Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 1859-1871.

THE INFLUENCE OF WEATHER PARAMETERS ON MALARIA OUTBREAKS OVER KILIMANJARO REGION IN TANZANIA

PRESENTER: MUSHI, SHAMIM. T.

INTRODUCTION

OVERVIEW OF THE PROBLEM

Malaria is endemic to the region and has been creeping upwards from the lowlands to the highlands; it is a serious disease in tropics because minimum and maximum temperatures are good for the development of the malaria parasites.

For countries north of 28^o north and south of 28^o South the problem is not serious because minimum temperatures are usually too low and maximum temperature too high for the development of the malaria parasites.

East Africa and Great lakes region, Burundi, Ethiopia, Kenya, Uganda and the United Republic of Tanzania, are subject to frequent and recurrent malaria epidemics that often affect the large numbers of people. The problem is more worse in coastal and mountainous areas in Tanzania due to the fact that the temperatures is favors the survival of the malaria vectors (Githeko, 2001)

Very young children and pregnant women are the population groups at highest risk of malaria morbidity and mortality in Africa. Most children experience their first malaria infections during the first year or second year of life, when they have not yet acquired adequate clinical immunity – which makes this early year particularly dangerous. Ninety percent (90%) of all malaria deaths in Africa occur in young children. (WHO, 2003).

.Poor people are also at increased risk both of becoming infected with Malaria and of becoming infected more frequently. Child mortality rates are known to be higher in poor households and malaria is responsible for a substantial proportion of these deaths. In a demographic surveillance system in rural areas of the United Republic of Tanzania, under-5 mortality following acute fever (much of which would be expected to be due to malaria) was 39% higher in the poorest socioeconomic group than in the richest. (Mwageni, 2002). Poor people are also less likely to be able to pay either for effective malaria treatment or for transportation to a health facility capable of treating the disease.

Malaria outbreak has been also associated with climate variability though there is little work that has been done to relate weather and malaria .Climate variability and change combined with land use changes and human population aggravate the malaria disease in different areas. Insects such as mosquitoes, sand flies and tsetse flies transmit the disease. Rainfall is one of the major factors influencing malaria epidemic in semi-arid and desert-fringe areas of Africa. Epidemics may occur after excessive rains, usually with a Lag time of several weeks during which mosquito vector populations and malaria infections gradually increase (Githeko, 2001).

These cold-blooded vectors are sensitive to direct effects of climate such as temperature, rainfall patterns, and wind.

Climate also affects their distribution and abundance through its effects on host plants and animals (WHO, 2001).

Recent evidence of the responsiveness of malaria incidence to local climate change and perturbations includes marked increases in the incidence and distribution (particularly with reference to occurrence of malaria at high altitude during a typical hot weather in Rwanda in 1987 (WHO, 1996). Similarly, annual fluctuations during the 1980s in falciparum malaria intensity in northeast Pakistan correlate with variations in annual temperature and precipitation experienced during those years.

Temperature, precipitation and extreme weather events can also have an effect on the variability and geographical distribution of the anopheline mosquitoes that transmit malaria. Most anopheline mosquito activities become active when the temperature is above 22^0C. Also, the mosquito survival rates become more sensitive to relative humidity at higher temperatures; precipitation influences the abundance of breeding sites and vector densities. (WHO, 1998).

Also, Lindsay et al (2000), found a reduction in malaria infection in the Usambara Mountains of Tanzania following 2.4 times more rainfall than normal, while excessive rainfall during the same period was associated with increased malaria in south-western highlands of Uganda (Kilian *et al*, 1999).

STUDY AREA

The area of study is Kilimanjaro region lying between (3 –5) °South, 37° East.

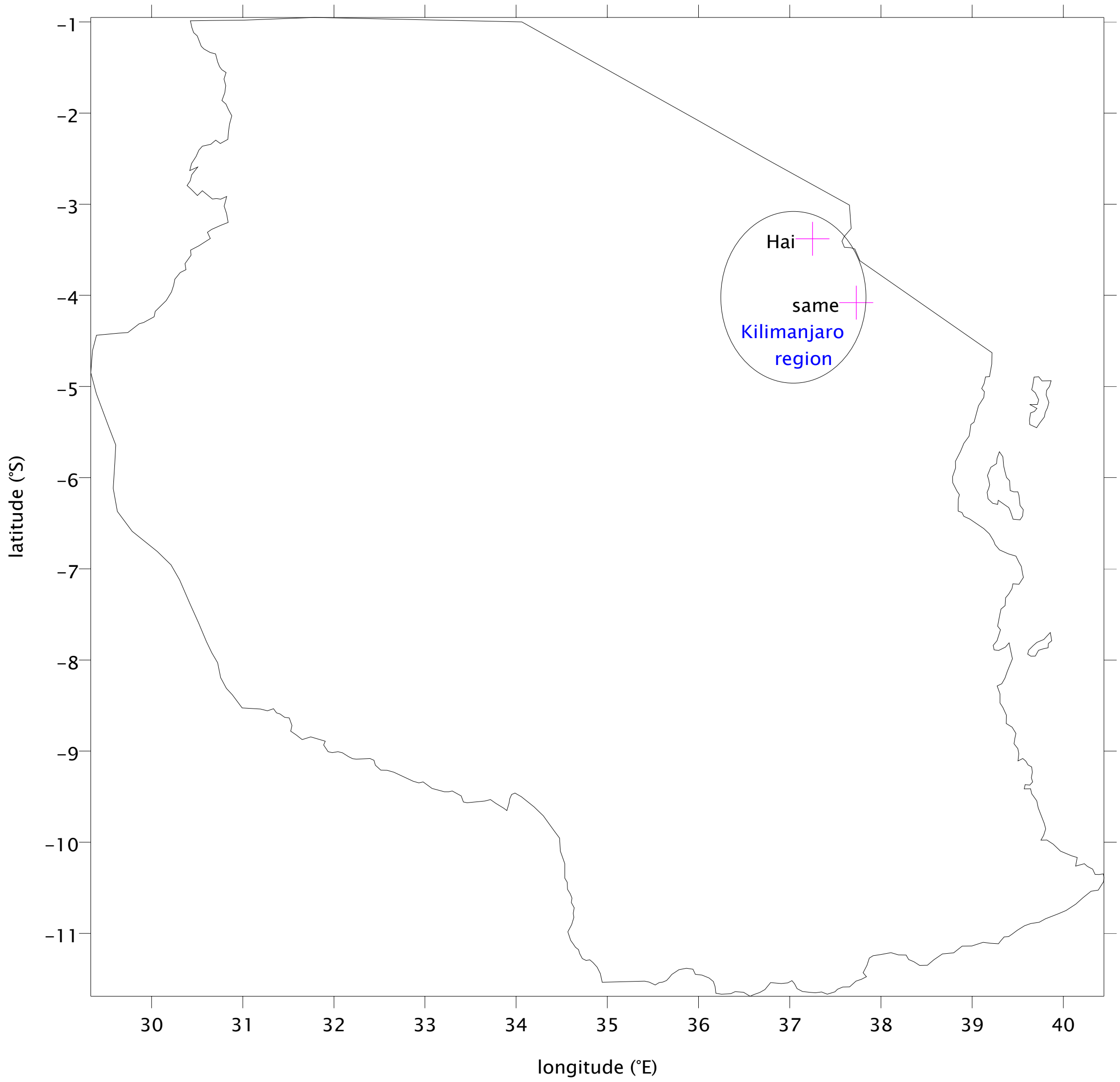

Figure: 1 Map of Tanzania showing Same and Hai district.

The area forms within the low lands of Kilimanjaro region down on the slopes of Mt. Kilimanjaro. When it rains on the elevated ground water remains on the surface for about two to three days before draining into the rivers. The area also experiences small water pools during the wet season (March, April and May) which provide breeding grounds for mosquitoes, the area generally observes two major rainfall seasons namely the long and short rains seasons. The rains are centered between March to May (MAM) and October to December (OND) respectively. Dry months in these areas are usually observed between January and February as well as from June to September.

DATA AND METHODOLOGY

Two data sets covered the period of 1984 to 2004 were collected, namely weather and malaria data. The weather parameters data were obtained from

Tanzania meteorological agency which comprised of monthly rainfall, mean monthly relative humidity and temperature for Kilimanjaro International Airport

- **Malaria Data**

Malaria data obtained from the Ministry of health in Tanzania consisted of records of total monthly number of patients diagnosed clinically with malaria for Hai and Same district hospitals for the same period as that of weather data.

Single mass curve was used to test for homogeneity for both malaria and weather data.

Both weather and malaria r data showed homogeneity as indicated by a straight line in the figure 2a and 2b below respectively.

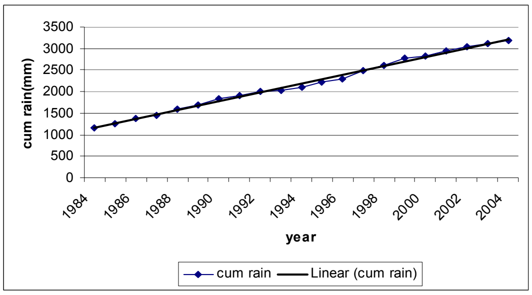

Figure 2a Mass Curve for rainfall at Kilimanjaro International Airport

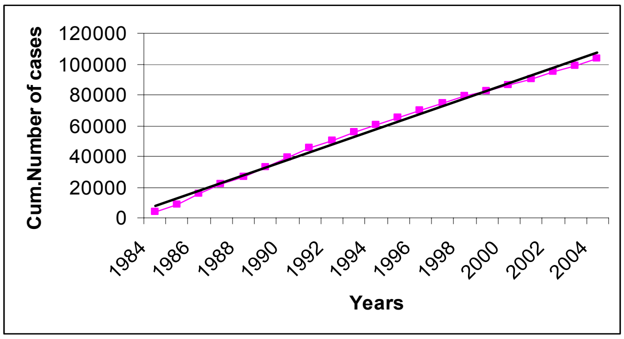

Figure2 b Single mass curves for malaria cases at Same/Hai district hospital

METHODOLOGY

Data analysis was done using the following methods estimation of missing data, data quality test, time series and temporal analysis correlation analysis and multiple regressions.

RESULTS AND DISCUSSION

Plots of malaria time series for Same and Hai district hospitals (figures 3a & 3b) showed the highest observed number of cases being in March 2002 and March 2004, while in Hai district the highest was in May 1984. During this period the ground contains water, so it provides potential breeding sites for malaria vectors

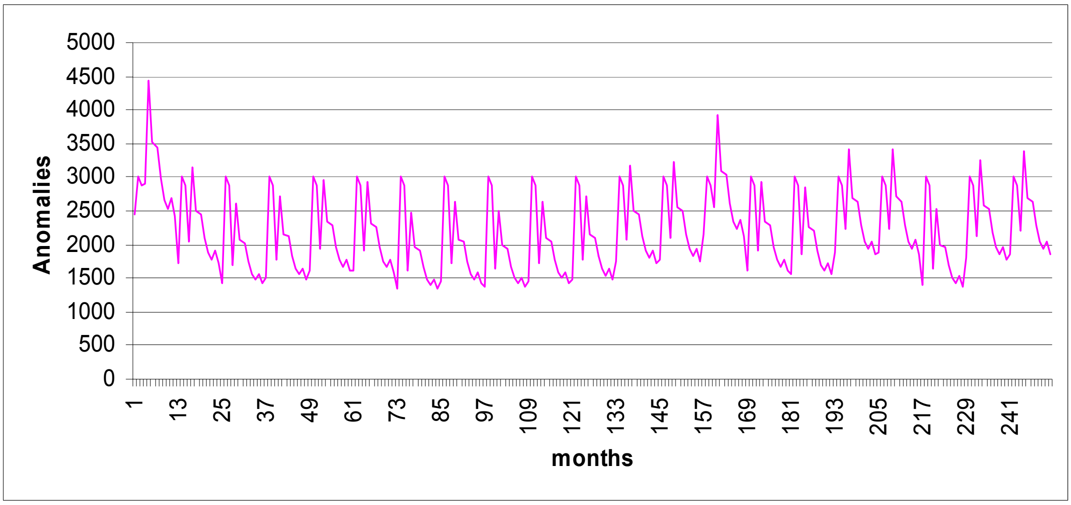

Figure 3a. Observed temporal malaria cases at Hai district hospital

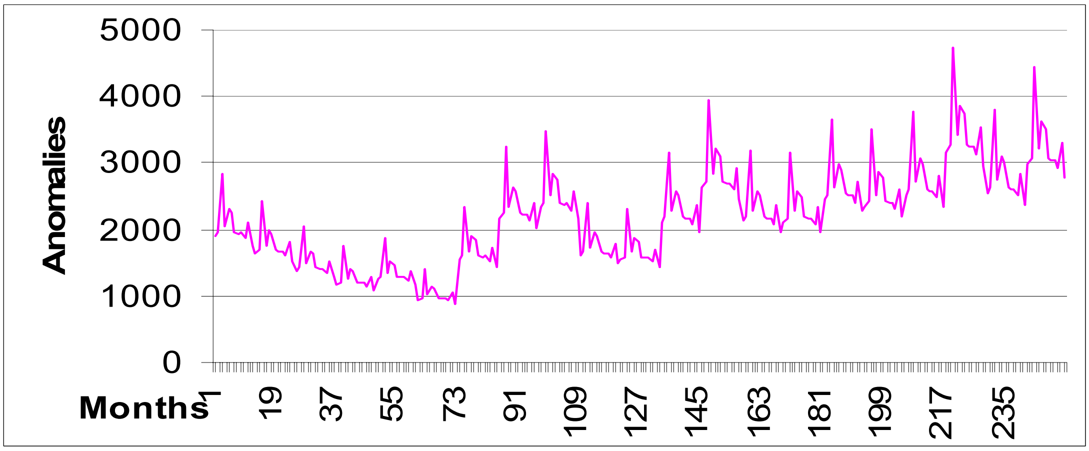

Figure 3b Observed temporal malaria cases at Same district hospital.

The maximum temperature was observed to be positively correlated with malaria cases in Hai and Same district hospitals during the months of March and October as indicated in table1.This may suggest that during these months' temperatures above 220c favor mosquitos' larva development.

Details of the correlation values are presented in tables 1 and 2.

Table 1: Correlation between malaria cases and Temperature in Hai district

Months	Variable	Correlation(r)
March	Tmax	0.45
Apr	Tmax,	0.290
Dec	Tmax	0.30
October	T-max	0.42

Table 2: Correlation between malaria cases and Temperature in Same district.

Months	Variable	Correlation(r)
March	Tmax	0.36
Nov	Tmax	0.24
October	T-max	0.49

In Hai district, by contrast, the effect of minimum temperature on malaria cases is more complicated. A significant positive association between malaria cases and Minimum temperature is observed

Table 3: Correlation between malaria cases and Minimum Temperature in Hai district

Months	Variable	Correlation(r)
may	Tmin	0.45
June	Tmin	0.36
July	Tmin	0.29

Table 4 Correlation between malaria cases and Minimum Temperature in Same district.

Months	Variable	Correlation(r)
Jan	Tmin	-0.51
Dec	Tmin	-0.45
Aug	Tmin	-0.36

In both district hospitals, rainfall is significantly associated with malaria cases. A significant and positive effect of rainfall in Hai district manifests at relatively short lags (lag 0) and remains positive onwards but declines and becomes non-significant for the longer lags. As shown in table 5.

Table 5: Summary of significant correlation coefficients between Malaria cases and Rainfall in Hai District

Months	Correlation(r)
May	0.24
June	0.38
July	0.41
Aug	0.29
Sept	0.11

For the Same district, a significant positive association at both longer and shorter lags is observed. (See table 6)

Table 6: Summary of significant correlation coefficients between Malaria cases and Rainfall in Same District.

Months	Correlation(r)
Marc	0.55
Apr	0.61
May	0.60
June	0.51
July	0.37
Aug	0.37
Sept	0.35

Weather parameters and malaria data were analyzed using SYSTAT program and the results summary is tabulated below

.

Table7: Summary of significant related parameters with Malaria cases in Hai district.

Month	Model equation	R^2	Sig- variables	P-values
Jan	1381.792-97.94*Tmin+7.909*RH+0.777*Cumrain	0.593	Tmin,RH,Cumrain	0.001,0.034,0.052
Feb	1182.365+697.104*Tmax-750.932*Tmin-687.38*Range+1.132*Rain	0.376	Tmax,Tmin,Range Rain	0.206,0.180.0.215.0.126
May	365.91-2023.97*Tmax+2012.25*Tmin+2065.08*Range	0.277	Tmax,Tmin&Trange	, 0.046,0.047,0.042
June	573.32-3.074*Cumrain	0.414	Cumrain	0.003
Aug	1883.8-63.339*T-min-63.97*Range-0.42*Rain+0.142*Cumrain	0.53	T-min ,Range,Rain,cumrain	0.062,0.1820.0340.056
Nov	2396.461-109.052*Tmax+109.879Range	0.303	Tmax & T-range	0.062,0.014
Dec	170.203+1.089*Cumrain	0.447	Cumrain	0.002

In general minimum and maximum temperatures, temperature range and cumulated rain (seasonal rain) showed association with malaria outbreaks.

SEASONAL VARIATION:

(a) December and January

During December and January weather parameters were having strong relationship with malaria outbreak, his was attributed by short rain of (OND) due to this the area contains rain pools and tall grasses close to human settlements which favor the survivor and abundance of mosquitoes .

The December-January months provide the favorable conditions for the excellent thrive of malaria spreading mosquitoes.

(b) June

June is off peak of long rains in Kilimanjaro region; it was observed that accumulated rain seems to be significantly associated with malaria outbreak.

During this period the ground still contains water, so it provides potential breeding sites for malaria vectors , also bushes and tall grasses provide resting places for malaria vectors soon after emergence from larval habitats and also shields them from being blown away by winds.

The matter is further complicated by the fact that in most third world countries, drainage systems, if any, are not well maintained and most of them are clogged and blocked providing perfect breeding sites for the malaria vectors.

(c) **August**

During this month, malaria outbreaks in Kilimanjaro are observed to be correlated to maximum temperature and Relative humidity as the maximum temperature offered a better R^2 compared to other weather parameters.

Weather parameters were not significantly related with other months of the year because there are other factors which contribute to the out break of epidemics. Epidemics may occur during complex emergency situations where normal malaria transmission might be exacerbated by sudden population movements and political instability. Also a neglect or breakdown in control activities may give previously controlled malaria the opportunity to re-emerge, leading to a subsequent increase in transmission. There has been a global resurgence of malaria over the past two decades. Reasons suggested include failure of malaria control programs, population redistribution and growth, changes in land use, increasing prevalence of drug and pesticide resistance, degradation of public health infrastructure, and climate variability and change (Githeko *et al.* 2001; Greenwood *et al.*, 2002).

MALARIA PREDICTION MODELS:

This model was developed using SYSTAT program so as to predict the outbreak of malaria .The models show strong association with the observed cases for the months of August and December for Same and Hai districts. While November and May prediction models showed close relation with the observed data for Same and Hai districts respectively. See figures below.

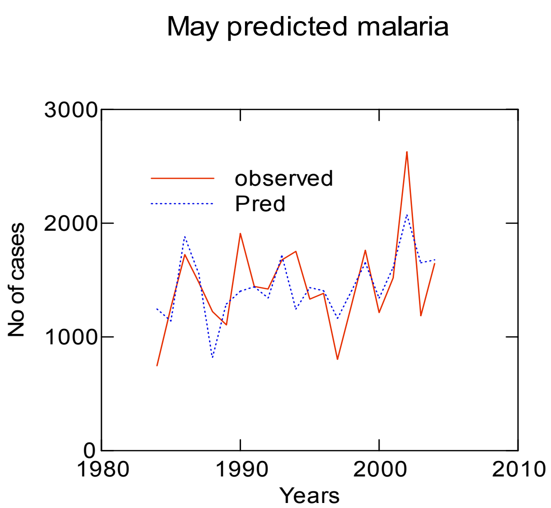

Figure: 4 (a) May Malaria prediction model in Hai district.

The model predicts well with 48% skill as showed by the regression equation below. The value of R is not as large as expected because malaria outbreaks are determined by number of factors rather than weather parameters.

Y=-735.17+0.949*Rain+23.6*T-max

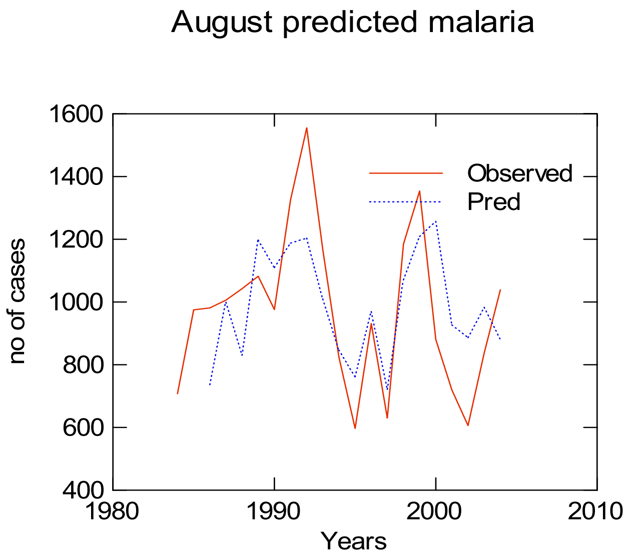

Figure: 4(b) .August prediction model in Hai district

The model predicts well with 53% as showed by the regression equation below. The value of R^2 is not as large as expected because malaria outbreaks are determined by number of factors rather than weather parameters. Rain, minimum temperature, temperature range and the cumulative rain plays major role in the malaria prediction model.

Y=1883.870-63.339*T-min-63.976*Range-0.42*Rain+0.142*Cum-rain

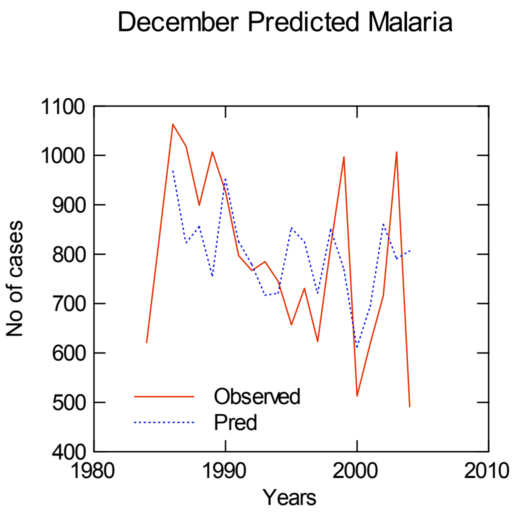

Figure: 4(c) December Malaria prediction model in Hai district.

The model seems to predict well with 45% as showed by the regression equation below. The cumulative rain plays major role in the malaria prediction model; this may be due to the fact that during this period the ground still contains water from the short rain which starts October and ends December in this region.

Y=170.203+1.089*Cum-rain

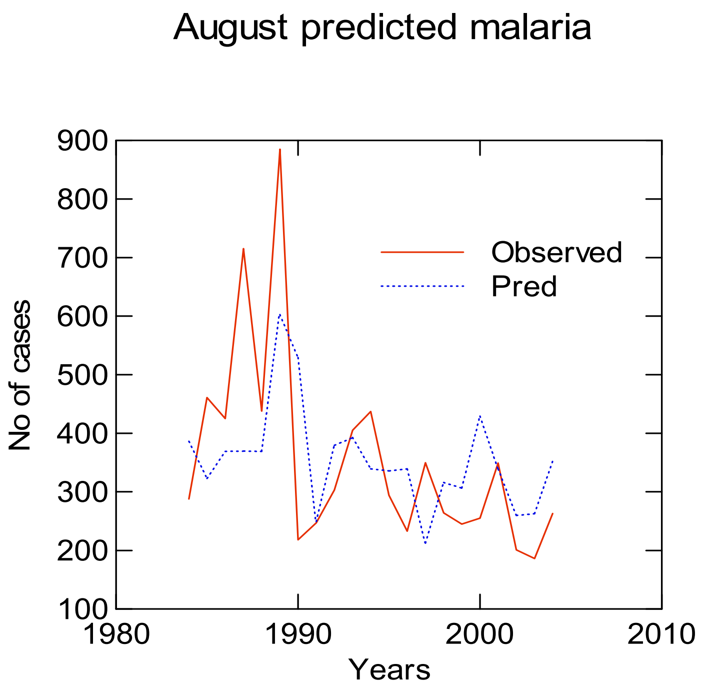

Figure: 5(a) August Malaria prediction model in Same district

The malaria prediction model predicts well with the 62% as offered by the value of $R^{2,}$ temperatures plays the major role in model prediction, this might be due to; feeding frequency of mosquitoes increases with temperature, resulting in increased proportions of infective mosquitoes the duration of the extrinsic phase of the parasite. The model equation is shown below.

Y=-667.461+1777*T-max-1761*Tmin-1751*Range +0.24

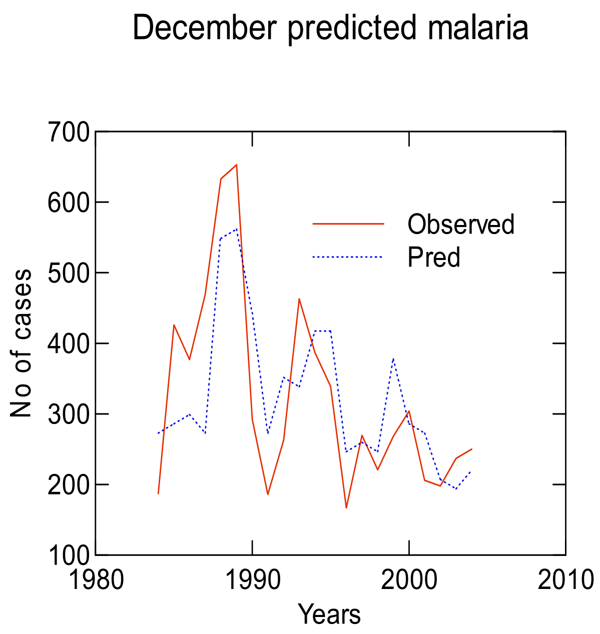

Figure: 5(b) December Malaria prediction model in Same district

The model seems to predict well with 57% as showed by the regression equation below. The temperatures and Relative humidity plays major role in the malaria prediction model; this may be due to the fact that .the place is very hot so people do not cover their bodies during the night also they spend more time outside waiting the place to be cooled, the situation is different from Hai district because this district is a bit lower in altitude.

Y=177.135+462*T-max-477.274*Tmin-455.992*Range+1.934*RH

CONCLUSION

Results from correlation analysis showed that, rainfall and temperature influenced malaria outbreaks more than relative humidity. Long rains (March, April, and May) had most significant coefficients. However, the significant correlation coefficient between malaria cases and rainfall in Hai district is a bit small compared to that in Same district. This suggests that other factors different from rainfall might have contributed to the outbreak of the malaria in Hai district.

There was small increasing in trend of cases, which indicates that the efforts made to control malaria epidemic in the region. From the time series plots years 1984 and1997 appeared to have the highest peaks in Hai district during the months of May for both years, while the years 2002 and 2004 showed the highest peaks in Same district during the months of March for both years. This may be due to facts, the government malaria control program fails also may be due to the increasing of the population over the area.

The malaria prediction model meets the criteria of a simple malaria epidemic prediction modal needing no special equipment or skills and so can be used by existing health personnel using readily available temperature and rainfall data of the meteorological stations throughout the country.

Malaria prediction model can be used since it meets simple criteria which can be used by health personnel for forecasting the epidemics.

SUGGESTIONS FOR FURTHER WORK

The development of capacity and mechanisms to incorporate climate variability and outlooks into the working plan of the Ministry of Health in Tanzania need to be undertaken. This will enhance in providing Malaria early warning System.

Further study for Malaria epidemic and weather parameter for the whole country is needed to be done so as to develop Malaria predication Model for the whole country.

In addition in order to have better research results, data keeping system should be improved in most hospitals.

REFERENCES

1. Githeko A.K., and Ndegwa W. (2001), ‘Predicting malaria epidemics in the Kenyan highlands using climate data: a tool for decision makers’, *Global Change and Human Health* 2, 54-63.
2. Kilian AH, Langi P, Talisuna A. Kabagambe G. (1999) Rainfall Pattern, El Nino and malaria in Uganda. Transactions of the Royal Society of Tropical Medicine and Hygiene, 93:22 –23.
3. Lindsay S.W., and Martens P. (1998), ‘Malaria in the African highlands: past, present and future’, *Bull. WHO* 76, 33-45
4. World Health Organization (WHO) (1996); Climate change and human health: A.J MC –Michael, A. Haines, R. Sloof and S. Kovats eds. Geneva.
5. World Health Organization (WHO) (2001), Fact sheet N’226
6. World Health Organization (WHO) (2003); Climate change and human health: Risks and Responses; A.J. MC Michael, D.H, Camphell, AK Githeko, eds. Geneva.
7. World Health Organization (WHO) (2003). The Africa Malaria Report.