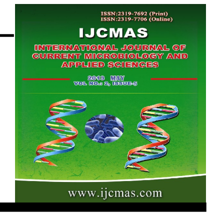
International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 2 Number 5 (2013) pp. 256-266**
http://www.ijcmas.com



Original Research Article

Influence of Climate Change on Malaria Incidence in Mahaboobnagar District of Andhra Pradesh, India

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A B S T R A C T

Keywords
Climatic variables; correlation; malaria incidence; Anopheles mosquitoes; Mahaboobnagar District.

Vector-borne diseases especially malaria is becoming most apprehend health problems in Mahaboobnagar district of Telangana region. Keeping in view that the climatic factors particularly temperature, rainfall and humidity may alter the distribution of vector species–increasing or decreasing the ranges, depending on weather conditions that are favourable for mosquito breeding, it is aimed to find out the effect of climatic factors on malaria incidence with particular emphasis to capture the essential events as a result of climatic variability. Mosquito sampling and identification was done using entomological methods (WHO) and follow-up of recognised keys and catalogues (1). Pearson's correlation analysis was applied for establishing relationship between climate variables and malaria transmission. Higher positive correlation of association was found between monthly parasite incidence and climatic variables. In this paper period of study is from January-2008 to December-2011. However, highest significant correlation was found between rainfall, humidity and malaria incidence are significant ($p < 0.001$) climate variables which are useful to predict the malaria incidences.

Introduction

Among vector-borne diseases, the malaria is influenced by seasonal or spatial changes in the environment. Climate has been established as an important determinant in the distribution of vectors and pathogens (Odetoyinbo,1969). In fact, the physical environment is an important modifier of local climate. Climate variability and the breeding activity of *Anopheles* are considered one of the important environmental contributors to malaria transmission. Gill (1921) assessed impacts of inter-annual and inter decadal climate variability of vector-borne disease on a continental basis with the aim of shedding light on the increased likelihood of climate change. As per their views the average global temperature with rise by 1–3.5°C, increases the likelihood of many vector-borne diseases in new areas. As the malaria vectors are poikilothermic, temperature is a critical variable in malaria epidemiology, For instance in the range of 18–26°C a change of only 1°C in temperature can change a mosquito's life span by more than a week (Jepson *et al*., 19474). Previously it was reported that the temperature of 20–30°C and humidity less than 60% are optimal for Anopheles to survive long enough to acquire and transmit the parasite (McMichael and Martens, 1995). According to the malaria transmission involves complex interaction between Plasmodium parasites, Anopheline mosquitoes and humans.

In the Nallamalla forest area of Mahaboobnagar district, the main vectors of malaria are *An.stephensi*, *An.culicifacius*, *Anopheles subpictus* and *An.fluviatilis*. For the last couple of years vector-borne diseases are becoming the most apprehend health problems in the state of Andhra Pradesh. Although many campaigns against these diseases have been conducted malaria is the major health problems in some of the area of Mahaboobnagar District particularly, Amrabad, Domalapenta, Lingal and Kollapur. Although, there have been few studies on the relationship between climatic variables and malaria rates in India, many studies have addressed the ways that other factors like urbanisation, irrigation, deforestation and agricultural practices have affected malaria rates (Reiter,2001).

Since no such study has been conducted in the forest area of Mahaboobnagar district, Andhra Pradesh, India, henceforth, it was decided to explore empirical relationship of primary climatic factors with the malaria incidence using Pearson's correlation analysis and to capture the essential events responsible for such variability.

Materials and Methods

Study area

The actual site selected for the present study is the forest area of Mahaboobnagar district, which geographically lies between 16°43'48''N and 77°58'48'' latitude, and 16°73'77''98 E longitude. The following four mandal area of the Mahaboobnagar district, Amrabad, Domalapenta, Lingal and Kollapur were chosen for recording climatic variables and malaria incidence (Text Figure 1).

Entomological data

Mosquito collection was done using oral aspirator and torch-light from both indoor and outdoor resting habitats during night hours (018:30–019:30 hrs) on fortnightly basis between January 2008 to December 2011. The collected mosquitoes were first narcotised, separated and sorted out genera wise and then identified as *Anopheles culicifacius*, *Anopheles fluviatalis*, *Anopheles subpictus* and *Anopheles stephensi*. Per man hour density (PMHD) of vector mosquitoes collected from every possible indoor habitats like human dwellings, cattle sheds and mixed dwellings was calculated by using the following formula:

$$PMHD = (N \times 60)/p \times t$$

n = Total no. of each mosquito species;
p = no. of persons involved during,
t = Time spent in mints.

Anopheles mosquitoes collected in mandal wise study areas of Mahaboobnagar district are shown in table-1.

Meteorological data

The data on monthly mean temperature, rainfall and humidity during the study period was obtained in a collaborative study with the Agro-Climate Centre Located at Agriculture Research Station (ARS),Rajendranagar, Rangareddy district.

Figure. 1 showing the study area in Mahaboobnagar District of Telangana Region of Andhra Pradesh, India

Parasitological data

Monthly parasite incidence is based upon epidemiological data for the years 2008–2011, obtained from the Additional Director, Directorate of Health, Hyderabad.

Data analysis

To examine the relationship between the monthly incidence of malaria cases and monthly mean temperature, monthly rainfall (in centimetres)and monthly mean relative humidity was done by applying Pearson's correlation analysis. A correlation of PMHD of vectors with malaria parasite incidence (MPI) and rainfall has also been developed to make the conclusion more informative.

Results and Discussion

Mosquito prevalence in the Mahaboobnagar district forest area

As many as four species of anopheline mosquitoes were collected during the study period. The collection includes both indoor and outdoor (Table-1). *An.culicifacius* was predominant species followed by *An.stephensi, An.subpictus, and An.fluviatalis*, in succession. The known primary vectors of malaria are *An.culicifacies, An.fluviatilis* and *An.stephensi* and *An.subpictus* constituted 41. 21% of the total anopheline population. Besides the anopheline mosquitoes other dominant groups in the collection belonged to *Cx.quinefasciatus* and *Ae.albopictus* (Diptera:Culicidae). Investigations made on the climate change and the resurgence of malaria in the Eastern Ghats (Nallamalla forest area) of Mahaboobnagar district Andhra Pradesh, if climate is not changed at the study sites, other changes must have been responsible for the observed increase in malaria (Hay *et al*., 2002).

Seasonal incidence of malaria in Mahaboobnagar 2008–2011

There was a remarkable high incidence of malaria in 2010 which showed a declining trend during the last three years and next successive one year. With regard to monthly variations in the incidence of malaria cases the peak seasons were monsoon and post-monsoon (July to October) (Figure 1). Although incidence occurred between May to November but during the winter months (November to February), it was almost negligible. high incidence in 2008 and 2011, the monsoon and post-monsoon (July to October) peak was more pronounced as compared to other years.

Correlation between climatic variables and monthly incidence of malaria

Pearson's correlation analysis was conducted relating to monthly incidence of malaria vs. monthly climatic measures (temperature, rainfall and relative humidity) following different lagged periods (Figure 2). All the variables showed positive correlation with the monthly incidence of malaria. Average temperature and rainfall showed consistently stronger correlation with a one month time lag. Less correlation was found with lags of pre-monsoon. In case of average temperature, highest correlation was found with two-month period lag. All correlation between relative humidity and monthly incidence of malaria with different lag periods were very low. But highest correlation was found during monsoon period lag, 0.091 in 18:30 hrs and 0.656 in 18:30 hrs.

Relative humidity (RH)h=633 of 18:30 hrs showed more positive relation with malaria incidence. On the basis of correlation analysis, highest significant correlation was found between rainfall and malaria incidence ($r = 0.473$; $p < 0.0001$) when the data were staggered to allow a lag of one-month. When the data of monthly rainfall, vector density and monthly parasite incidence were plotted, the rainfall was found highly seasonal with maximum in July and almost no rain between November and December (Figure 1). Although malaria cases were seemed to be prevalent throughout the years, higher incidence of malaria cases was mostly found during August and September. When rainfall was more, higher numbers of malaria cases were recorded.

At some points there was a slight change, which may be due to other factors. As far as the vector density is concerned, there was a shoot up in the PMHD of vectors with corresponding increase in rainfall and MPI. In general, it can be mentioned here that PMHD of vectors showed a direct relationship to rainfall and MPI. Both the MPI and rainfall data showed statistically positive correlation with PMHD($r = 0.473$;

$p > 0.001$ and $h = 0.656$; $p < 0.0001$) of vectors.

Table. 1 Anopheles mosquitoes collected weekly random sampling at 18:30hours to 19:30 hours from different habitats of study areas in Mahaboobnagar District, India

Name of the species	Amrabad		Lingal		Domalapenta		Kollapur		Total area		p-value
	Out door	In door	Out door	In door	Out door	In door	Out door	In door	Out door	In door	
An.fluviatalis	53±3.6	50±1.3	56±2.1	46±2.1	55±2.7	48±2.5	53±2.2	52±2.1	217±1.5	196 ±2.5	<0.001*
An. stephensi	51±1.3	49±2.2	58±2.1	47±2.2	54±2.3	45±2.2	51±1.7	49±2.2	214±3.3	190±1.9	<0.001*
An .subpictucs	50±1.3	46±2.1	55±1.7	44±1.4	51±1.7	50±2.3	52±2.1	48±2.1	208±2.1	188±2.5	<0.001*
An.culicifacies	47±1.7	47±1.7	55±1.7	42±1.7	48±2.1	49±1.7	55±1.7	52±2.1	212±4.3	191±4.2	<0.001*

Figure.1 Showing correlation Between Monthly rainfall, average temperature, humidity and parasite incidences in Mahaboobnagar during 2008–2011.

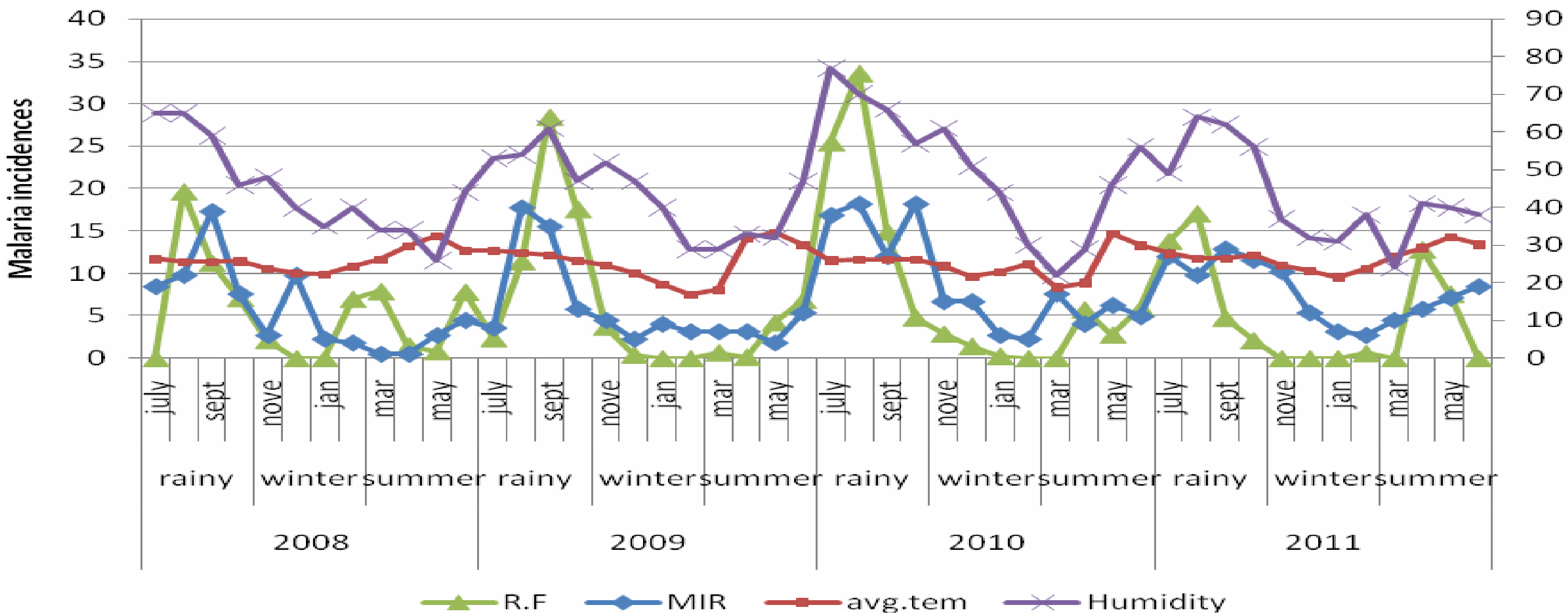
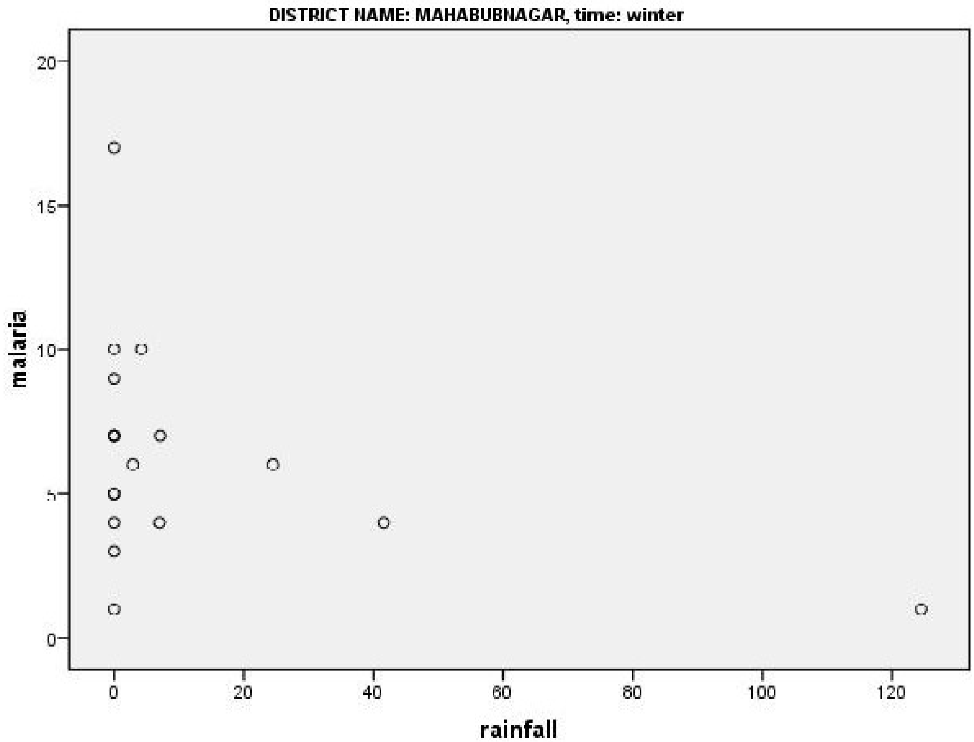
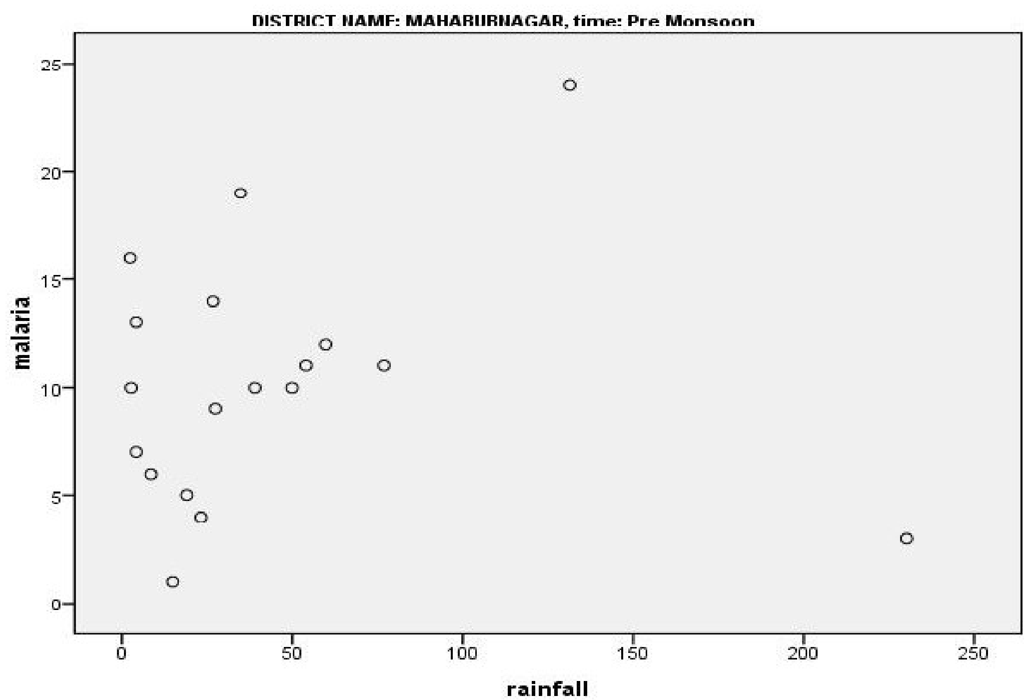
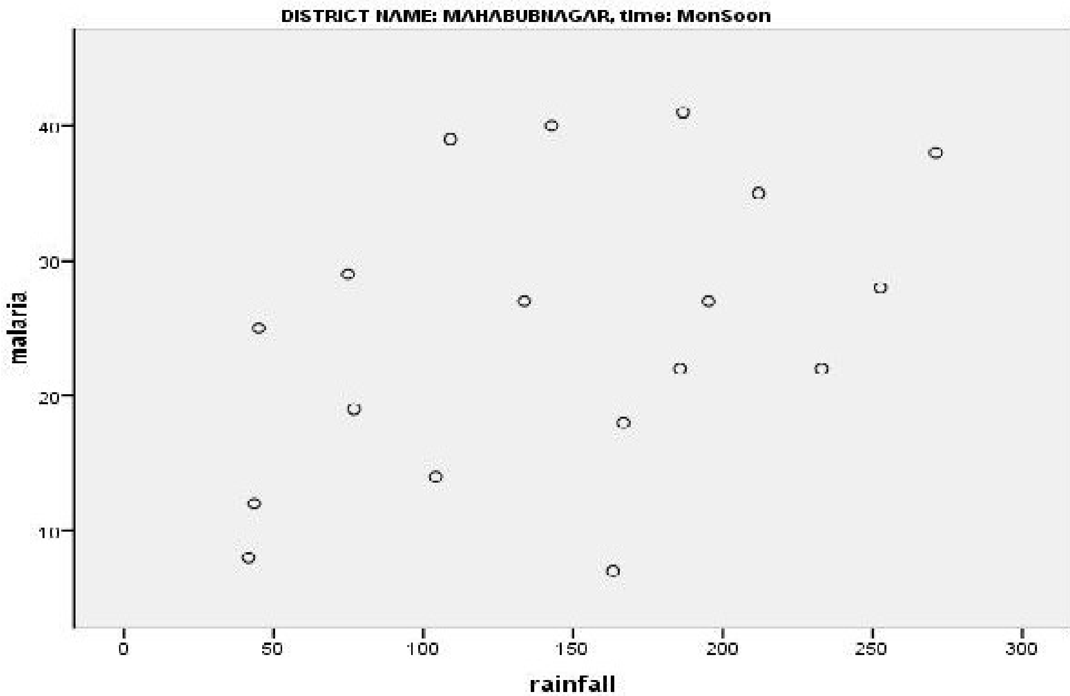


Figure.2 Correlation between climatic variables and monthly parasite incidence of malaria in the study area



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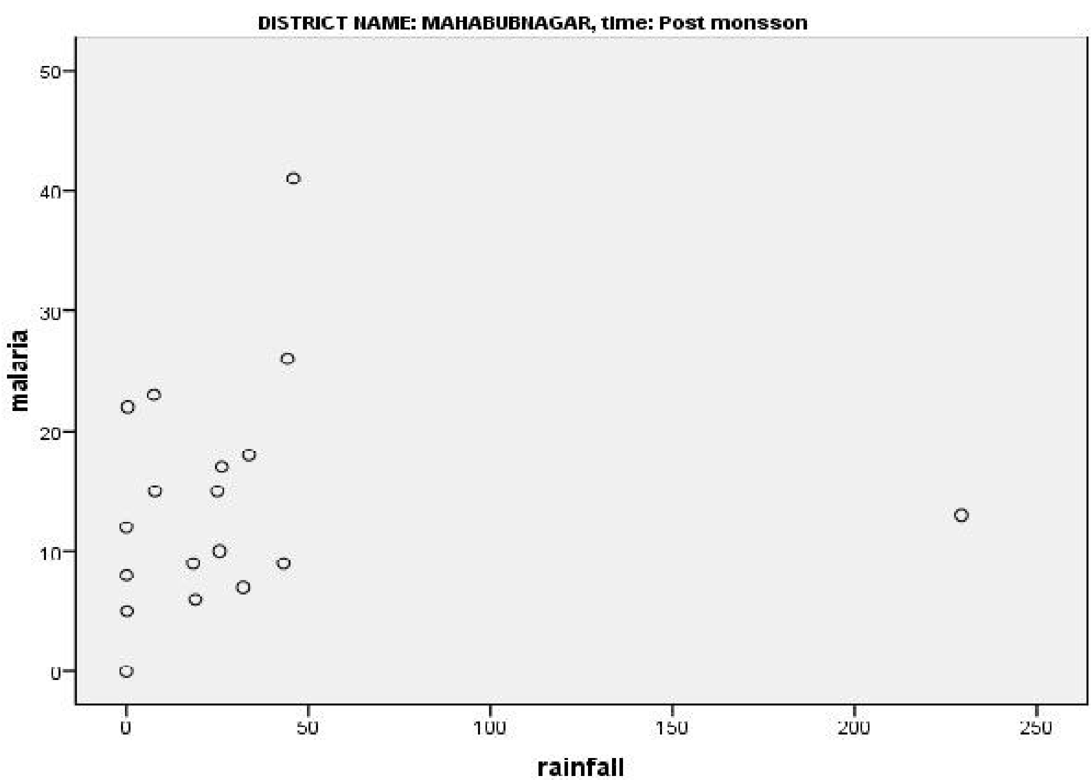
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The transmission of malaria is determined by climatic, non climatic and biological factors. The climatic factors include all the independent variables like temperature, rainfall, humidity, etc. while the non climatic factors are human activities, socio-economic conditions like developmental changes, housing and living conditions, adopted control measures, local ecological environment (vegetation, introduction of irrigation schemes) and drug resistance in malaria parasites. The biological factors comprise abundance of *Anopheles* species, the propensity and frequency of the mosquitoes to bite human beings, its susceptibility to the parasite, the longevity of mosquitoes, the rate at which the parasite develops in mosquitoes, aquatic stages of immature, etc. that are dependent on independent climatic variables(14). It is already mentioned that climatic variables exhibit impact on the incubation rate of *Plasmodium* parasites and the breeding of *Anopheles* (Reiter, 2001; Singh *et al.*, 1994; Christopher's,1993) and thus considered as the important environmental contributors to malaria transmission (Reiter, 2001).

The present study shows higher positive correlation between monthly incidence of malaria and monthly average temperature and rainfall with a one-month lag effect. The correlation coefficient for the association between monthly rainfall and monthly incidence of malaria was found greater than that for the association between temperature and malaria incidence. This indicates that rainfall seems to play a more important role in the transmission of the disease than temperature does. Several works from different places (Gupta, 1996; Greenwood and Pickering 1993; Ramasamy *et al.*, 1992) found the same results. Moreover, it has been previously shown that a strong positive association exists between the incidence of *plasmodium falciparum* malaria and rainfall (Gupta, 1996). Rainfall plays an important role in malaria epidemiology because water not only provides the medium for the aquatic stages of the mosquito's life but also increases the relative humidity and thereby the longevity of the adult mosquitoes (Gill, 1921).

The impact of rainfall on the transmission of malaria is very complicated, varying with the circumstances of a particular geographic region and depending on the local habits of mosquitoes. Rains may prove beneficial to mosquito breeding if it is moderate, but may destroy breeding sites and flush out the mosquito larvae when it is excessive (Gill, 1921). The authors agree with this statement and in particular with establishment of an interrelationship between climatic variability and breeding of anophelines. The study reveals highest correlation between rain- fall and malaria with a lag of one-month. Estimates for the duration of lag period include 15 days for the pre-imaginable development of vector *Anopheles* 4–7 days for the gonadotrophic cycle for porous/nulliparous female mosquitoes and 12 days for the sporogonic cycle for the *Plasmodium falciparum* parasites in the vector mosquitoes (Peng *et al.*, 2003).

In fact about 29 days are needed for the development of a new generation of infective female insect vectors. Many processes get accomplished between the onset of rains and appearance of malaria cases. After a heavy rain, there is a possibility for water to recede so as to provide new breeding sites. Further, time is needed for larvae to hatch, mature pupae and form adults, for the adult female to find an infected host and become infected itself and for completion of sporogonic development of malaria parasite within the vector. Additional time may be required for the infected mosquito to bite an uninfected host. Our findings in respect of one month lag effect are supported by earlier studies of Prakash *et al.,* (1997) who observed a two-week time lag between rainfall and vector abundance in a forest-fringed villages of Mahaboobnagar.

The authors also agree to the fact that rainfall also increases the rate at which humans were bitten (Onori and Grab, 1980). In the dry zone of Andhra Pradesh, two-month time lag between rainfall and increased malaria was observed (Vander Hoek *et al*., 1997). However, Vanderwal and Paulton (Vanderwal and Paulton) found strongest correlation for a time lag of 9–11weeks between rainfall and malaria. Due to the nature of biological processes and the degree to which they depend on such physical factors as altitude, topography, temperature, surface water, vegetation and humidity (Woube,1997), it seems probable that the time lag between rainfall and malaria would be somewhat region specific. Peng *et al.,* (1996) reported highest positive correlation between monthly incidence of malaria and monthly average temperature with a one-month lag effect.

A rise in temperature, especially temperature, would, in some locations, enhance the survival chances of *Plasmodium* and *Anopheles* during winter and thus accelerates the transmission dynamics of malaria and spread it into populations that are currently malaria-free and immunologically negative. If annual parasitic index (API) or monthly parasitic index (MPI) are directly related to climate, it should be possible to predict malaria outbreak before its occurrence, either to strengthen control measures enough to prevent the outbreaks or at least to create adequate facilities for the appropriate treatments. As long-term weather forecasting becomes more accurate, it may even be possible to forecast the weather that might trigger an outbreak (Bouma *et al*., 1996).

Rainfall provides the breeding sites for mosquitoes and increases relative humidity necessary for mosquito survival, leading to increase in the number of mosquitoes biting an individual per unit time, the human biting rate (Onori and Grab, 1980; Mahmood and McDonald, 1985; Lindsay and Martens, 1998). The authors are of the opinion that without sufficient rainfall or water collections mosquitoes cannot proliferate and infect humans. Although malaria cases usually occur after periods of heavy rainfall, excessive rainfall does not always trigger an epidemic (Robert W. Suthers) conclusively, the climatic variables that predict the presence or absence of malaria are likely to be best suited for forecasting the distribution of this disease at the edges of its range. However, the transmission of malaria is very complicated and detailed ecological and epidemiological studies are still needed to assess the true local risk factors.

Acknowledgement

The Additional Director, Directorate of Health (F&M), Hyderabad. Agriculture Research Station (ARS) Agro-climate centre (ARC) Rajendranagar for providing relevant data on climatic factors of Mahaboobnagar. The financial assistance rendered by UGC-BSR, New Delhi, India is gratefully acknowledged.

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