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IMPACT OF CLIMATE ON MALARIA INCIDENCE: A CASE STUDY

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Abstract: The objective of this paper is to recommend simple, accurate and reliable suggestions to the health department in the district of Dhenkanal, Odisha for taking steps to control the impact of malaria well in advance. A time-series study of malaria incidence and its relation to the weather conditions such as rainfall, humidity and temperature are analyzed. Monthly suspected malaria cases among the population of all ages are collected respectively in six government health care centers between 2007-2011.The data are forecasted with two statistical time series models in order to determine the best fit model. Errors are found out for both the cases and established that simple exponential smoothing is the best fit model for the forecasting of malaria in the district of Dhenkanal. It is statistically demonstrated that in the month of July and August the outbreak of malaria incidence is highest.
Keywords: Malaria, Time series, Simple exponential smoothing, Tracking signal, Control charts.

1. INTRODUCTION

Malaria is caused by a parasite that is passed from one human to another by the bite of infected *Anopheles* mosquitoes. Delay in treatment may lead to serious consequences including death. Malaria is the one of the major micro-parasitic infections affecting nearly two million each year in the world. It is estimated that almost half of the world‘s population is at a risk of these disease. Malaria was declared endemic and a major health problem in 109 countries including India. Around 1.5 million confirmed cases are reported annually by the National Vector Borne Disease Control Programme (NVBDCP) in India. In Odisha, around 23% of total malaria cases in India reported which is an alarming public health problem. Fifty percent of malaria deaths are reported in the country and more than 60% of tribal population of Odisha lives in high risk of malaria. Though the tribal communities contribute 8% of total population of the country, they contribute 25% of total malaria cases in India. Malaria control has always been unattainable due to technical and operational problems.

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The spread of the epidemics, malaria, usually depends on favorable climatic conditions and the geographical locations of the place, such as forests, hills, rainfall, humidity and temperature. Dhenkanal, being a centrally located land-locked district of the State of Odisha, has dense forests, hills all-around and a moderate temperature and rainfall which becomes a favorable place for the spread of malaria epidemic. Further, the outbreak of malaria and its control in the district has become a major health problem keeping in view of the poor health service amenities available in the district.

Therefore, there is a need to forecast the occurrence of malaria outbreak so that more effective control measures can be undertaken by the government and the health service department well in advance. The main objective of this paper is to have a best-fit forecasting method by which the disease can be predicted effectively and to recommend simple, accurate and reliable suggestions to the health department in Dhenkanal district so that necessary steps may be taken to control the impact of malaria well ahead.

2. LITERATURE REVIEW

Several research works has already been done in forecasting malaria and the factors such as temperature, humidity, rainfall, etc. that affect the spread of malaria. The temperature is an important factor that determines the rate of development of parasites in the mosquitoes. Rainfall is also found as one of the significant predictors. It provides aquatic medium for the growth and development of mosquitoes. But excessive rainfall might have a negative effect by washing off the breeding sites. In all, using climatic factors as predictors for malaria occurrence are different from one location to another. The following sections take a brief account of the works carried out in this area.

2.1 Relation between Rain Fall and Malaria

Some authors assessed correlation between the rainfall and malaria by fitting a generalized linear model to the data via an over-dispersed Poisson model [1]. The results suggest that malaria pattern was mainly associated with the rainy season flooding and not irrigation. Further, in one study the author describes in his paper about the relation between rainfall and increase of malaria cases with time-series methods, using generalized additive models with a negative binomial family [2]. This study allowed specifying the excess risk of rainfall on the occurrence of suspected malaria episodes in an intermediate rainfall area. Many authors established relation between monsoon rainfall and increase of malaria cases in India. The results confirm the strong role of rainfall, and quantify this effect with transmission model(s) for malaria that include rainfall and are shown to exhibit a remarkable prediction skill [3], [4], [5], [6].

2.2 Relation between Temperature and Malaria Cases

Ying Zhang, analyzed 20-year historical time-series data and examined the relationship between meteorological variables, including maximum and minimum temperatures, rainfall, humidity, and cases of malaria in Jinan, a temperate city in northern China. The Seasonal Autoregressive Integrated Moving Average (SARIMA) model was used to quantify the relationship between the meteorological variables and malaria cases. The model indicate that a 1°C rise in maximum temperature may be related to a 7.7% to 12.7% increase and a 1°C rise in minimum temperature may result in approximately 11.8% to 15.8% increase in the number of malaria cases. Similarly, Menno Jan Bouma, examined in his article about effects of temperature on the epidemiology of malaria [7], [8].

2.3 Relation between other Factors and Malaria

M. C. Thomson et al described in his paper that skilful seasonal climate forecasts should be provided for early warning of changes of risk in epidemic-prone region. In 2004, a comparative assessment of the malaria and schistosomiasis risks associated with surface and sprinkler irrigation systems in Zimbabwe. An assessment of seasonal climate forecasts, monitoring of meteorological conditions, and early detection of cases could have helped to prevent the 2002 malaria emergency in the highlands of western Kenya [8], [10], [11].

2.4 Forecasting Techniques

In this paper two quantitative methods such as Weighted Moving Averages and Simple Exponential Smoothing are used. A brief overview of these two methods are given below;,

Weighted Moving Averages (WMA)

A weighted moving average forecast model is based on an artificially constructed time series in which the value for a given time period is replaced by the weighted mean of that value and the values for some number of preceding time periods. The weighted moving average method of forecasting is best suitable under the situations where there is neither a growth nor a decline trend observed in the time series data.

The general formula for calculating the weighted moving average is as follows;

$$F_t = w_{t-1}A_{t-1} + w_{t-2}A_{t-2} + w_{t-3}A_{t-3} + \ldots\ldots + w_{t-n}A_{t-n} \qquad \ldots\ldots\ldots\ldots\ldots 2.1$$

Where;

F_t = *n-period weighted average forecast for period t*

w_{t-1} = *weight for the period (t-1) and so on…*

A_{t-1} = *Actual value for the period (t-1) and so on…*

Simple Exponential Smoothing

Simple Exponential smoothing is a sophisticated weighted averaging method that is relatively easy to use and understand. When the past data is limited to last few periods, in this situation simple exponential smoothing can be a best fit method for investigating the forecasts. Each new forecast is based on the previous forecast plus a percentage of the difference between that forecast and the actual value of the series at that point. That is,

$$F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1}) \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2.2$$

i.e.; Forecast for period t = forecast for period (t-1) + α *[forecast error in period (t-1)]*

Where:

F_t = *forecast for period t*

F_{t-1} = *forecast for period (t-1)*

A_{t-1} = *actual value in the period (t-1)*

$(A_{t-1} - F_{t-1})$ = *forecast error in the period (t-1)*

α = *smoothing constant* $(0 \leq \alpha \leq 1)$

From the above equation it is clear that we require data only for the last period to arrive at the forecast for the next period. Therefore the data for the past periods excluding the most recent one is not required.

2.5 Measurement of Errors

It is always desirable that the forecast values should be as close as possible to the actual value in the coming periods. Practically, some forecasting errors such as deviation from the actual value do take place. Therefore, we need to measure these errors and then try to minimize them as much as possible. The different types of forecasting errors are given below;

1. *Running Sum of Forecast Errors (RSFE)* = $\sum_{t=1}^{N} e_t$

2. *Mean Forecast Errors (MFE) = RSFE/N =* $\frac{\sum_{t=1}^{N} e_t}{N}$

3. *Mean Absolute Deviation (MAD) =* $\frac{\sum_{t=1}^{N} |e_t|}{N}$

4. *Mean Squared Errors (MSE) =* $\frac{\sum_{t=1}^{N} e_{t^2}}{N}$

5. *Mean Absolute Percentage Errors (MAPE) =* $\frac{\sum_{t=1}^{N} \left| \frac{e_t}{A_t} \times 100 \right|}{N}$

6. *Tracking Signal (TS) = RSFE/MAD*

   Where, e_t *= (Actual Value – forecast value)*

   N = number of periods

   A_t *= Actual Value*

3. METHODOLOGY

3.1 Study area

Six locations of the district of Dhenkanal, Odisha are selected for this study as it is identified that the malaria transmission occurs throughout the year in these locations. These are Dhenkanal, Gaondia, Hindol, Kamakhyanagar, Paranjang and Bhuban which broadly represent the entire geography of the district. There are usually four seasons in this district, each season lasts about three months. The general climate in this district is sub-tropical with heavy rainfall from July to September. Temperature and humidity are moderate to high during these periods.

3.2 Data Collection

The monthly incidence of malaria cases were obtained from the Dhenkanal district hospital with the permission of Chief District Medical Officer (CDMO). The data were collected for all the six places for last sixty months (5 years) i.e. from January 2007 to December 2011. The total number of cases, as per the doctor’s advice and the number of positive cases are recorded and the actual % of detections was calculated (Table 3.1; Column 2). The data from the private laboratories could not be collected as the author believes that these data may not be reliable. The percentage of detection of malaria of Dhenkanal district as a whole has been considered by taking the mean % detection of malaria at the six places of interest. It is observed that the mean percentage detection of malaria in the district of Dhenkanal as a whole is 41.22% with maximum and minimum value as 57.58% and 19.39% respectively.

Table 3.1: Average Actual Percentage Detection, Metrological data and Forecasting of Malaria in District of Dhenkanal

(1)	(2)	(3)	(4)	(5)	(6)	(7)
					Forecasting	
Year & Months	**Actual % Detection**	**Average Rain fall (mm)**	**Average Temperature (^oF)**	**Average Humidity (%)**	**Weighted Moving Average (4 months)**	**Simple Exponential Smoothing (α = 0.6)**
Jan 07	53.21136351	0	72.9	54.8	#N/A	#N/A
Feb 07	57.58475273	108	74.995	61.65	#N/A	53.21136
Mar 07	42.60427161	0	83	56.2	#N/A	55.8354
Apr 07	38.50812178	39	86.25	57.6	47.97713	47.89672
May 07	44.80941802	316.6	87.25	63.6	45.87664	42.26356
Jun 07	55.08239621	1153	86.25	73.9	45.25105	43.79108
Jul 07	51.31804124	1314.1	82.55	83.8	47.42949	50.56587
Aug 07	55.73371643	1794.3	81.15	82.4	51.73589	51.01717
Sep 07	51.8482021	2449.6	82.35	88.6	53.49559	53.8471
Oct 07	31.8880964	599.1	79.6	79.65	47.69701	52.64776
Nov 07	37.37408737	79.2	77.5	68.8	44.21103	40.19196
Dec 07	24.41041533	10.2	70.5	56.75	36.3802	38.50124
Jan 08	48.76808474	282	69.2	65.15	35.61017	30.04674
Feb 08	54.53267478	356	76.295	65.4	41.27132	41.27955
Mar 08	42.69759775	68.2	82.65	62.2	42.60219	49.23142
Apr 08	38.93609095	88.78	88.3	60.7	46.23361	45.31113
May 08	34.81143027	316	89.9	80.1	42.74445	41.48611
Jun 08	49.32117329	1679.8	84.5	75.8	41.44157	37.4813
Jul 08	45.21963622	1676	82.6	80.95	42.07208	44.58522
Aug 08	48.33186466	2080.2	82.45	86.85	44.42103	44.96587

Sep 08	39.68737659	1890.5	83.5	71.8	45.64001	46.98547
Oct 08	41.49843324	132.2	81.1	77.15	43.68433	42.60661
Nov 08	34.34315099	0	73.9	57.8	40.96521	41.94171
Dec 08	19.39121625	0	68.45	54.2	33.73004	37.38257
Jan 09	49.04224423	297	68.5	67.45	36.06876	26.58776
Feb 09	41.90474405	0	73.7	50.85	36.17034	40.06045
Mar 09	40.5092981	15	87.25	60.8	37.71188	41.16703
Apr 09	53.89480579	0	88.5	51.25	46.33777	40.77239
May 09	57.3383595	637	89.8	63.1	48.4118	48.64584
Jun 09	41.335305	470	84.45	76.35	48.26944	53.86135
Jul 09	50.39560857	3853	82.65	83.6	50.74102	46.34572
Aug 09	52.07977381	1324	82.1	85.45	50.28726	48.77565
Sep 09	34.70438445	682	83.25	81.9	44.62877	50.75813
Oct 09	32.79903776	1135	81.15	82.15	42.4947	41.12588
Nov 09	20.61991989	51	74.8	59.7	35.05078	36.12978
Dec 09	35.47651749	0	69.6	54.48	30.89996	26.82386
Jan 10	40.43436724	0	69.9	52.2	32.33246	32.01546
Feb 10	31.01294297	0	75.2	52.9	31.88594	37.0668
Mar 10	29.1601819	54.5	85.45	60.05	34.021	33.43449
Apr 10	34.21117403	22	86.5	69.95	33.70467	30.8699
May 10	34.98717141	829.2	90.05	69.4	32.34287	32.87467
Jun 10	34.16226234	1081	87.15	77.5	33.1302	34.14217
Jul 10	34.35489964	1144	84.3	80.85	34.42888	34.15423
Aug 10	38.69440858	1362	81.9	83.8	35.54969	34.27463
Sep 10	29.26452854	1112	83.65	80	34.11902	36.9265
Oct 10	38.46673354	658	80.9	76.7	35.19514	32.32932
Nov 10	42.67919553	68	73.1	57.85	37.27622	36.01177
Dec 10	32.44590825	233	65.7	55.25	35.71409	40.01222

Meteorological data from climatic record was obtained from the Meteorological unit of the district of Dhenkanal from 2007 to 2011 (Table 3.1; Column 3, 4, 5). The climatic variables include mean minimum and maximum temperature, humidity and average rainfall. These variables are collected and recorded at the meteorological unit which maintains the records of all the major places in the district. The summary of the above data shows the following information. The maximum temperature of the whole region varies between 10°F and 25°F; mean minimum temperature ranges between 10°F and 20°F. Average relative humidity ranges between 60% and 90%. Amount of rainfall greatly varies from month to month, ranging from zero to 3000 mm per month.

4. RESULT ANALYSIS AND DISCUSSIONS

As discussed earlier, data are collected from the six major location of the district of Dhenkanal and the percentage detection of malaria in the above locations is determined. The average % detection of malaria at all the six locations is represented as the average % detection of malaria in the district as a whole.

Error (e) = Actual (A) - Forecast (F)

In this paper, two statistical forecasting methods such as **(1) weighted moving average and (2) simple exponential smoothing** have been employed. The reason is that weighted moving average method of forecasting is suitable under situations where there is neither a growth nor a decline trend is observed. Since, it is observed that the malaria data collected for last five years are not following increasing or decreasing trend, hence this method of forecasting have been selected. Secondly, when the past data is limited to last few periods, in this situation simple exponential smoothing can be a best fit method for investigating the forecasts. Therefore, these two methods are selected for comparison. In simple exponential smoothing, when α is small, it leads to give lower weightage to recent demands and more consideration to old demands. On the other hand, if α is large, the reverse is true. Therefore, the value of α is decided judiciously according to the gravity of service or products.

The values of forecasting are presented in Table 3.1 Column 6 & 7 with four month weighted moving average and $\alpha = 0.6$ simple exponential smoothing models. $\alpha = 0.4$ and $\alpha = 0.8$ are also tested, but the value of smoothing constant 0.6 gives minimum errors. The actual % of malaria detection for 2011 is kept for comparing with the forecasting value.

Considering the above forecast values, graphs are plotted from January 2007 to December 2010 as shown in Figures 4.1. From the graph a general decreasing trend is observed in both the models. In fact, the incidence of malaria is high from the month of May to October in all the year with some exceptions. Actual percentages of malaria incidence from January 2007 to December 2010 are considered for forecasting of the next 12 months i.e. 2011 and are kept for comparing with the forecasted value (Table 4.1). The forecast for the next 12 months i.e. from January 2011 to December 2011 are carried out with the same procedure to have a clear idea of the trend (Figure 4.2). The trend is found to be almost same and confirming the actual values.

From the above analysis it is not concluded which method can be used to forecast the malaria epidemics in Dhenkanal district as both the models show almost the same trend of forecasting rather, in a repetitive manner. Therefore, it is desirable to analyze the errors in each case and find out the best model for forecasting the incidence of malaria.

In contexts, where forecasts are being produced on a repetitive basis or the trend does not establish any clear result, the performance of the forecasting system may be monitored using a **Tracking Signal (TS),** which provides an automatically maintained summary of the forecasts produced up to any given time. This can be used to monitor for deteriorating performance of the system.

A tracking signal monitors any forecasts that have been made in comparison with actual, and warns when there are unexpected departures of the outcomes from the forecasts. It is a simple indicator that forecast bias is present in the forecast model. It is most often used when the validity of the forecasting model might be in doubt. Therefore, in our case it is appropriate to analyze tracking signal for both the models for the year 2011. Quantitatively,

Tracking Signal, TS = RSFE / MAD

Where, RSFE = Running Sum of Forecast Errors

MAD = Mean Absolute Deviation

Tracking signals are calculated for both the methods used in this study and are shown in the Table 4.1. All other errors are also calculated with the forecasting values of 2011 (Table 4.1). The mean squared error for weighted moving average method is found to be 20.51 whereas that for exponential smoothing is 39.75. The values of tracking signal thus found are plotted as shown in the figure 4.3 & 4.4. Analyzing **Model 1, i.e. Weighted moving average,** it is evident that the minimum value of TS is -1 in January 2011 and the maximum is 4.47 in October 2011. The value of TS gradually increases up to the month of May and then suddenly falls in June. Then, it is increasing up to October and falls gradually till December 2011. August, September and October shows nearly equal values of TS. In the **Model 2, i.e. Simple exponential smoothing**, the initial trend is almost equal to the first model till August 2011. However, the TS value for the month of September and October 2011 decreases slightly. The minimum and maximum values of TS are 0.67 & 4.24 in the month of June and August respectively. The mean squared error is 39.75 and the standard deviation is 6.30 in this case. From both the models, it is clear that malaria incidence is at its peak during the period ranging **from July to October**. This may be because of mean temperature; humidity and the rainfall which provide the favorable condition for breeding of anopheles mosquitoes. However, in the month of May also the % detection of malaria is substantially high. This may be attributed to the unusual climatic change which might have favored the growth of anopheles.

The values of TS range between -1 to 4.46 in Model 1 and 0.67 to 4.24 in Model 2. In actual practice these limits are based on experience and judgment and often range from ±3 to ±8. Therefore, for both the models it is evident that the forecast is performing adequately. However, Model 2, i.e. simple exponential smoothing with smoothing constant 0.6 gives better TS values. When the signal goes beyond the maximum and minimum range, corrective action is appropriate. The resulting tracking signal values are compared to predetermined limits. Considering tracking signal for both the models it is established that the TS values are well under the predetermined limits.

The present study is related to the health service which requires a very high accuracy of forecasting. Therefore, it is important to monitor forecast errors through **statistical control charts** to insure that the forecast is performing well. If the model is performing poorly based on some criteria, then it may be reconsider the use of the existing model or switch to another forecasting model or technique. The forecasting control limit charts are drawn using individual values of forecast errors for both the models as shown in Figure 4.5 & 4.6. It is assumed that the forecast errors follow a normal distribution curve and are randomly distributed around the mean which is zero. The control charts are drawn considering two sigma limit. Looking into the control charts for both the models, it is observed in both the models that in the month of July

Year & Months	Actual % Detection (D)	Forecasting Techniques	Forecasts (F)	(D-F)	RSFE	Absolute (D-F)	Cumulative (D-F)	MAD	TS = RSFE/MAD	$(D-F)^2$
Jan 11	37.04549919	WMA	37.65933	-0.61383	-0.61383494	0.61383494	0.61383494	0.61383494	-1	0.376793
		SES	35.47243	1.573065	1.573065	1.573064668	1.573064668	1.573065	1	2.474532
Feb 11	39.39018541	WMA	37.8902	1.499988	0.886153375	1.499988315	2.113823255	1.056911627	0.838436585	2.249965
		SES	36.41627	2.973912	4.546977	2.97391209	4.546976758	2.273488	2	8.844153
Mar 11	39.73664566	WMA	37.15456	2.582086	3.468239406	2.582086031	4.695909286	1.565303095	2.215698299	6.667168
		SES	38.20062	1.536025	6.083002	1.536025083	6.083001841	2.027667	3	2.359373
Apr 11	37.85632959	WMA	38.50716	-0.65084	2.817404035	0.650835371	5.346744656	1.336686164	2.107752822	0.423587
		SES	39.12224	-1.26591	4.817096	1.265906034	7.348907875	1.837227	2.621938	1.602518
May 11	44.9242687	WM	40.47686	4.44741	7.26481539	4.44741136	9.79415601	1.95883120	3.70875008	19.7794

		A		1	7	2	9	4	7	7
		SES	38.36269	6.561577	11.37867	6.561576699	13.91048457	2.782097	4.089963	43.05429
Jun 11	33.46341964	WMA	38.99517	-5.53175	1.733069137	5.531746261	15.32590228	2.554317047	0.678486306	30.60022
		SES	42.29964	-8.83622	2.542454	8.836218387	22.74670296	3.791117	0.670635	78.07876
Jul 11	50.17752236	WMA	41.60539	8.572137	10.30520642	8.572137287	23.89803957	3.414005652	3.018508893	73.48154
		SES	36.99791	13.17962	15.72207	13.17961537	35.92631833	5.132331	3.063339	173.7023
Aug 11	52.01899046	WMA	45.14605	6.87294	17.17814659	6.872940166	30.77097973	3.846372467	4.466064256	47.23731
		SES	44.90568	7.113314	22.83538	7.113314243	43.03963257	5.379954	4.244531	50.59924
Sep 11	43.51589736	WMA	44.79396	-1.27806	15.90008649	1.278060095	32.04903983	3.561004425	4.465056651	1.633438
		SES	49.17366	-5.65777	17.17762	5.657767401	48.69739997	5.410822	3.174678	32.01033
Oct 11	47.12194521	WMA	48.20859	-1.08664	14.81344286	1.086643633	33.13568346	3.313568346	4.470540914	1.180794

		SES	45.779	1.342941	18.52056	1.342940896	50.04034087	5.004034	3.701125	1.80349
Nov 11	38.12286329	WMA	45.19492	-7.07206	7.741382074	7.072060787	40.20774425	3.655249477	2.117880632	50.01404
		SES	46.58477	-8.46191	10.05865	8.461905563	58.50224643	5.318386	1.891298	71.60385
Dec 11	38.20927375	WMA	41.74249	-3.53322	4.208160921	3.533221153	43.7409654	3.64508045	1.154476829	12.48365
		SES	41.50763	-3.29835	6.7603	3.298351767	61.8005982	5.15005	1.312667	10.87912

Table 4.1: Errors and Control Chart for Weighted Moving Average Method

Weighted Moving Average (WMA)

Average $(D-F)^2$ = 20.51066

MSE Standard Deviation s = $\sqrt{20.51066}$ = 4.52887

Control limits are usually set at two sigma limit

UCL = 9.05774

CL = 4.52887

LCL = -9.05774

Simple Exponential Smoothing (SES)

Average $(D-F)^2$ = 39.75099

MSE Standard Deviation s = $\sqrt{39.75099}$ = 6.304839

Control limits are usually set at two sigma limit

UCL = 12.60968

CL = 6.304839

LCL = -12.6097

2011, the error increases substantially followed by August 2011. June and November 2011 are nearer to the lower control limit, which is not an alarming situation in case of health service. Examining the metrological data, in July and August 2011, the rainfall ranges from 1100mm to 3800mm, humidity from 74% to 96% and the temperature 74°F to 90°F (23°C to 33°C) which is a very favorable condition for breeding the Malaria mosquitoes 'anopheles'.

The best-fit model for the district of Dhenkanal is found to be the simple exponential smoothing with smoothing constant as 0.6.with an error percentage of 8.72% and the predicted cases with the actual cases for the year 2007 to 2011 are presented. This best model can be fitted to forecast the malaria cases in future i.e. in 2012.

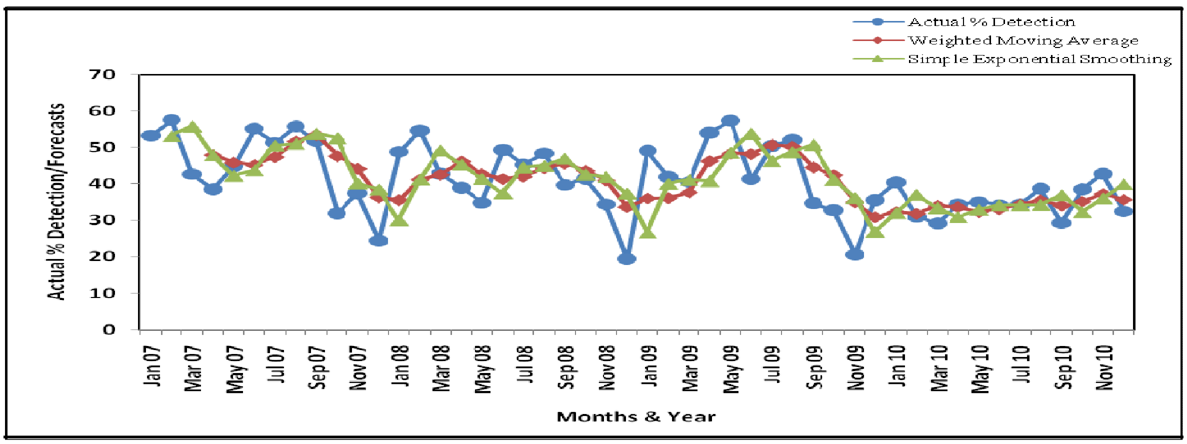

Figure 4.1: Comparison between Actual % Detection and Forecasts for Weighted Moving Average and Simple Exponential Smoothing

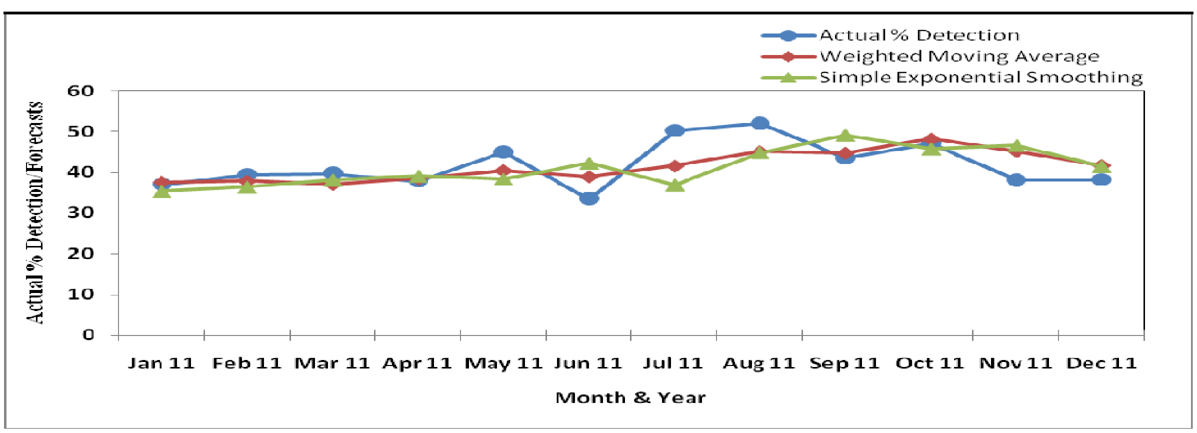

Figure 4.2: Comparison between Actual % Detection and Forecast for Next 12 Months i.e. 2011 for Weighted Moving Average and Simple Exponential Smoothing

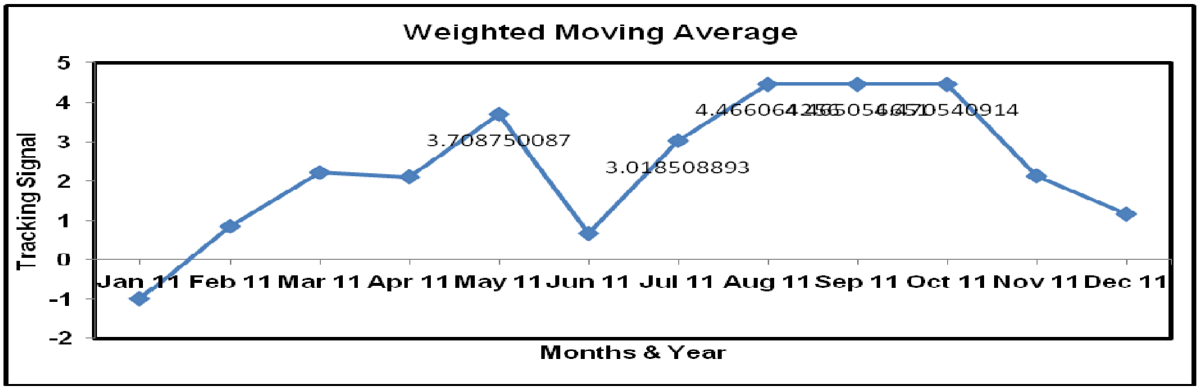

Figure 4.3: Tracking Signal for Weighted Moving Average

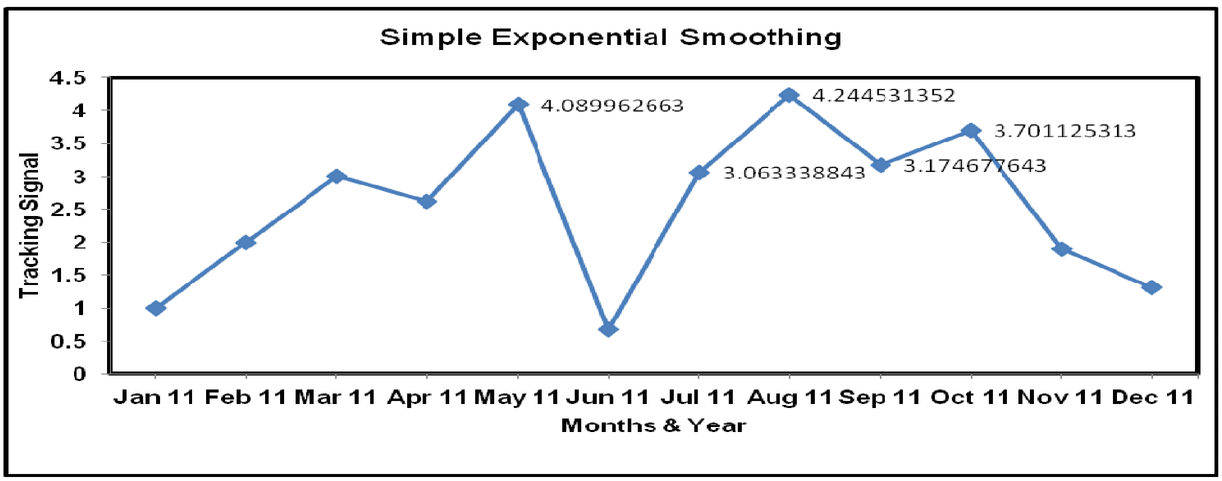

Figure 4.4: Tracking Signal for Simple Exponential Smoothing

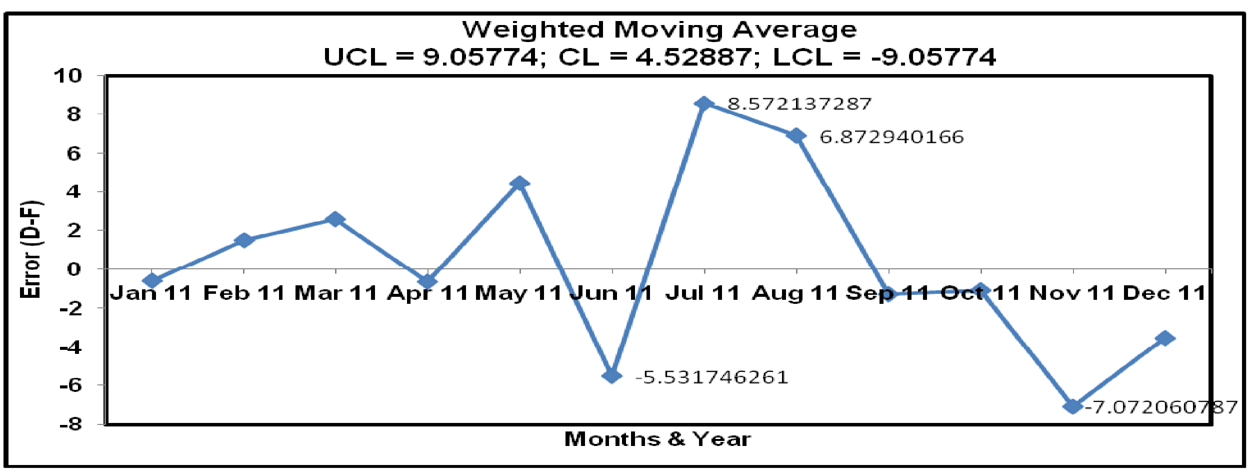

Figure 4.5: Forecast Control Limit Chart for Simple Exponential Smoothing

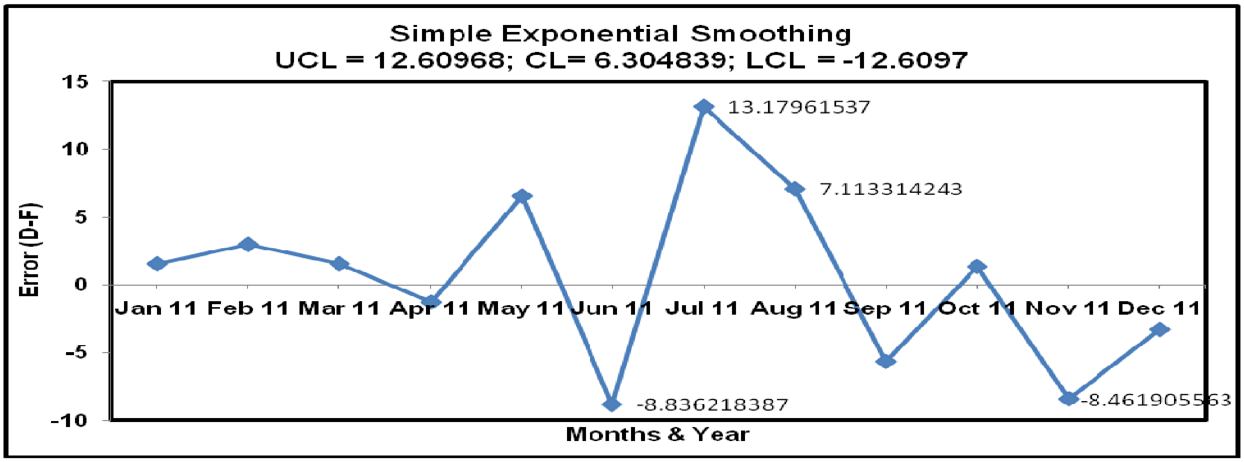

Figure 4.6: Forecast Control Limit Chart for Simple Exponential Smoothing

5. CONCLUSIONS

This work has been carried out according to the trend of the malaria cases over the years and presuming pattern stability of all other conditions such as climatic factors, control and preventive measures. The best fit model is validated and appeared to fit well at the overall districts, providing tolerable error levels of 8.72% in forecasting. On the other hand, different malaria trends are observed among six locations that have similar climatic characteristics. Though the percentage detection of malaria in whole district is in a decreasing trend but still it is suggested that control measures should be accelerated. Therefore from the above discussion it is suggested to the district health departments that control measures and treatment of malaria cases may be accelerated specially in the month of July & August in future and the forecast for the future can be carried out with Model 2 i.e. Simple Exponential Smoothing. This study can also be extended in the same way for different chronic diseases such as Typhoid, cholera, T.B, Chickenpox considering other suitable techniques. As a limitation of this study, the data from the private laboratories could not be collected.

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