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A correlation Analysis among Malaria Infection and Climatic Factors in Kass, South Darfur-Sudan

Hussien Eltom Hassan, Yong Bin

Abstract— Malaria has been endemic in Sudan within the South Darfur region over the past years, particularly in Kass district with a maximum prevalence within the current years. Climatic elements, inclusive of rainfall, temperature and relative humidity in Kass had been particular in comparison to other in South Darfur state in addition to other parts of Sudan. Therefore the objective of this work become to examine the correlation between malaria prevalence and climatic factors in Kass, to be able to seek the specific interventions for malaria manipulate. The climate and malaria data throughout 2005-2008 in Kass district had been studied to examine the statistical relationship among climatic records and malaria prevalence data. The correlation among malaria prevalence and climate factors had been analyzed the using of numerous statistical techniques. The spearman correlation analysis was carried out to study the Interconnection between monthly malaria prevalence data and climate. Cross-correlation analysis of monthly malaria prevalence series and monthly climatic data discovered the time lag(s). Climatic factors were highly influential roles in malaria transmission particularly in Kass district. Spearman correlation analysis demonstrated that positive monthly rainfall correlated to monthly malaria infection ($r = 0.915$, $P < 0.001$). Monthly relative humidity positively correlated with monthly malaria infection ($r = 0.727$, $P < 0.001$). Positive correlation between malaria infection and maximum and minimum temperature ($r = 0.640, 0.621$, $P < 0.001$). Climatic variables were highly influential roles in malaria transmission particularly in Kass district. Rainfall became have a bearing on factors, which affected the mosquito lifestyles without delay. The relationship among malaria prevalence and relative humidity turned into additionally strongly affected component.

Index Terms— Correlation, malaria, infection, climatic factors, endemic, transmission, spearman correlation.

1 Introduction

Malaria is one of the most excessive infectious diseases which can be seriously dangerous to health, specifically in border regions of western Sudan. Consistent with the report of countrywide surveillance project [1], [2], malaria became risky and fluctuated in intensity both spatially and temporally, in Sudan. South Darfur is located within the western part of the Sudan shares borders with Republic of South Sudan and The republic of central Africa, and Kass district locates in the north of South Darfur.

Completion of 4494 malaria instances were reported from South Darfur from 2005 to 2008, generally because of Plasmodium Falciparum, and 1914 of those cases (43%) were from Kass district. In recent years, the malaria prevalence of Kass was higher in the country due to its small population approximately 281165 people. The transmission and the incidence of malaria are encouraged by means of many factors, among which (variability in) climatic factors are taken into consideration to play a chief role.

With growing climate variability and capability to forecast weather, there is an interest in developing systems or malaria forecasting that include climate associated factors as explanatory variables. Many researches [3], [4] in diverse parts of the world had related to malaria time series to climates including rainfall, temperature and humidity.

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For example, malaria became related to rainfall and minimum temperature (with the strength of the affiliation vary with altitude) in Ethiopia via the use of polynomial disbursed lag models. Rainfall and maximum temperature to efficiently match the transmission model to malaria case in a district in Zimbabwe. The monthly variations in malaria were related to rainfall, humidity and temperature in Burundi [5].

However, others did no longer find out a strong or an obvious relationship. A examine in Mozambique combine rainfall as a linear or nonlinear interpretive variable fully convenient into a seasonal auto-regressive integrated moving average (ARIMA) model. The model confirmed a modicum refinement in malaria forecasting without a rainfall predictor [Modelling the influence of climate on malaria occurrence in Chimoio Municipality Mozambique].

Climate impacts the malaria prevalence commonly through its effects on each the mosquito vector and the improvement of the malaria parasite in the mosquito vector. Kass is under a semi-humid tropical climate with masses of sunshine and rainfall. The various landscape patterns and weather conditions provide favorable breeding area for mosquitoes [6], [7], [8].

Considering the special feature of climate factors in Kass with higher malaria prevalence, it could be the climate factors play an important function in malaria transmission. In this study, the relationship among climate factors and malaria prevalence in Kass was examined. A good knowledge of the relationship may additionally contribute to enhance forecasting of modifications in malaria prevalence, which could shed light to public health authorities on the way to efficiently distribute resources for malaria control programs on the country wide and provincial stage.

2 METHODS

2.1 Studr area

Kass locates in the north part of South Darfur state as shown in Figure 1. The population of the Kass estimated to 281165 by the end of 2008 (data from South Darfur Bureau of Statistics). Kass has a tropical climate with plenty of sunshine and rainfall, and near Jabal Marra Mountains which has multi climate.

Kass is situated at 23° 41' -24° 52' East and 11°08'-13°08' north, The altitude of the mountainous county ranges between 900 and 3,100 m (mean: 2,000 m). In addition most villages can only be reached by foot. According to the undulation of ground, almost all the malaria patients are scattered all over the district.

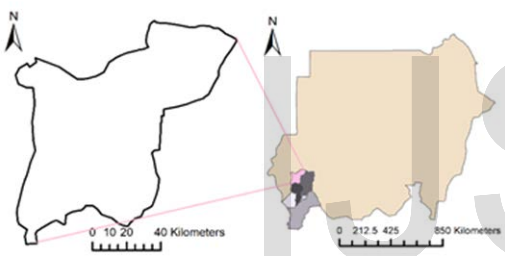

Fig. 1. The location of Kass district.

2.2 Data collection

Data on malaria were discovered in the Neglected and Tropical Diseases Nyala Office, South Darfur state of Sudan. The monthly data of examined blood for malaria has been obtained. Data were developed and combined for the years 2005-2008. Population for the district was gained from Nyala Bureau of Statistics. It took for granted that each resident in Kass was in danger for malaria infection.

Monthly rainfall, relative humidity, maximum temperature, and minimum temperature from 2005 to 2008 in Kass were obtained from Nyala Meteorological Data Office. Rainfall and temperature variables are taken in millimeters (mm) and centigrade (C) respectively. Data analysis the monthly prevalence of malaria in Kass classified under a dependent variable, and climate data including monthly rainfall, relative humidity, and temperature have been independent variables.

The statistical relationship among climate records and malaria incidence over the duration 2005-2008 in Kass was studied. The analyses have been made in two aspects: Spearman correlation analysis and cross correlation analysis. Since there should be a possible correlation between malaria incidence and the climatic variables through time, a seasonal auto-regressive integrated moving average (SARIMA) model had been compared on the monthly time series analysis of malaria infection data.

Spearman correlation evaluation changed into accomplished to examine the association between monthly malaria prevalence and climatic factors the usage of EVIEWS software (version 9.5, IHS global Inc.). Correlations among the monthly malaria prevalence and climatic data had been studied to discover the time lag(s) of climatic factors, previous malaria at which the series confirmed the correlation. Malaria infection time series confirmed strong long term inconstancy in Kass.

However, in rainfall, relative humidity and, temperature, those long time inconstancy had been absent. Therefore, it became predicted that climate factors couldn't give an explanation for the long time inconstancy in malaria, which had been possibly related to other factors, inclusive of malaria management measures, socioeconomics, and population changes.

Those inconstancy concealing the correlation among malaria and climate variables and due to the fact no records at the underlying factors become available within the data. The long-term period inconstancy needed to be eliminated previous to calculate cross-correlations. It was supposed that monthly malaria prevalence follows a seasonal model of form:

$$\gamma_t = m_t + s_t + \varepsilon_t \qquad (1)$$

Where m_t is the mean level in month t, s is the seasonal effect in month t; and ε_t is the Gaussian random error.

The long-term variation m in the monthly malaria incidence series were calculated using a 13-point centered smoothing filter with the months at the excessive given half weight:

$$m_t = (0.5\gamma_{t-6} + \gamma_{t-5} + ... + \gamma_{t+5} + \gamma_{t+6}) / 2 \qquad (2)$$

Smoothing become performed. From the de-trended collection $\xi_t = \lambda_t - m_t$, implicitly long term developments have been removed. Cross-correlation evaluation become applied to the de trended malaria occurrence series and positive climatic variable time series x_t. The cross correlation become predicted for malaria at a lag l of 12 months at the back of rainfall as:

$$r_l = \sum_{t=1}^{N} (x_t - \bar{x})(\xi_{t+1} - \bar{\xi}) / N s_x s_\xi \qquad (3)$$

Where s_x, s_ξ are the sample standard deviations of observations on x_t and ξ_t respectively.

The cross-correlation have become calculated due to the fact the average *t* over all months, and feasible variable correlation relying on the season become no longer considered i.e. if rainfall had a strong advantageous impact on malaria in a few months, and a strong negative in others, the average detected cross-correlation might be vulnerable. Despite the fact that the above technique may additionally discover strong correlations, these may not be very useful for malaria prediction if deviation from the long term seasonal mean of rainfall have been weakly associated with deviation from the long-term seasonal mean of the malaria case. Further, the standard cross-correlation assumes observations were independent, at the same time as in reality the malaria statistics have been correlated.

3 Results

There has been a significant annual variation in rainfall, however an extra or much less comparable seasonal pattern, with at the least 5mm within the year (2008) and a maximum of 91mm within the year (2005) (Figure 2). Changes in temperature and humidity had a seasonal pattern in the course of the year, which changed into followed by means of a growing trend in the duration of the years of study. As indicated in Fig. 3. The average maximum peak temperature expanded over time. But, the peak average minimum temperature reduced at some stage in this time. Change of humidity additionally observed a seasonal trend. But, in contrast to changes in temperature, changes in humidity have been no longer regular. Figure 4 suggests the changes that happened throughout the study duration.

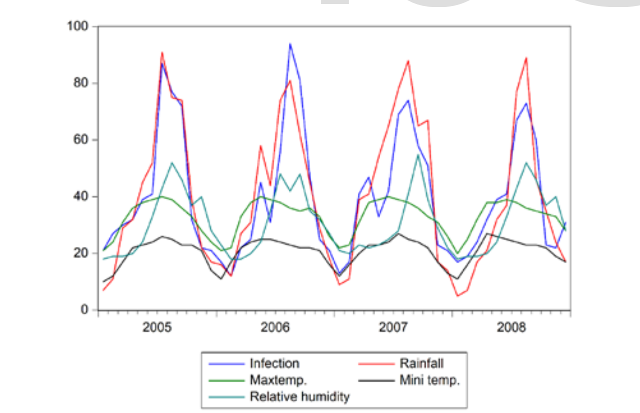

Fig. 2. Monthly malaria case count, rainfall and maximum temperature (°C), minimum temperature (°C), and relative humidity (%) in Kass, years (2005–2008)

Table 1 display the spearman correlation analyses have been achieved referring to monthly malaria prevalence to monthly climatic variable. The monthly rainfall, relative humidity, maximum and minimum temperature, have been notably high correlated with recurrent malaria prevalence over the observed period. Among the climatic variables, monthly rainfall became significant highly correlated to monthly malaria prevalence (r = 0.915, P <0.001). In addition to the monthly

TABLE 1 Spearman correlations between malaria infection and climatic variables

	INFECT	RAIN	MAX_TEMP	MINI_TEMP	R_HUM
INFECT	1.000000				
RAIN	0.915944*	1.000000			
MAX_TEMP	0.640894*	0.754626*	1.000000		
MINI_TEMP	0.621864*	0.727788*	0.943603*	1.000000	
R_HUM	0.727134*	0.723681*	0.453453*	0.476513*	1.000000

** = P < 0.001.*

relative humidity became relatively correlated with monthly malaria prevalence (r = 0.727, P < 0.001). There has been intimately correlation between different temperature variables. The correlation between malaria infection and maximum and minimum temperature is also has a high correlation (r =0.640, 0.621, P < 0.001).

Fig 3 shows the cross correlation between malaria infection and climatic variables. The crest coefficient of correlation between malaria infection and rainfall is higher than 0.8. The crest coefficient of correlation among malaria infection and the humidity and temperature is less than 0.8

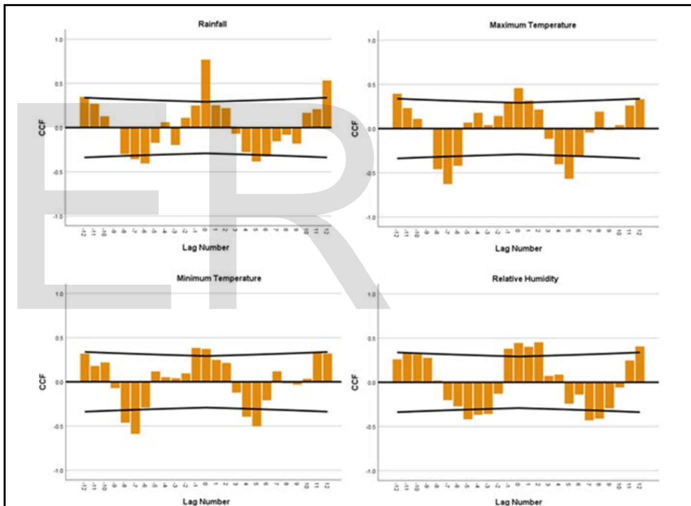

Fig. 3. The cross correlation between malaria infection and climatic variables

4 Discussions

Variations in annual incidences indicated that certain factors rather than organic characteristics of parasites decide the transmission of the diseases. Numerous factors, which include vector species and abundance, human behavior, population immunity, socio-economic repute and management measures, are known to have considerable impact on the transmission of malaria [9]. Climate variables are viewed, because the environmental factors for accelerated risk of malaria impacts on the plasmodium incubation rate and mosquito vector activities [10], [11]. Spearman correlation was done relating monthly malaria infections to numerous periodic climatic factors.

From table 1, it may be determined that climate variables, consisting of rainfall, relative humidity, and temperatures. In other hand malaria infection confirmed strong effective significant correlations against most of the climatic factors. Rainfall and malaria infection showed a highly significant correlation (0.915, P < 0.001). The correlation coefficient among maximum and minimum temperature against malaria infection became (0.641, P < 0.001), (0.622, P < 0.001) respectively. It was reasonable to deduce that temperature has an impact on the activities of the mosquitos, which indicates breeding and biting rates. Furthermore, relative humidity has a highly significant correlation with malaria infection (0.727, P <0.001).

Relative humidity turned into closely correlated with temperatures and rainfall. And it put an end result of temperatures, rainfall and different environmental factors. It has been investigated that rainfall and temperature played a determinant role of environmental factors within the transmission of malaria disease. However, the influence was not directly or linearly. Nevertheless, rainfall and temperature won't have direct effect on the transmission of malaria. In particular the rainfall factor influencing malaria transmission because of extra complicated manners. Rainfall regularly leaded to ponds and jungle which serving as mosquito breeding sites and will increase humidity.

Malaria infection time series and climatic factors have excessive cross-correlation. Positive maximum cross-correlation became observed between malaria infection and rainfall. But this was discovered among malaria and temperature at a lag of months. Although malaria infection and climatic factors confirmed high cross-correlations in Kass district, and consequently climatic factors might also be used for predicting malaria incidence.

This study showed that climatic factors had an extraordinary affection with malaria responses fast while the factors still varying. The correlation coefficient between monthly malaria infections and monthly rainfall changed into the correlation between malaria infection and temperature. It is further meant that malaria prevalence became at risk of temperature changes. It is able to be interpreted that rainfall also has an effect on the lifestyle cycle of the mosquito and behavior of biting humans. Nevertheless, the correlation between malaria infection and humidity is equally high and significant. Those findings are examined in in future while dealing with malaria prevalence and management tasks for improving malaria transmission models in Kass district. The malaria elimination plan for the health authorities in such situation is required in South Darfur state.

Figure 4 Shows the result appear to be highly statistically significant (based on p-values/t-stats). The R-squared value is rather high, results inspire that around 80.96% of the variation in log (m1) can be illustrated by the other variables in the model. Commonly this might inspire a very good fit for the model. The results with high R-squared does not necessarily inspire that the model is definitely good or informative. The residuals of this regression appear to have long periods of positive values followed by long periods of negative values, providing strong visual evidence of serial correlation.

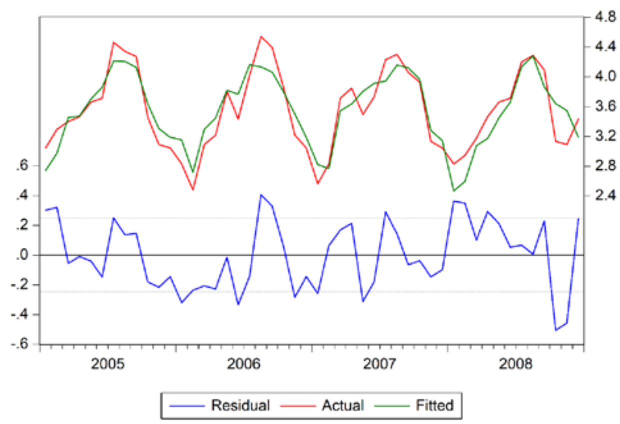

Fig. 4. Monthly malaria case count, rainfall and maximum temperature (°C), minimum temperature (°C), and relative humidity (%) in Kass, years (2005–2008)

4 Conclusion

Climatic variables were highly influential roles in malaria transmission particularly in Kass district. Monthly rainfall correlated to monthly malaria prevalence (r = 0.915, P <0.001). Monthly relative humidity correlated with monthly malaria prevalence (r = 0.727, P < 0.001). Correlation between malaria infection and maximum and minimum temperature (r =0.640, 0.621, P < 0.001). Rainfall became have a bearing on factors, which affected the mosquito lifestyles without delay. The relationship among malaria prevalence and relative humidity turned into additionally strongly affected component. Annual various consequences, of climatic factors like rainfall and relative humidity perhaps employed expecting malaria.

5 C Acknowledgments

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