival and reproduction of Aedes mosquitoes which are the major vector in dengue viral infection [3]. It has been found that higher environmental temperature reduces time interval for the replication of dengue virus in mosquitoes during Extrinsic Incubation Period". These viruses then transferred to salivary glands of mosquito and transmitted to human [3, 5]. Therefore, there is a high probability for mosquitoes to grow and become infectious rapidly in presence of high temperature. This climatic change also plays an important role in mosquito breeding, as well as also has influence on biting rate and survival of life cycle of mosquitoes especially those infected with dengue virus [6, 7]. Similarly, rainfall (precipitation) also has a great impact on the life cycle of Aedes mosquitoes as it facilitates aquatic stages of life cycle and promotes its population [8].

Due to global warming, the anthology of the mosquito is increasing. Accordingly, it is obvious that the significant factor responsible for this escalation is climate which also controls mosquito habitat [3, 6]. For the forecast of endemics and epidemics by dengue, the understanding of climatic changes may be beneficial and can provide an insight to improve our strategies to combat this infection.

2. Data description and methodology

The Karachi city is situated at the south part of the Pakistan, which has a population over the city of Karachi, is located to the subtropical climate region. Karachi and its suburbs lie in semi-arid Zone. Rainfall in the region is very uncertain and irregular. Rain occurs mostly in the months of June, July and August; the average annual rainfall does not exceed 9 inches. Karachi has a moderate climate, which occasionally becomes dry, otherwise, intensely humid. The average monthly wind speed during the year varies from 3.2 to10.7 knot per hours. The hottest months are May, June and October. The mean daily maximum temperature ranges between 33.33 ^{0}C to 46.6 ^{0}C lowest temperature recorded being 5 ^{0}C An ENSO 3.4 index, which has led to increasing the risk of dengue spread. This is a marked effect on the disease when values range from 27 ^{0}C to 28 ^{0}C, but a sharp decline when the El Nino 3.4 is less than 27◦C.The annual assortment of rainfall from 0 to 270.4 mm, which occurs during monsoon seasons in mainly June to August. The city lies at the fringe of the monsoon belt and receives.

Monthly data of dengue cases from January 2001 to December 2016 are obtained from the Dengue Survival Cells. While, climate data are collected from Karachi metrological department, the Karachi city weather station (23°N, 68°E), which records temperature and rainfall data on an hourly basis. These data were summarized on mean monthly temperature and monthly rainfall basis (from 2001 to 2016).We also included the monthly ENSO 3.4 index in the analysis. The monthly ENSO 3.4 Index (from 2001 to 2016) was obtained from the Global Climate observing system, which is supported by the National Oceanic and Atmospheric Administration (www.ncdc.noaa.gov/teleconnections/enso/).

2.1 Descriptive statistics and trend analysis

This study is required to estimate climate influences on dengue outbreak in the city of Karachi, Pakistan. Descriptive statistical tests are used to analyze the correlation among the number of dengue fever cases and climate parameters. Descriptive statistical test such as mean, range, variance, standard deviation, correlation(r), skewness, kurtosis and coefficient of determination (R^2) etc., in the time series are significant parameters, which might be cooperative in diagnostic checking test and forecasting future values of our applicable data [4, 5, 9, 10].

Skewness: The Skewness obtains the asymmetry degree of the data series.

$$\text{Skewness} = \frac{\sum_{i=1}^{n}(X_i-\bar{X})^3}{(n-1)S^3} \qquad (1)$$

Where, mean of data is $\bar{X}$, S is standard deviation and n is the number of data values. If the data is generally distributed, so the distribution is symmetric it is considered that the value of skewness is equivalent to zero. The distribution is positive skewed that is larger than zero and negative skewed if it is a smaller than zero.

Kurtosis: The Kurtosis determines the highest (peak) values of the data series. Kurtosis is found as

$$\text{Kurtosis} = \frac{\sum_{i=1}^{n}(X_i-\bar{X})^4}{(n-1)S^4} \qquad (2)$$

Where, mean value of data is $\bar{X}$, S is standard deviation and n is the total numbers of the data series. The normal distribution called Kurtosis is called mesokurtic if it is equal to 3. However, if the leptokurtic is higher than 3 it is Platykurtic if the value is fewer than 3.

Coefficient of Determination: The R-square error is a quantity of how close data are to the fitted regression line. It is also called coefficient of determination [11]. The R-square values of fitted model are indicating the variability of the data around its mean.

$$r = \frac{n(\sum xy)-(\sum x)(\sum y)}{\sqrt{\left[n\sum x^2-(\sum x)^2\right]\left[n\sum y^2-(\sum y)^2\right]}} \qquad (3)$$

The P-value is less or equal to alpha (α) ($p < .05$), then null of hypothesis reject, we say the result is significant. If P-value is more than Alpha (α), we have failed to reject the null hypothesis and the result is non-significant.

The consistent trend analysis is necessary for any forecast, monitoring and management of local weather such as temperature and rainfall and global climate ENSO 3.4 index. The Trends, variances, etc., in the data set is appropriate parameters, which is useful in forecasting forthcoming values [5, 7, 9]. The trend equation to assist as an escort in the valuation in the of climatic parameters on dengue count data.

Data interval = trend + stochastic variations

$$D(t) = T(t) + \xi(t)$$

Here, D(t) is the data intervals with respect to $t = t_1, t_2, t_3 \ldots t_n$; it is denoted arithmetic time series T(t): the deterministic function in time and ξ (t) is the stochastic variations or a random variable. To use the more adequate mathematical expression, trend analysis is form.

$$y_t = b_0 t_n + a_0 \qquad (4)$$

The parameter a_0, b_0 are the slope/gradient and intercept respectively. a_0, b_0 represents the growth rate of the dengue and climatic parameter per year. t represents the time (monthly year) under consideration. We implement the above trend models to temperature, rainfall and ENSO 3.4 index series with dengue count series and obtain the following trend equations for twelve months of the year from the period of 2001 to 2016 Minitabs version 21 was utilized for the estimation of model parameters. Results are summarized in the result and discussion section.

2.2 Life cycle of *Aedes-Aegypti* dengue mosquitoes

The epidemiological outbreak of dengue fever occurs when the female Aedes mosquitoes bite and suck blood containing the dengue virus from infected human individual. The viruses in mosquito then undergo a period recognized as 'incubation' period in which the virus replicates itself in the mosquito. This lasted about seven to twelve days after which the mosquito can transmit this virus present in its salivary gland to other human by biting for blood meal [7].

The female *Aedes aegypti*, being vector of this disease, completes its life cycle in 8 to 15 days, which consist of four phase's i.e egg, larva, pupa and adult phased [1]. This mosquito produces 100 to 200 eggs after taking blood meal. These eggs are usually laid on damp surfaces such as tree holes, water containers, flower vases, tyres etc. The development of these eggs takes just few days in warm climates however this duration may extend to weeks in cooler temperate climates. Secondly, these laid eggs can survive in this phase for long duration even for more than a year if remain in dry state but immediately hatch when submerged in water. The eggs are then hatched to produce second phase of life cycle i.e. "larva" which feeds on organic materials [1]. The growth of larva is also temperature dependent as in case of low temperature the larval stage can even extends up to months depending on availability of water. This larval stage enters in to Pupa stage which can be longer as 2 days and then adults emerge by air ingestion and expansion of abdomen The maturing period of larvae to adult is about 7 to 12 days [4, 10, 12]. The first and second steps are with an egg and lava, whereas the third and the pope and the adult are mature. These steps can only be familiar with their unique appearance are depicts in Fig 1.1.

2.3 Climate change and human health

Climate is a complex phrase, and this refers to weather conditions in excess of an era of time. Climate is a typical condition of metrological parameters such as maximum and minimum temperature, precipitation (rainfall) and ENSO 3.4 index of a consign. Many of these factors work as seasonal factors. Climate is an important matter of scientific inquiry; mostly it has its effect on vegetable, soil and health. Consequently, it differs from affecting human life. The natural risks of storm, flood and desert are the results of climate change. Shortly, there are many perspectives in which the climate impacts our everyday life, and the weather (maximum or at least the temperature) affects humans, crops, animals and mosquitoes' life cycles. It is especially - *Aedes-aegypti* mosquito which causes dengue fever [13, 14].

The effect of force of antibiotic on environmental change is a major problem, about which each person has his own opinion. Climatic variables that vary at a particular time in a specific area known as climate. Various climatic parameters are an important decision of many vector-borne diseases (dengue fever and adrenaline diseases and some water related diseases [15]. The relationships between year-to-year variations in climate and contagious diseases are the majority of obvious where climate variations are cleared, and in vulnerable populations. The dengue fever various place of the world exploring vulnerability on population groups give facts that age and gender act on cruelty of the disease [16, 17]. On the contrary, further study must be properly recognized in the risk for the purpose of directing the groups to control the most dangerous population.

Climate Change (IPCC) was established at the United Nations International level due to the major problem of climate change. The IPCC has presented scientific evaluation of the current, past and future climate change 2007 (IPCC) report. Most of the events are often associated with climate change, due to natural disorders groundwater pollution and Floods can be caused by floods, it is noted that such extreme weather conditions are the first possible.

In this view of above mention flowchart cycle (figure 1.1) are based third Assessment Report [(TAR) in 2001] [18] are examining the correlation between the Earth systems and human systems and its association with climatic changes and impacts from socio-demographic and **s**ocio-economic. Similarly, the correlation between stratospheric ozone air depletion, temperature, precipitation (rainfall), ENSO, stratospheric ozone air depletion and virus rate of dengue are shown the relationship between metrological parameters (climatic factors) and dengue breaks out to indicate or predict variation in dengue incidence that effects the population and its health.

3. Results

The monthly dengue fever incidences for the time period from January 2001 to December 2016 are considered in this study. Table.1 summarized the descriptive statistical analysis for, mean monthly temperature, monthly rainfalls, and monthly ENSO 3.4 index and dengue fever incidences. A total of 43cases of dengue patient are diagnosed in 2001 while the maximum dengue fever count 6043 occurred in 2015. The mean value for the total monthly period is 129.6667 and the standard deviation is $31.7e^{01}$. From Figure 1.2(a), we examine that the histogram is positive skewed to the right which is depiction of dengue count data. High dengue incidences are detected in the months of September, October and November depicts in figure 1.2(b). Dengue count data has kurtosis value is greater than 3 indicated leptokurtic in temperance positive kurtosis with flatten tail, determine the descriptive statistical test for observed all data series (table 1). The time series monthly plots for land surface mean temperature in Figure 1.3(a) and Figure 1.3(b) presented time series plot for monthly temperature, temperature versus dengue fever data over the Karachi city (covering 192 months) from 2001 to 2016. As, the time series monthly rainfall and a time series monthly aggregated the rainfall verse dengue plots (during 2001 to 2016) are depicted in figure 1.4(a) and 1.4 (b). In Figure 1.5(a) and 1.5(b) depicted a time series monthly aggregated the El Nino3.4 index, The El Nino Southern Oscillation (ENSO) related to the dengue fever of the Karachi city, from 2001 to 2016.

These all descriptive statistical test results and related time series plots shown a strong positive association between mean temperature and dengue count, It is noted that there is no strong trend in the annual rainfall data due to lack of rainfall in Karachi region, rainfall and dengue outbreak, Enso exposed the significant negative effect on dengue fever transmission.

Applying trend analysis technique revealed in Section 2.1 Now, we get following results acquired (at $\alpha = 0.05$ level) in Table 2 to 1.4. The monthly and annual total trend analysis performed on the complete set for monthly dengue fever counts, mean temperature, monthly rain falls, ENSO3.4 index

(2001 to 2016). The total annual trend equations are indicated that the slopes of these annual trend is the higher and F-value and Pr>F analysis shown that the annual trends for all the equations are statistically significant (table 2 and 3).

The monthly trend equations (dengue fever counts, mean monthly temperature, monthly rainfall and ENSO 3.4 index) in Table 4 Shown, more or less, similar increasing trends except for the month of February and July for ENSO (R^2= 0.009 and 0.000007) and Rainfall series indicated the almost zero trend described in figure 1.6. In September to November slopes of these months are higher than other months of the year, Temperature trend equations slopes and coefficient of determination values are shown most strong association as compare to other climatic variables, ENSO exposed the negative (temperature decreasing) effect on dengue out breaks (table 5).

4. Discussions

This study reveals a statistically significant relationship among land surface mean temperature, rainfall and sea surface temperature ENSO 3.4 index and dengue outbreaks. Our descriptive results are indicated that monthly data of climatic variables has statistically significant effect on dengue fever outbreaks in the city of Karachi, Pakistan. This substantiates several research studies that have shown a relationship between climatic variables and dengue incidence in around the world [8, 19]. The temperature time series plots are indicated that monthly temperature in the city of Karachi fluctuation in the months of March, April, August and September, October between 27.9◦C to 35.7◦C, summer season are viewed a perfect condition for the development of Acedes species and consequently the spread of the dengue fever. The city of Karachi has two summers seasons, it has been observed a seasonal pattern concerning hot conditions, the first season is started from the month of April to June and second summer seasons is starting from September to November, it is most perfect season of the occurs of dengue. Due to reduction in the duration of integration in various biological studies in the dengue transmission, the temperature ranges up to 40 ^{0}C to 35 ^{0}C [19, 20] is ranked. As a result, the mosquito gets more rapidly affected and more quickly. Our statistical analysis also confirmed that warmer temperatures affect the spread of the dengue fever in various ways. Thus, a higher temperature reduces the larvae size of mosquitoes which try into reduced adults [12, 21].

The rainfall time series plots are also investigated that the months of the July and September most appropriated for rainfalls occurrence. It is also revealing two summer periods with a seasonal pattern are concerted rainfall (>50mm). The first summer period start April to June and the second period start September to November. The highest duration of rainfall is detected in (from 270.0 mm in September 2003 and 212mm in September 2012 respectively). This pattern is an annual change which requires to be completely extracted from the dengue occurrence in Karachi City. On the other hand, in the month of January, February, March and June, were renowned as the driest months with low levels of rainfall (< 10mm). The trend analysis is clearly indicated that the whole yearly rainfall data interval has there is no trend, finally, It is clearly indicated that the effect on the dengue disease when values temperature range from 27 ^{0}C to 28 ^{0}C, but a sharp decline when the El Nino 3.4 is lower than 27 ^{0}C (The land surface temperature data has strongly correlated with the transition of dengue [22].

It is important to note that the trend values are highest since September to November to the premier months for dengue fever outbreaks. It is showing that the dengue fever outbreaks for second summer (September to November) is higher as compared to first summer which shows higher increasing rate due to temperature and ENSO 3.4 index (table 2 and 2). The trend fluctuation and the time plots are expressed the positive correlation among dengue and temperature, Enso is negative, and rain is no trend as compare the first to second summer duration. The strong correlation between temperature and dengue fever is shown the breaks out to indicate or predict variation in dengue incidence that effects the population and its health. As results are concluded more studies are needed to fully understand the association of dengue transmission with a wide range of socioeconomic factors.

5. Conclusion and Recommendation

Dengue fever remains an important public health problem in the city of Karachi, Pakistan. The number of populations increasing is a main effect of increase the population of the Karachi city on the spread of several diseases is also requires attention by the researcher and the governments. The main objective of this study is explored climatic/weather factors such as temperature, rainfall and ENSO 3.4 index associated with dengue incidences. The study used monthly data for the period January 2001 to December 2016 in Karachi. This study showed a more significant association between monthly dengue incidence and climate parameters that is temperature and ENSO 3.4 index. Monthly temperature is statistically significant for the months of September to November. Enso revealed the significant negative effect on dengue for the complete data sets as revealed by trend analysis. The trend equation is clear that there is no perfect trend in the yearly rainfall data due to lack of rainfalls in Karachi region. The results also suggested that temperature and trace rainfall are positively significant on monthly dengue outbreak whereas ENSO is negative significant predictor for dengue incidence in the view of results from correlation coefficient.

The findings provide better insight of climate effects on dengue and provide important information for dengue prediction. It is observed that temperature is a strong predictor of dengue outbreak (September to November) in Karachi city.

We find that over population of the cities not only creating social problems but also creates health problems. It is suggested that government should not only control the population and control cities from having over crowded population by making new cites where people can get job and can have health facilities and daily necessities. We suggested that dengue surveillance cells not only in provincial’s capital also at district and towns levels whose function should be awareness medical and fumigation on regular basis.

At the base of the findings of this study, we have framed out the following recommendation for better prevention and control of dengue disease through community.

1. To understand the dengue safety measures and improve the knowledge, government organizations and non-government agencies should start their program on a fairly educational campaign.
2. Educational materials should be available in all public education, healthcare, and other community centers, where more and more people may be able to improve their knowledge of dengue.

3. The dengue fever data need to be collected at the waged people level and Government should starts spray their respective areas.
4. To develop spatial-statistical dengue model for identification of risk prone areas by linking environmental, demographic and land use/cover parameters with dengue cases.

Table 1: Descriptive statistical analysis for dengue fever patients and climatic parameters from 2001 to 2016

Variable	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Dengue count	192	2510.0	0.00	2510.00	129.66	22.877	31.7e01	100.490	4.965	.175	27.765	.349
ENSO 3.4 index	192	0.00	-5.20	4.80	0.2786	0.1130	1.56594	2.452	0.371	.175	0.610	.349
Temperature(c)	192	17.40	16.39	33.79	27.273	0.3177	4.40316	19.388	-.739	.175	18.201	.349
Rainfall(mm)	192	270.40	0.00	270.40	15.196	2.881	40.033	160.265	3.990	0.175	-0.715	0.349

Table 2: The annual Trend analysis for dengue fever and temperature, ENSO and rainfall

Yearly	Trend equation for Dengue count	Trend equation for Land temperature	Trend model Sea surface ENSO	Trend Rainfall
2001- 2016	Yt= 5.338D-12.5	Yt = 0.033T+ 19.55	0.417+0.043*E*	-0.282R+5.75

Table 3: Descriptive ANOVA analysis for Yearly data series

ANOVA	ENSO	Mean Temperature	Rainfall	Dengue
R2	0.442	0.52	0.342	0.394
F	36.419	42.156	39.877	40.278
Pr> F	< 0.0001	0.00294	0.0005	0.0006

Table 4: Trend Analysis performance for monthly dengue count and climatic parameters (2001 to 2016).

Months	Trend equation for Dengue count	Trend equation for Land temperature	Trend model Sea surface ENSO	Trend Rainfall
January	Yt= 5.338D-12.5	Yt = 0.033T+ 19.55	Yt = - 0.043*E*+0.417	Yt-0.282R+5.75
February	Yt = 3.438D- 6.02	Yt = 0.0166T+ 1.667	Yt =- 0.015E+0.822	Yt = -0.269R+6.942
March	Yt = 2.59D+ 0.1	Yt = 0.0497T+ 26.12	Yt =- 0.06E+1.227	Yt = 0.142*R*+2.072
April	Yt = 4.75 D-11.0	Yt = 0.090 T+29.19	Yt = 0.097E-0.257	Yt = 0.3971*R*-1.5
May	Yt = 7.19D-23.62	Yt = 0.0655T+31.091	Yt = 0.088E-0.727	Yt = 0.021R-0.097
June	Yt = 7.71D-23.72	Yt = 0.0715T+31.582	Yt = 0.041E-0.217	Yt = -0.55R+19.515
July	Yt = 7.558D-13.5	Yt = 0.100T+29.631	Yt = 0.0021E+0.02	Yt = -4.366R+9.208
August	Yt = 15.01D-33.82	Yt = 0.049T+29.145	Yt = -0.325E-0.03	Yt = -0.66R+60.928
September	Yt = 40.43D-120.6	Yt = 0.063T+29.377	Yt = -0.036E+0.44	Yt = 2.44R+12.153
October	Yt = 71.37D-107.23	Yt = 0.0785T+28.894	Yt = -0.067E+0.58	Yt = -0.439R+5.987
November	Yt = 38.15D+17.1	Yt = 0.0349T+25.303	Yt = -0.026E+0.41	Yt = 0.0388R+0.195
December	Yt = 19D-1.0	Yt = - 0.0038T+20.756	Yt = 0.046E+0.027	Yt = -0.509R+13.59

Table 5: Comparison of Coefficient of Determination (R2) for linear trend

Months	Coefficient Determination (Dengue)	Coefficient Determination (Temperature)	Coefficient Determination (Rainfall)	Coefficient Determination (ENSO)
January	0.399	0.0307*	0.085*	0.013*
Feb	0.3824	0.0018*	0.0281	0.009*
March	0.3568	0.0332*	0.0062	0.0338
April	0.479	0.1592	0.0635	0.148
May	0.4791	0.2138	0.0949	0.173
June	0.4152	0.2925	0.0056	0.049*
July	0.3706	0.1555	0.0780*	0.000007*
August	0.5013	0.3087	0.0021*	0.0119*
September	0.5123	0. 508	0.0388*	0.0124*
Oct	0.6071	0.686	0.059*	0.045*
Nov	0.721	0. 541	0.0192*	0.0099*
December	0.2544	0.0002*	0.0222*	0.0112*

*Statistically not significant trends as revealed by P-value analysis.

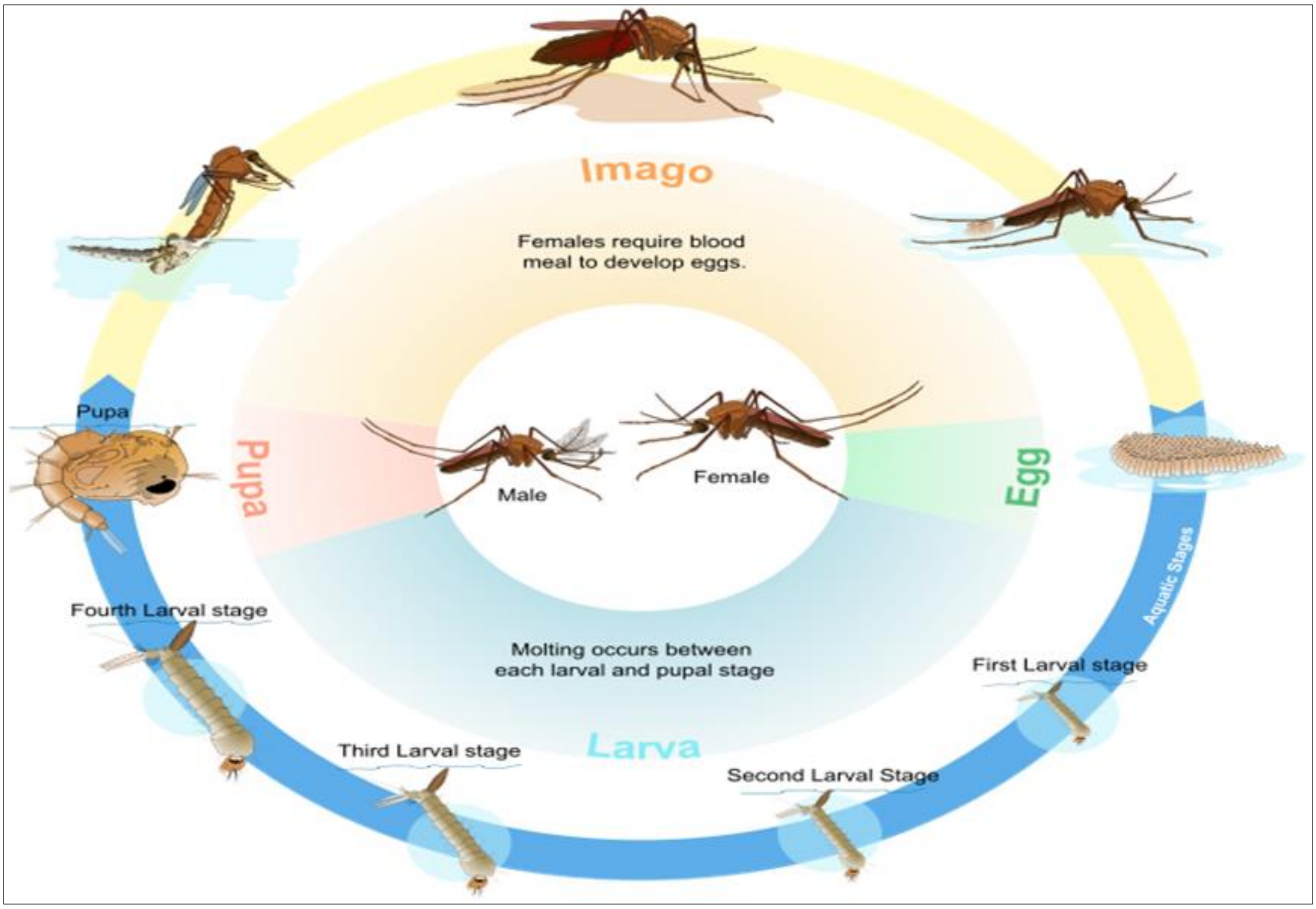

Fig 1: The dengue Aedes-Aegypti Mosquito cycles [13]

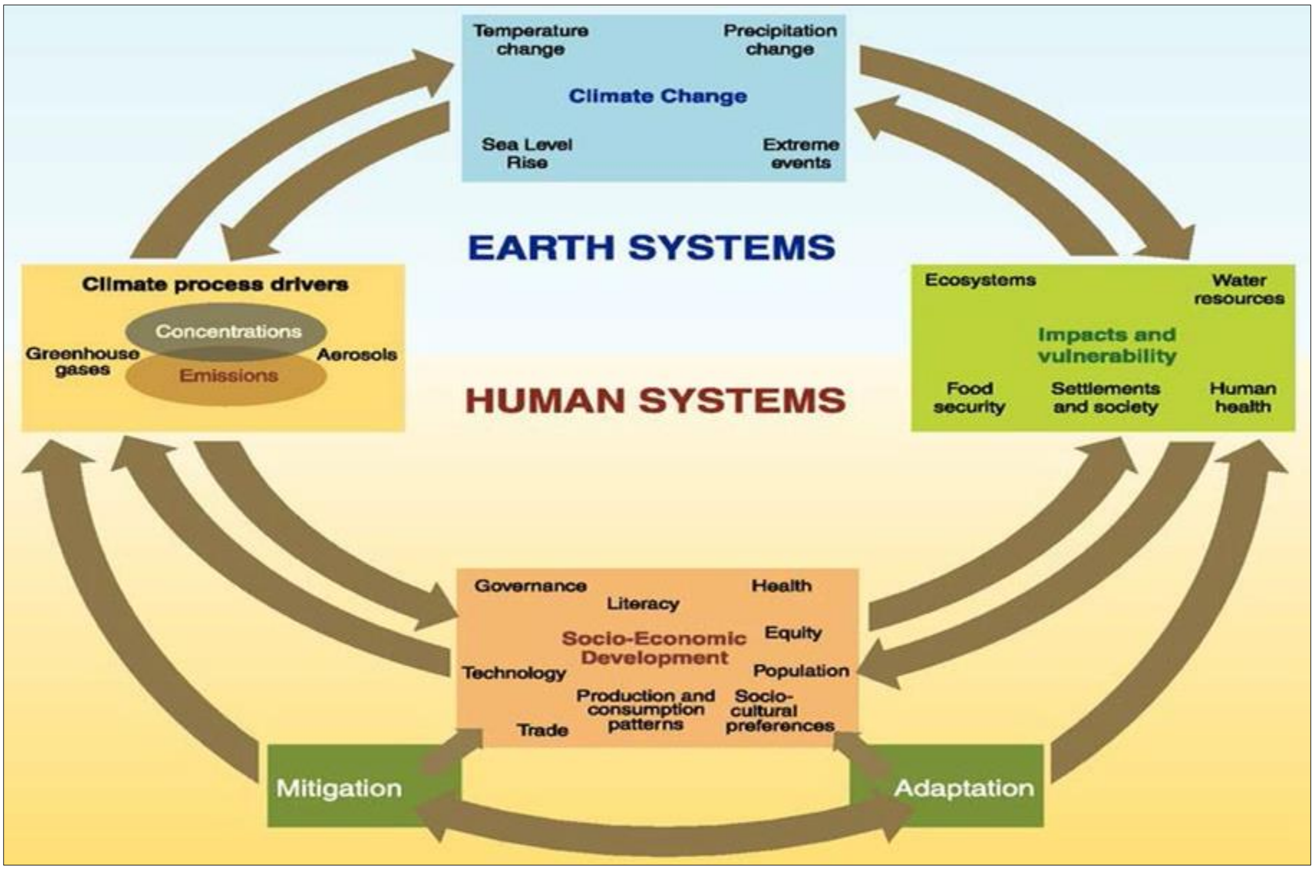

Fig 1.1: The flow chart representing anthropogenic drivers, impacts of and responses to climate change, and their connection human health system [18].

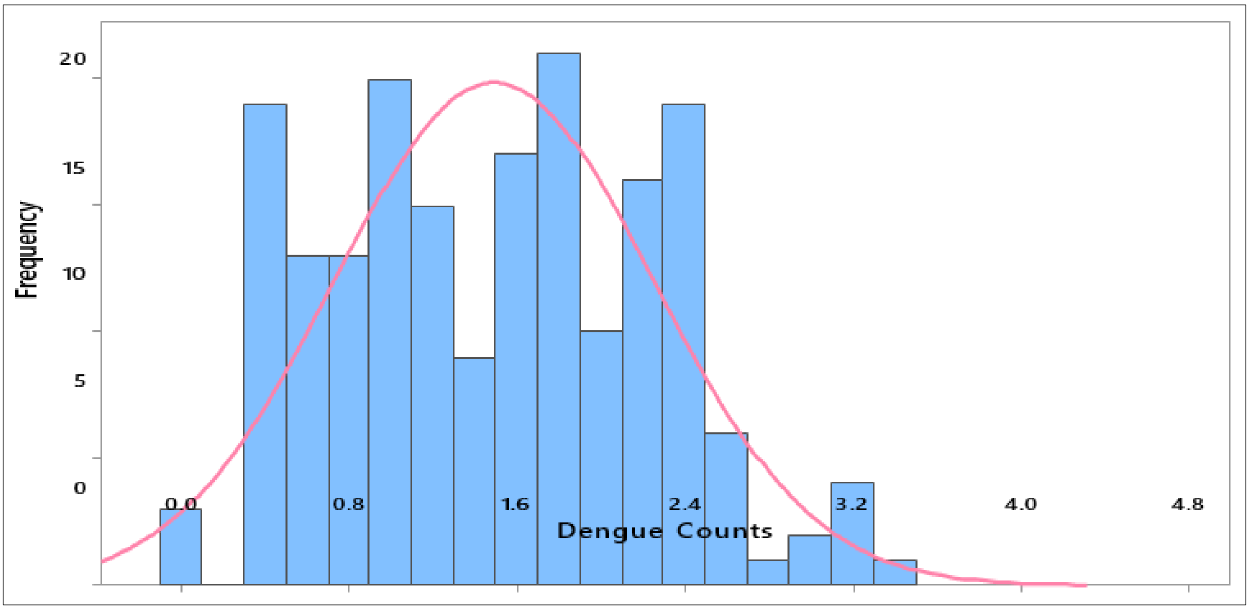

Fig 1.2(a): Histogram Dengue Fever counts for positive skewed to the Right Tail

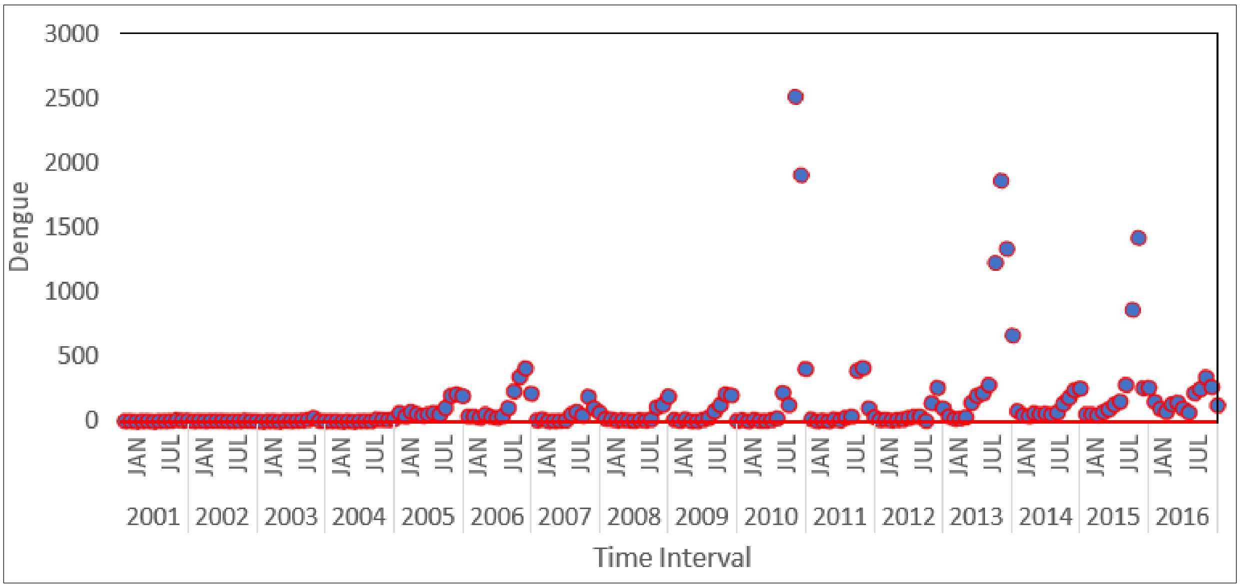

Fig 1.2(b): The time series monthly plot for dengue count for the duration of 2001 to 2016

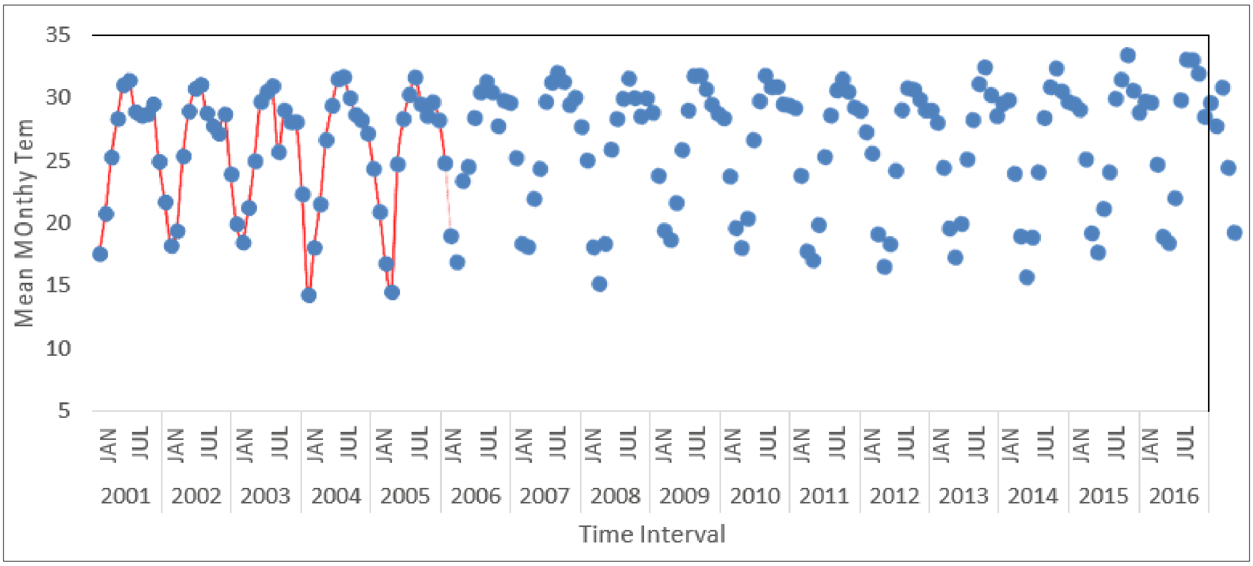

Fig 1.3(a): Time series plot for mean monthly temperture for the period of 2001 to 2016.

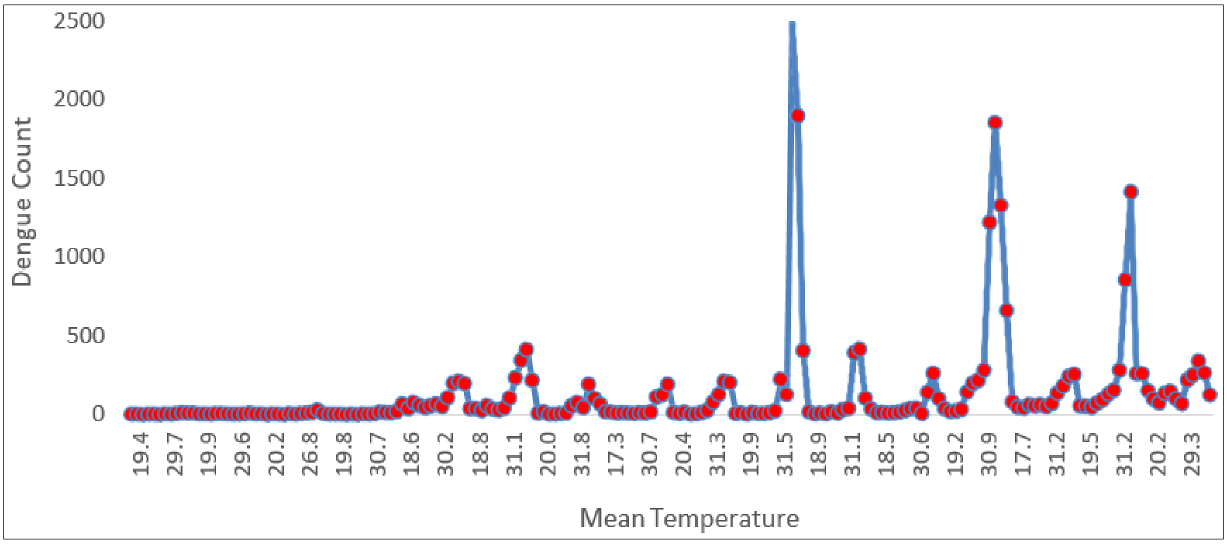

Fig 1.3(b): The time series plot for mean monthly temperature verse monthly dengue count (2001 to2016)

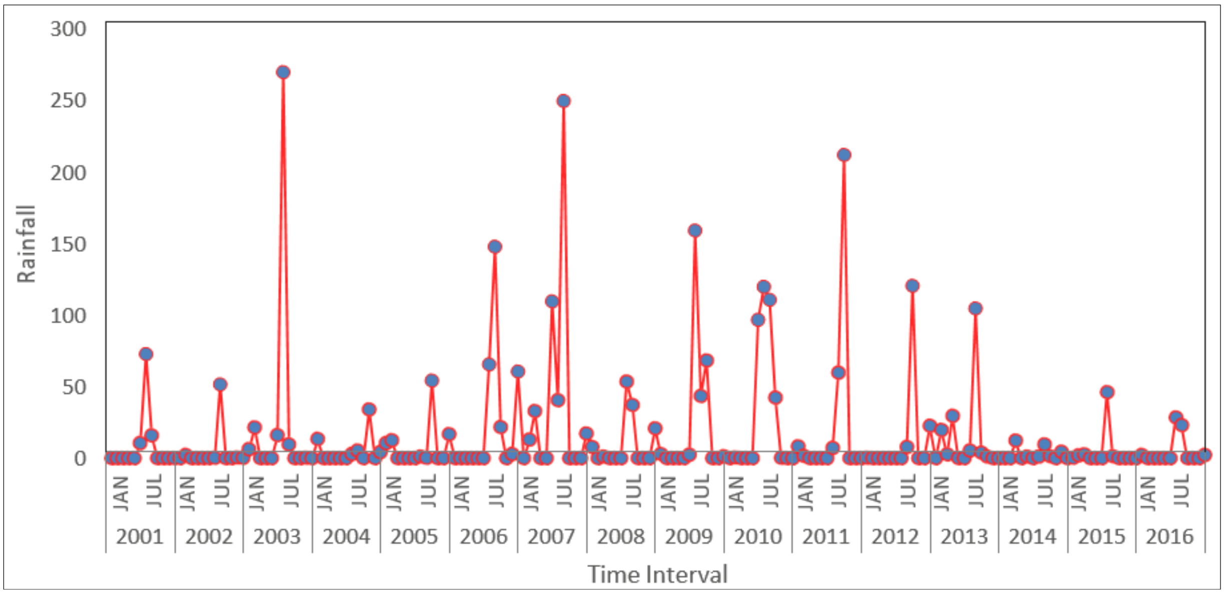

Fig 1.4(a): Time series plot for monthly rainfall from 2001 to 2016.

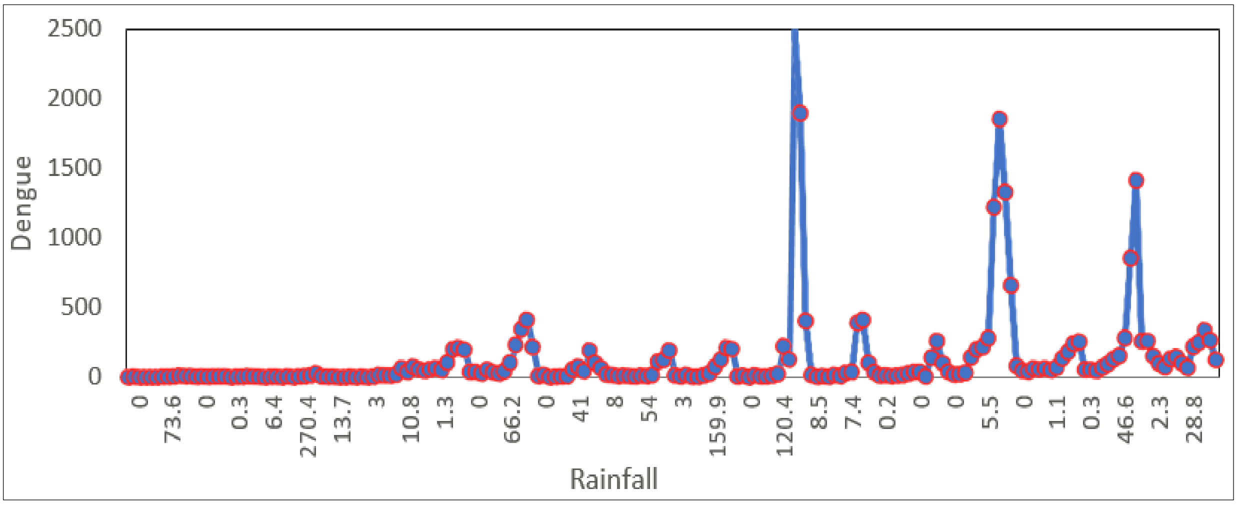

Fig 1.4(b): The time series plot for mean monthly temperature verse monthly dengue count (2001 to2016).

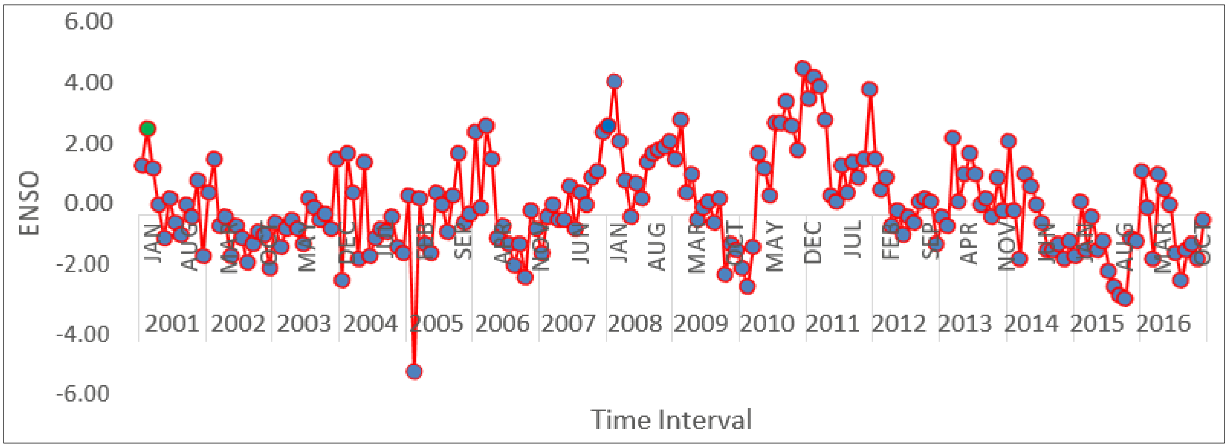

Fig 1.5(a): The time series plot for monthly ENSO3.4 index from 2001 to 2016.

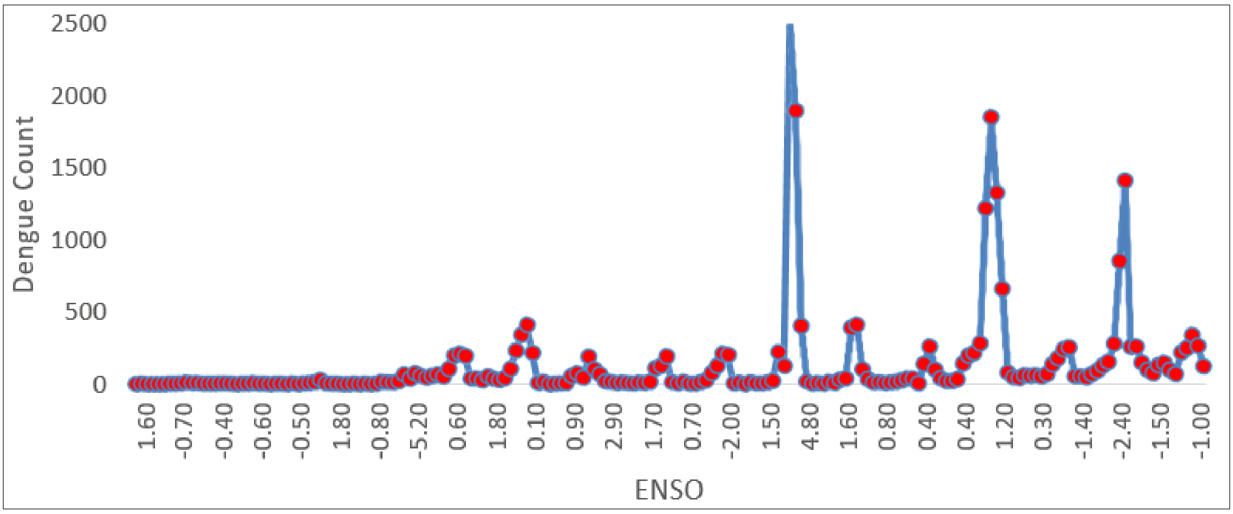

Fig 1.5(b): The time series plot for monthly ENSO 3.4 Index verse Dengue count from 2001 to 2016.

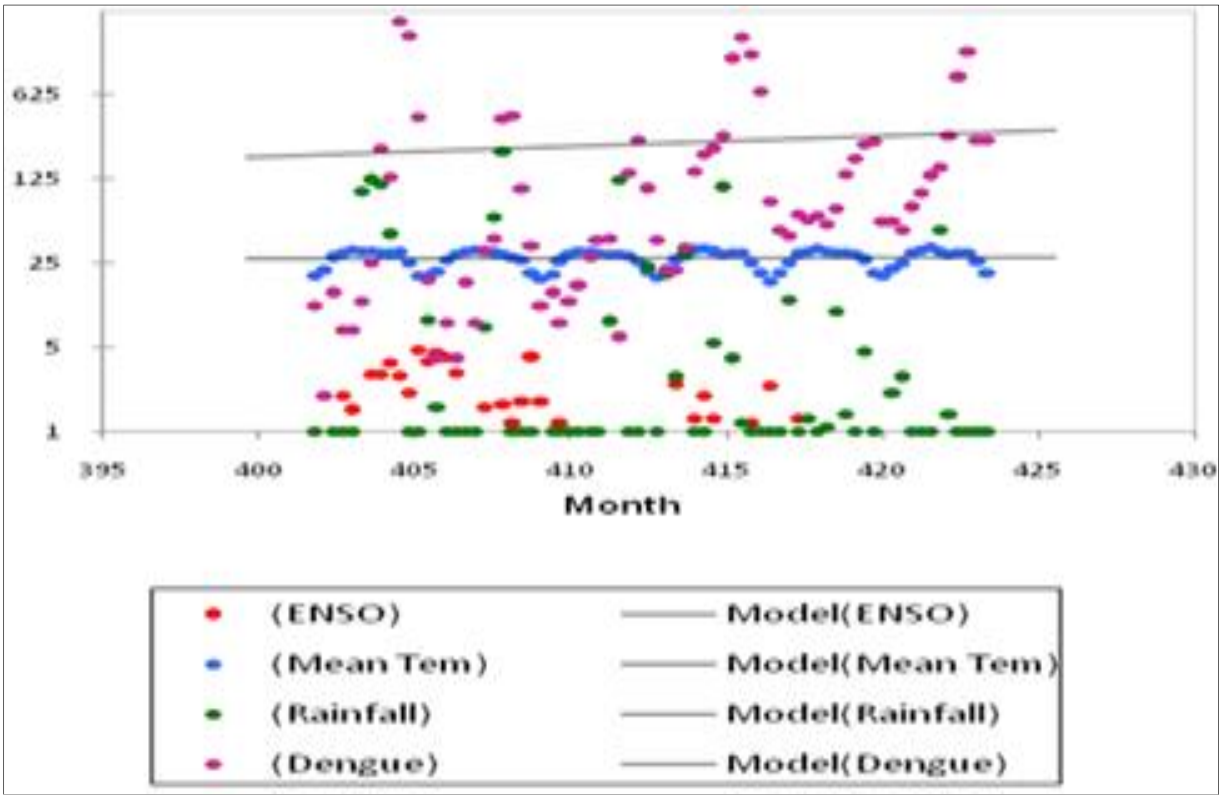

Fig 1.6: Trend analysis for monthly ENSO3.4 index, Temperature, Rainfall with Dengue counts.

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