RELATIONSHIP BETWEEN MALARIA CASES AND WEATHER PARAMETERS OVER MOROGORO MUNICIPALITY

A POSTGRADUATE DIPLOMA RESEARCH PROJECT

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RELATIONSHIP BETWEEN MALARIA CASES AND WEATHER PARAMETER

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DECLARATION

This research project is my original work and has not been presented for a degree in any other University.

Signature…………………………… Date………………………….

AHMAD ATHUMAN

REG. NO: I45/84333/2012

This research project has been submitted with our approval as University Supervisors.

Signature………………………… Date………………………….

Prof. J.M ININDA

Signature……………………………… Date……………………………..

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ABSTRACT

The study examined the influence of weather parameters on malaria outbreaks over Morogoro Municipality. It is well established that malaria is the leading health problem in Tanzania where it accounts for the most outpatients and inpatients hospital attendances and is among the leading causes of hospital deaths for all ages in the country, and the most vulnerable groups are children under five years and pregnant women.

In Morogoro Municipality malaria cases increase during the month of February to May and to a less extent during November to December. Thus the relationship between malaria cases and weather parameters was investigated by applying single mass curve, time series analysis, simple linear regression, multiple linear regression and error analysis.

Monthly data for malaria cases from 2007 to 2011 was compared with monthly rainfall, maximum and minimum temperature and relative humidity at 0300Z, 0600Z, 0900Z and 1500Z in order to determine whether malaria epidemics are related with weather parameter as well as to verify if such relation can be used to predict malaria outbreaks.

Results indicated that malaria cases prevailed throughout the year and high peaks were reported from February to May and November to December period. Also time series analysis of both malaria cases and weather parameters were increasing from February to May and November to December period. This attributed to the coinciding highest peaks of malaria cases and rainfall, minimum temperature and relative humidity in April and December and lowest peak during the month of July.

Simple linear regression showed strong positive relationship as indicated by coefficient of determination, rainfall (65%), maximum temperature (13%) and minimum temperature (50%) respectively. Relative humidity showed a coefficient of determination of 18% at 0300Z, 45% at 0600Z, 29% at 0900Z and 41% at 1500Z.

Prediction model was based on multiple regression analysis. Graphical presentations indicated that the model performed well. Its accuracy assessment showed that model deviate little from the mean malaria cases.

Also the study noted that five years data was very short to show the accuracy of the model and thus further researches should be done using data of many years. Moreover, data from private hospitals should be included in model development.

The relationship observed between malaria cases and weather parameters is the challenge for health sector in Tanzania. More studies need to be done to come up with many strategies that can eradicate malaria over Morogoro Municipality.

DEDICATION

I would like to dedicate this work to the memory of my late mother Khadija Athuman who untimely died on 2008. She was beloved mother and I shall miss her. Also my dedication should go to my beloved wife Rahma Ramadhan and my brothers Ashir Athuman, Ghanim Athuman and Windoumi Siao for unique support and encouragement they gave to me during my studies.

ACKNOWLEDGEMENT

I would like to acknowledge the almighty GOD for giving me the opportunity, strength, ability and good health to carry out this research and my entire studies.

I wish to express my sincere gratitude to my supervisors Professor Joseph Mwalichi Ininda and Dr. Christopher Oludhe inculcating in me the spirit of hard work. As my supervisors, their tireless mentorship and valuable discussion made it possible to complete this work. In fact it was moving experience to work with them.

Special thanks go to Tanzania Meteorological Agency (TMA) for financing my studies and providing me meteorological data that was used in this study. Also medical officers over Morogoro Municipality whom provided me data for malaria cases reported.

Special thanks are to the entire academic and technical staff at the department of meteorology at the University of Nairobi for their continued support throughout the study.

I extend my special gratitude to Mr. Joshua Ngaina, my roommate's Juma Hamis and Kapakala Isaya for their assistant and strong opinions which encouraged me to accomplish this study in time.

MAY GOD BLESS YOU ALL

AHMAD ATHUMAN

UNIVERSITY OF NAIROBI

AUGUST 2013

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LIST OF ACRONYMS

MAM………………………….. March- April- May

OND………………….......... October- November- December

RBCs……………………..… Red Blood Cells

TMA………………………... Tanzania Meteorological Agency

URT………………………… United Republic of Tanzania

SYSTAT……………………. System Statistics

CHAPTER ONE

1.0 INTRODUCTION

Malaria is one of the killer diseases especially in the tropics. This chapter discusses the background of malaria, problem statement and objectives of the study will also be provided.

1.1Background Information

Malaria is a disease caused by *Plasmodium falciparum* parasite that is transmitted by mosquitoes. It is a disease that affects millions of people mainly in the tropical region. About 90% of the reported malaria cases worldwide come from Africa. There are several species of anopheles mosquitoes that transmit malaria in Africa, and these are namely *Anopheles gambiae* and *Anopheles funestus*. But *Anopheles gambiae* is the most efficient vector transmission of malaria and more than 90% of its blood meals are from human being, thus optimizing the chance of transmitting the malaria parasite. In addition parasites *Plasmodium falciparum* is transmitted to humans through the bite of these female mosquitoes (i.e. *Anopheles gambiae)*. The disease is associated with fever, headache, chills, shivering and loss of appetite, vomiting, general body weakness and joint pains (Githeko, 2009; Makundi *et al*, 2006).

The mosquitoes require stagnant water to lay their eggs. Due to that rainfall is associated with undergoing change and development of malaria vector population and spread of the disease. So malaria vector increase during the onset of rainy season because vector breeding sites are not flushed out during the end of rainfall season. Also temperature and relative humidity plays a major part in the life cycle of the malaria vector which favors development of the parasite within the mosquito and the daily survival of the vector. On other hand low temperature and relative humidity shortens life span of the mosquitoes. (Yazoumé *et al*, 2007).

In Tanzania malaria is the leading health problem where it accounts for the most outpatients and inpatients hospital attendances and is among the leading causes of hospital deaths for all ages in the country, and the most vulnerable groups are children under five years and pregnant women. Normally malaria cases increase during the rainy season. For Morogoro municipality this situation occurs during the months of March to May (MAM) and to a less extent during October to December (OND) when the area receives long rains and short rains seasons. (Msemo, 2010; Makundi *et al*, 2006).

Morogoro region is situated south eastern part of Tanzania and is an area with holoendemic malaria transmission with seasonal peak. Apart from Uluguru mountain ranges other areas are very flat with a high risk of standing water during the rainy season which provides breeding sites for mosquitoes.

Furthermore recent wet years occurred in Morogoro include 2007, 2009, 2010 and 2011. During these years rainfall were above normal that caused floods to southern parts of Morogoro region. For example in 2007 there was narrow flood in Magombera village in Kilombero district. Also in December 2009 and January 2010, very heavy rains were experienced in Morogoro region which resulted to flood in Kilosa district. Thus heavy rainfall and floods increase the spreading of insect-borne diseases such as malaria (URT profile, 2011).

Malaria epidemics occur when weather conditions favor this vector borne disease, and the highest peaks of malaria cases in Morogoro Municipality occurred in long rainfall seasons on April and in short rainfall on month of December.

Therefore the purpose of this study was to investigate the relationship between malaria cases and weather parameters over Morogoro.

1.2 Problem statement

Malaria outbreak leads to increased rate of morbidity and mortality. This occurs mostly in children under five years, pregnant women and their new born because of their weaker immune systems. While the majority of healthy adults bitten up twice a day by malarial mosquitoes during rainy season and withstand the malaria parasite many children are hospitalized. Furthermore insecticide in the vector is still a problem in Morogoro Municipality during rainy season. On other hand sudden hot or cold spells have strong effects which lead discomfort to people (Makundi *et al*, 2006).

1.3 Objectives

The overall objective of this project is to examine the influence of weather parameters on malaria outbreaks over Morogoro Municipality. To achieve this main objective, three specific objectives were pursued. These are;

a) To determine temporal pattern of malaria cases over Morogoro Municipality.
b) To determine the relationship between malaria cases and weather parameters.
c) To investigate the predictability of the malaria outbreaks using meteorological parameters.

1.4 Justification of study

The interest of this project was to know if there is any relationship between malaria cases and weather parameters like increase of malaria's patients due to increase of temperature, rainfall and relative humidity in both long and short rainfall seasons over Morogoro Municipality. Furthermore after knowing the existence of their relationship, the project attempted to provide better strategies that will be used to reduce morbidity and mortality of people due to malaria like provision of treated bed nets, indoor spraying mosquitoes' killer, spraying insecticide over stagnant water, drainage of stagnant water, also to convince government to increase fund for malaria control programs. Moreover in areas like Morogoro which have intense year round transmission of malaria it is important to provide continuous anti malaria protection to pregnant women and children less than five years, which is not occurring at present.

1.5 Study area

1.5.1 Overview of Morogoro Municipality

Morogoro Municipal Council is the regional headquarter of Morogoro region. It is one of the oldest region in Tanzania and established in 18th century. It is about 195 kilometres from the west of Dar-es-salaam and is situated on lower level slopes of Uluguru Mountains whose peak is about 1,600 feet above the sea level. This region is located at 06°49'South latitude and 37°40'East longitude at an average elevation/altitude of 522 meters from mean sea level with a population of 350,000 people. Also it is bordered to the east and south by the Morogoro Rural District and to the north and west by Mvomero District. (Morogoro Municipal Council, 2008).

In addition Morogoro Municipal Council has the total land area of 260 sq.km, constituting 4 percent of the total regional area. The major physical features include the Uluguru Mountains, which lie in the southeastern part and Mindu Mountains in the western part. There are three main rivers with several tributeries which found in Morogoro Municipality. These rivers include Morogoro, Kikundi and Ngerengere. Another source of water is Mindu dam which was built in the late 1980s to serve both industrial and domestic use (Morogoro Municipal Council, 2008).

Figure 1: Map of Tanzania showing Morogoro region

Source: (Morogoro Municipal profile, 2008)

1.5.2 Climate characteristics of study area

Despite the variation of climatic conditions throughout the year, the weather is attractive because of its high altitude. Morogoro experiences average daily temperature of 27°C to 30°C degrees centigrade with a daily range of about 5°C centigrade. The highest temperature occurs in November, December and January during which the mean maximum temperatures are about 33°C centigrade. The minimum temperatures are in June, July and August when the temperatures go down to about 16°C centigrade. The mean relative humidity is about 66% and drops down to as far as 37%. The total average annual rainfall ranges between 821 mm to 1,505 mm. Long rains occur between March, April and May (MAM) and short rains occur between October, November and December (OND) each year. Furthermore the major economic activity over Morogoro Municipality is agriculture as the majority of the populations are farmers (substance and commercial farming). Other economic activities include industrial activities, small-scale enterprise (Morogoro Municipal Council, 2008).

CHAPTER TWO

2.0 LITERATURE REVIEW

This section review previous works that have been carried out in different study areas to determine the relationship between malaria cases and weather parameters.

2.1 Malaria cases

Plasmodium falciparum malaria is one of the major health problems in tropical and subtropical areas of the world. About two- fifths of the world's population live under constant threat of infection by the parasite. Every year 300-500 million people are infected and 1.5-3 million die. The vast majority of these are children under five years and pregnant women. Moreover Malaria continues to be a major public health burden in Tanzania, a country with the world's third largest population at risk of stable malaria after Nigeria and the Democratic Republic of Congo. About 35 million Tanzanian's people are at risk with this disease while 1.7million cases per year is among the pregnant women alone. (Mubyazi, 2005; Wort *et al,* 2004).

The rate of development of the malaria parasite within the female mosquito and the daily survival of the vector both depend on ambient temperature. The life cycle of mosquito larvae depend on temperature, thus at temperature below 16°C development of *Anopheles gambiae* stops and below 14°C they die. In cold temperature the larvae develop very slowly may be eaten by predators and may never live to transmit the disease. Once larvae grow to become adults, the rate at which they feed on humans is depending upon the surrounding temperature. The female mosquitoes (*Anopheles gambiae)* feed on humans every four days at temperature of 17°C, while at temperature of 25°C they take blood meals from humans every two days. Thus at temperature between 16°C and 36°C the daily survival is high and rapidly drops at temperature above 36°C. Also rainfall increases the breeding habitats for mosquitoes which cause to an increase population size and rates of malaria transmission. (Githeko, 2009; Minakawa *et al*, 2002).

However there are many variables that affect malaria transmission in addition to climatic changes, so that changes in malaria risk must include the basis of environmental conditions like deforestation, increase in irrigation, and swamp drainage (Zhou *et al*, 2005).

Analysis of time series and weather parameters have been conducted in many parts of the world and have indicated that increase in rainfall is correlated with change in malaria incidence which results on population dynamics of the Anopheles species mosquito vector. Additionally vector borne diseases are influenced by temperature, humidity, surface water, wind and biotic factors such as vegetation, host species, parasites and human intervention. The rise or fall of temperature affects the life cycle of both vector species and pathogenic organisms such as bacteria and viruses and also disease transmission (Thomson *et al*, 2005; Drakeley *et al*, 2005).

2.2 Mosquito life cycle

All mosquitoes need standing or stagnant water to complete their life cycle. The life cycle of all mosquitoes consists of four distinct life stages: egg, larva, pupa and adult. The first three stages occur in water, but the adult is an active flying insect that feeds upon the plant nectar or blood of humans or animals. The female mosquito lays the eggs directly on water or on moist substrates that may be flooded with water. The eggs later hatches within 24-48 hours into the larva, the elongated aquatic stage most commonly observed as it swims in the water. In about 7-10 days the larva transforms into the pupa where internal changes occur for about two days to form adult mosquito. The newly emerging mosquito has to stand on still water for few minutes to dry its wing before it can fly away. When flies it seek a protective environment in the surrounding vegetation to allow its wings to complete development (Renchie *et al*, 2007).

Thereafter female mosquito require sugar solution from plant nectar throughout their life to maintain energy for flying, mating, and seeking hosts for blood meals several days after emerging from water. This female mosquito takes a blood meal because needs extra protein to develop her eggs. On other hand, male mosquitoes do not bite humans except they feed only on plant nectar. Male mosquitoes have a life span of one or two weeks while female mosquitoes can live for a period of four weeks and producing multiple batches of eggs (Renchie *et al*, 2007).

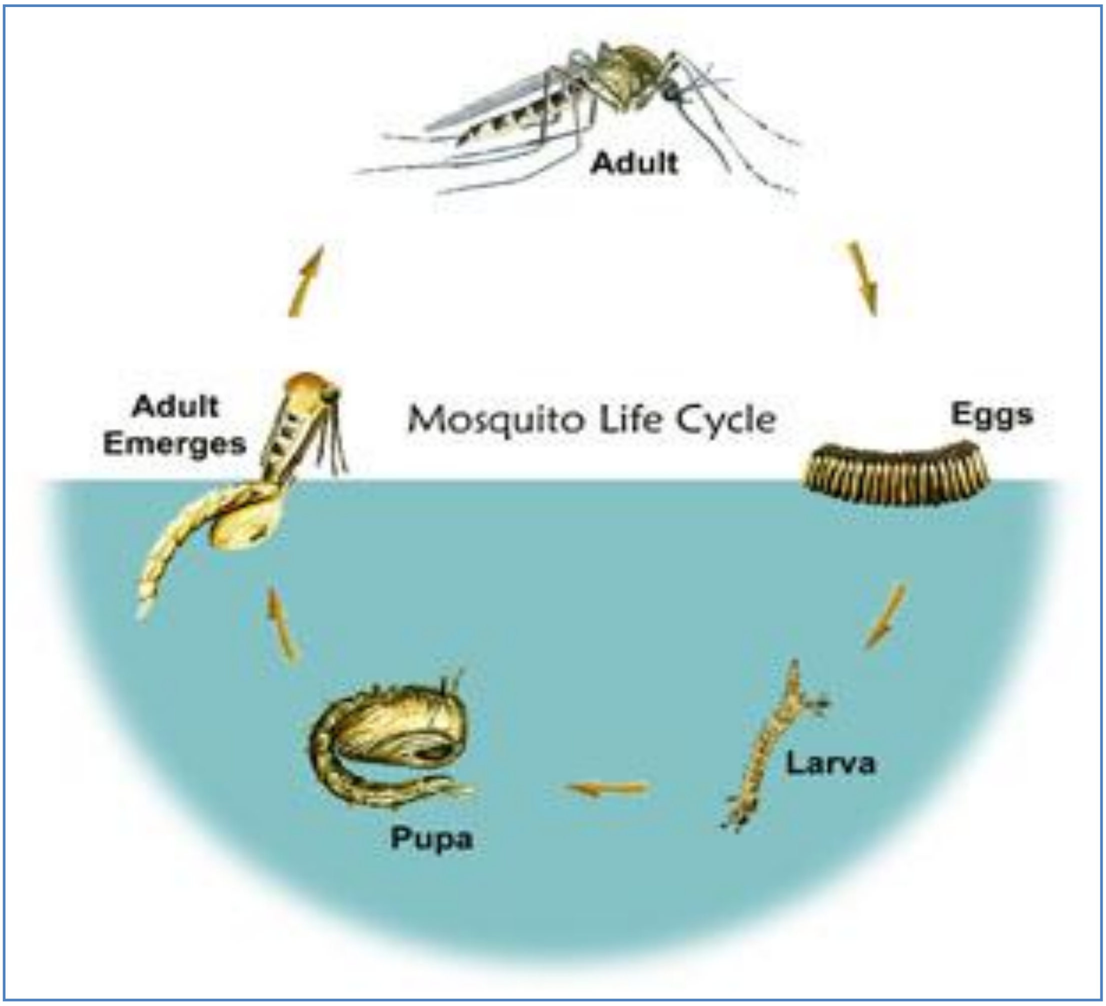

Figure 2: Stages of mosquito life cycle.

Source: (Renchie *et al*, 2007).

2.3 Stages of *Plasmodium* malaria parasite

Plasmodium requires two hosts (human and mosquitoes) to complete its life cycle. When female *Anopheles* mosquito bites a healthy human being, it releases *Plasmodium*, which lives in its body as sporozoite (infectious form). The parasites initially multiply (asexual reproduction) within the liver cells and then attack the red blood cells (RBCs) resulting in their burst. Thereafter bursting of red blood cells (RBCs) is associated with release of a toxic substance called haemozoin which is responsible for the chill and high fever recurring every three to four days. In the RBCs, sporozoites change into gametocytes (sexual stage) which then multiply. When a female Anopheles mosquito bites an infected person, these parasites (gametocytes) enter the mosquitoes' body and undergo further development. Also the Gametocytes multiply and develop inside the intestine of mosquito to form sporozoites that are stored in their salivary glands. When these mosquitoes bite a human, the sporozoites are introduced into his/ her body, thereby initiating malaria (Roy, 2006).

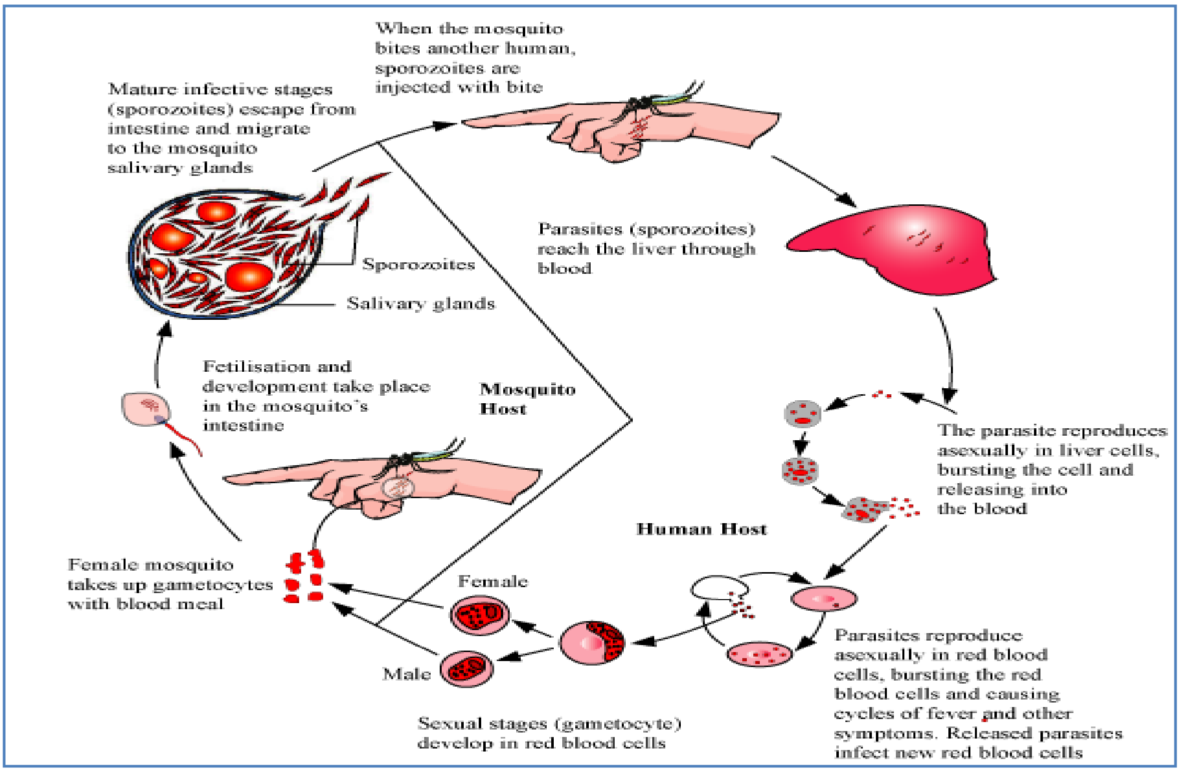

Figure 3: Stages of *Plasmodium* malaria parasite **Source:** (Roy *et al*, 2006)

CHAPTER THREE

3.0 DATA AND METHODOLOGY

This section describes the data and various methods that used to achieve the objectives outlined in this study.

3.1 Data sources

Two types of data sets have been used in this project. These are mean monthly meteorological data for rainfall, maximum temperature, minimum temperature and relative humidity for 0300Z, 0600Z, 0900Z and 1500Z over Morogoro Municipality in order to identify the best indicator of malaria cases. The second type of data was monthly malaria cases from the same place.

Both meteorological data and malaria cases used in this study covered a period of five years from 2007 to 2011. The meteorological data were collected from Tanzania Meteorological Agency (TMA) and malaria data were obtained from three different hospitals over Morogoro Municipality. These hospitals are Mazimbu, Sabasaba and regional hospital.

3.2 Methodology

Different methods were used to achieve the objectives of this study. These methods are discussed in the sub-sections below.

3.2.1 Data quality control

Data quality control is very important because involves estimation of missing data and homogeneity test. In this study there was no missing data, and also test for homogeneity were performed by plotting single mass curves for each of the weather parameters.

3.2.2 Time series analysis

A time series is a collection of observation made sequentially in time, where seasonal trends of various parameters are plotted. Time series plots are useful for detecting trends and seasonal variation in the data set. So in this study, time series analysis was applied to determine seasonal variation of malaria cases and weather parameters over Morogoro Municipality from 2007 to 2011.

3.2.3 Regression analysis

Regression analysis involves identifying the relationship between a dependent variable and one or more independent variables. When one independent variable is used in a regression, it is called a simple linear regression**;** when two or more independent variables are used, it is called a multiple linear regression.

3.2.3.1 Simple linear regression

A simple linear regression uses only one independent variable, and it describes the relationship between the independent variable (x) and dependent variable (y) as a straight line. In simple linear regression, the size of the coefficient for each independent variable gives the size of the effect that variable is having on the dependent variable, and the sign on the coefficient (positive or negative) gives the direction of the effect. In regression with a single independent variable, the coefficient tells how much the dependent variable is expected to increase (if the coefficient is positive) or decrease (if the coefficient is negative) when that independent variable increases by one.

Coefficient of determination is the portion of the total variation in the dependent variable that is explained by variation in the independent variable. It is also called R-squared and is denoted as (R^2). The coefficient of determination uses statistic to evaluate the model fit of a regression equation. The value of R-square ranges from 0.0 to 1.0 and can be multiplied by 100 to obtain a percentage of variance explained.

In this study simple linear regression analysis was used to determine the degree of relationship between malaria outbreaks(y) and weather parameters(x) for the period of five years from 2007 to 2011. Therefore simple linear regression between dependent variable(y) and independent variable (x) was given by the following formula.

$$y_i = b_0 + bx_i + e_i \text{ .... } (1)$$

Where y_i = dependent variable, x_i = independent variable, b= coefficient of regression line, b_o = intercept, e_i = predictor error.

3.2.3.2 Multiple linear regressions

Multiple linear regression analysis is a technique used for predicting the unknown value of a variable from the known value of two or more variables. The variable whose value is to be predicted is known as the dependent variable (predictant) and the ones whose known values are used for prediction are known independent variables (predictors). Hence for this project, muliple linear regression anaylsis was performed by using SYSTAT program to create a model for predict malaria cases from weather parameters. The prediction model equation was given in the form of:

$$y = b_0 + b_1x_1 + b_2x_2 + \text{.........................} + b_px_p \text{ ....} (2)$$

Where y =dependent variable, x= independent variables, b_0 is the intercept and b_1, b_2, b_3 and b_p are regression coefficients for the predictor x_p.

3.2.4 Error analysis

Error analysis of the prediction model was obtained by using root mean square error. The root-mean-square error (RMSE) is a frequently used measure of the differences between values predicted by a model or an estimator and the values actually observed. Formula of RMSE was given as follows:

$$RMSE= \sqrt{\frac{\sum (predicted - observed)^2}{N}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This section outlines the results and discussion on data quality control, time series and regression analysis.

4.1 Results from data quality control

4.1.1 Missing data

The data on malaria cases and weather parameters used in this study was complete with no missing values.

4.1.2 Test for data homogeneity

Test for homogeneity was done for all weather parameters included in this study. The single mass curve was used to test the homogeneity, and results for homogeneity test were shown in figures 4 to 10 below. The coefficient of determination (R^2) in the figures showed the goodness of fit of the points. So it is evident from these figures that the data used in the study were generally homogeneous. Except figure 4 showed meandering may be due to measurement errors or instrumental errors. Since its coefficient of determination (R^2) was nearly one then it considered to be homogeneous.

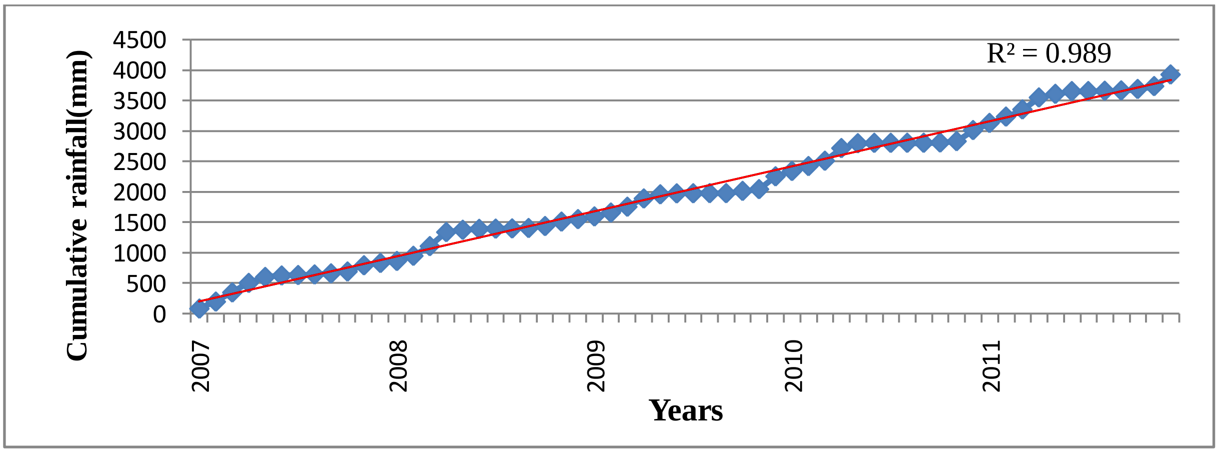

Figure 4: Single mass curve for cumulative rainfall (mm) over Morogoro Municipality (2007-2011).

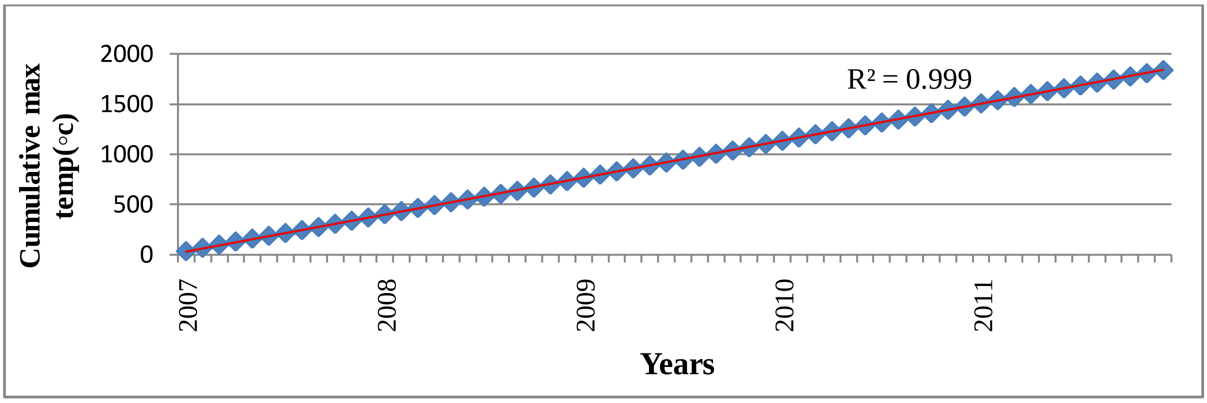

Figure 5: Single mass curve for cumulative maximum temperature (◦C) over Morogoro Municipality (2007-2011).

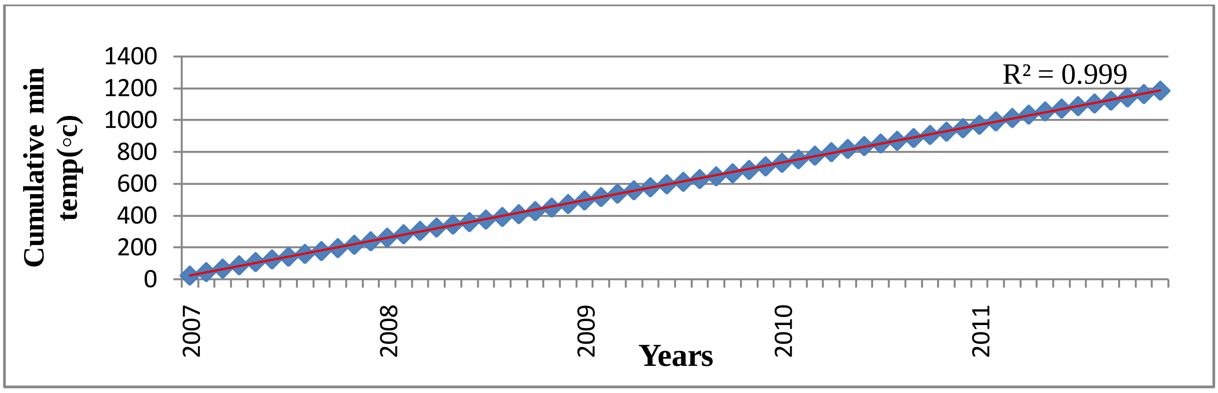

Figure 6: Single mass curve for cumulative minimum temperature (◦C) over Morogoro Municipality (2007-2011).

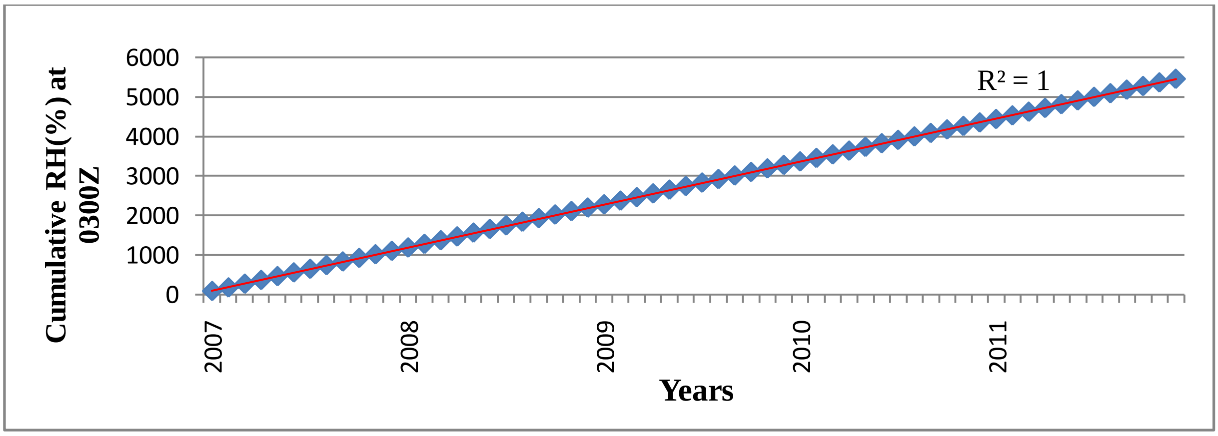

Figure 7: Single mass curve for cumulative Relative humidity (%) at 0300Z over Morogoro Municipality (2007-2011).

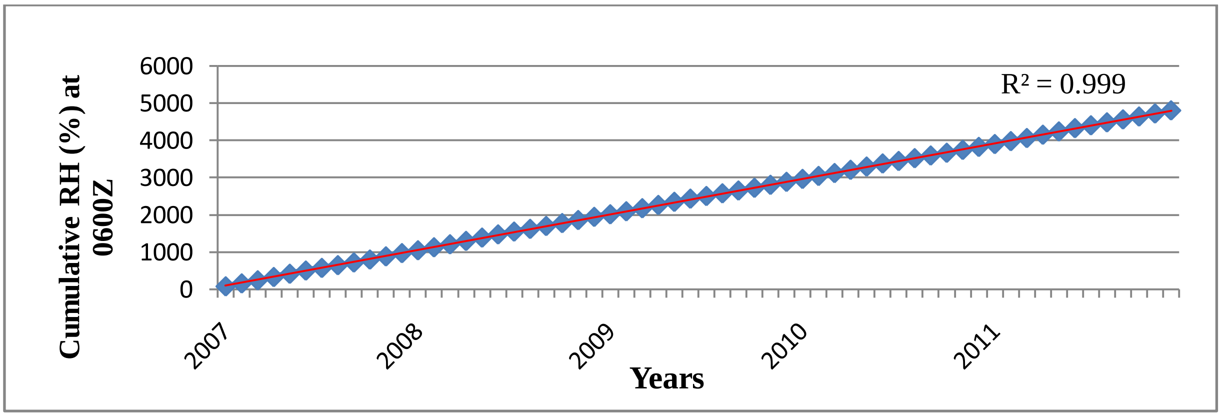

Figure 8: **Single mass curve for cumulative Relative humidity (%) at 0600Z over Morogoro Municipality (2007-2011).**

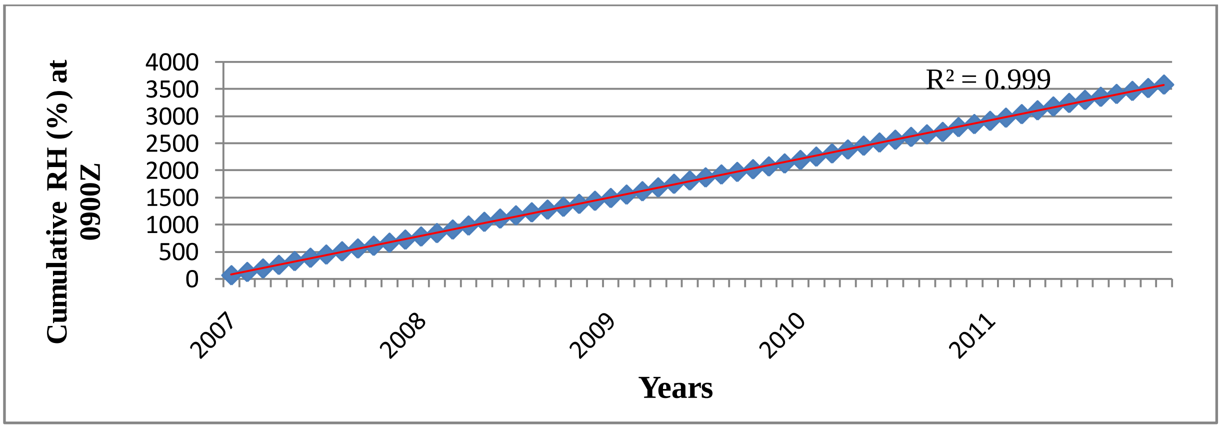

Figure 9: **Single mass curve for cumulative Relative humidity (%) at 0900Z over Morogoro Municipality (2007-2011).**

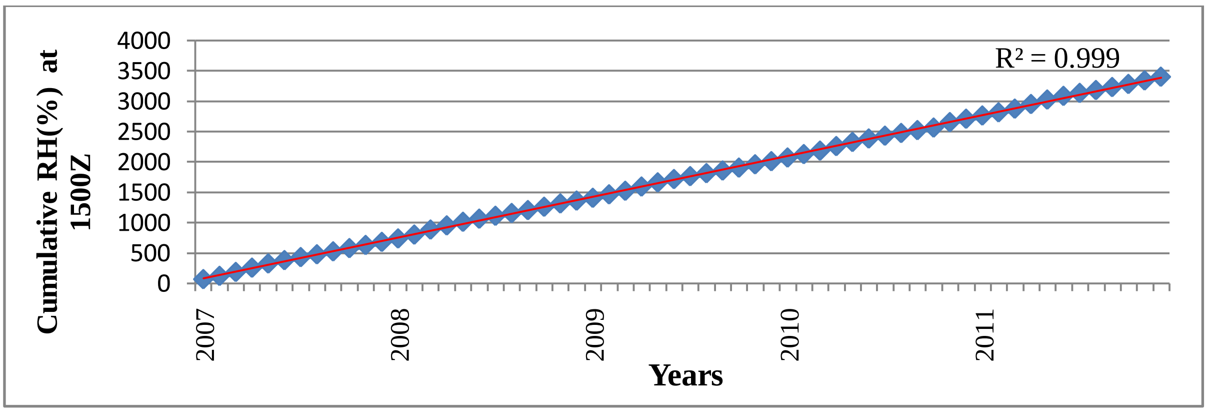

Figure 10: **Single mass curve for cumulative Relative humidity (%) at 1500Z over Morogoro Municipality (2007-2011).**

4.2 Temporal pattern of malaria cases

In this part the time series was used to plot mean monthly malaria cases against time in an attempt to observe the behavior of malaria cases reported over study area.

So a plot of histogram in figure 11 below examined the seasonal variation of malaria cases over Morogoro Municipality from 2007 to 2011. This time plot depicted that mean monthly malaria cases were high in the months of February to May and November to December but the highest peak was on the month of April and the lowest peak on the month of July. It should be noted that malaria cases in study region prevails throughout the year. There was no any month in which the region was free from malaria cases.

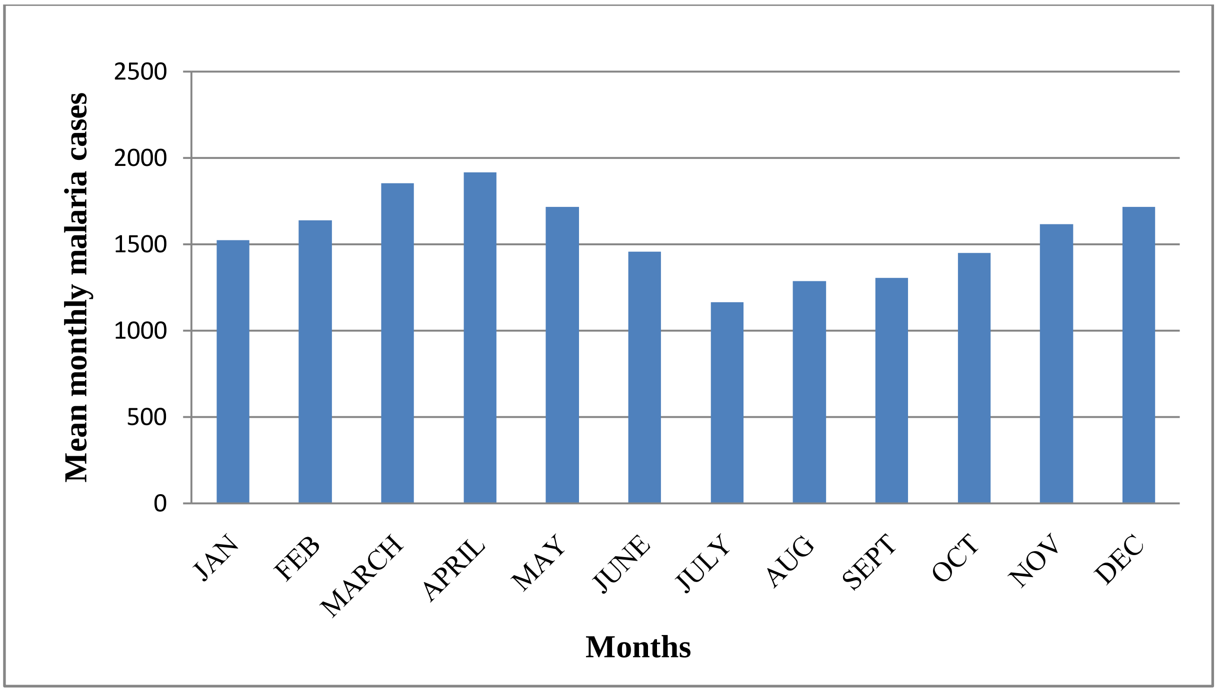

Figure 11: Mean monthly malaria cases over Morogoro Municipality (2007-2011).

4.3 Seasonal Relationship between malaria cases and weather parameters

In this subsection time series analysis and simple linear regression were used to show relationship between malaria cases and weather parameters and discusses their comparison.

4.3.1 Time series analysis

Results from time series analysis were given below as follows;

4.3.1.1 Patterns of Malaria cases and Rainfall (mm)

Figure 12 below indicated relationship between malaria cases and rainfall over Morogoro Municipality. Malaria cases were recorded throughout the year indicating perennial transmission in the study area. Observation from figure show that malaria cases were high between February-May as well as November-December. Two peaks of high malaria cases were observed, each peak coincided with a peak of rainfall pattern of the bimodal annual rainfall season. The highest number of malaria cases was during April with 1918 malaria cases by considering highest rainfall (198.9 mm) recorded in this month. On other hand low incidences of malaria occurred in July and August. The lowest peak may be recognized due to the fact that the months of July and August were very dry which could not favor mosquito larval habitat.

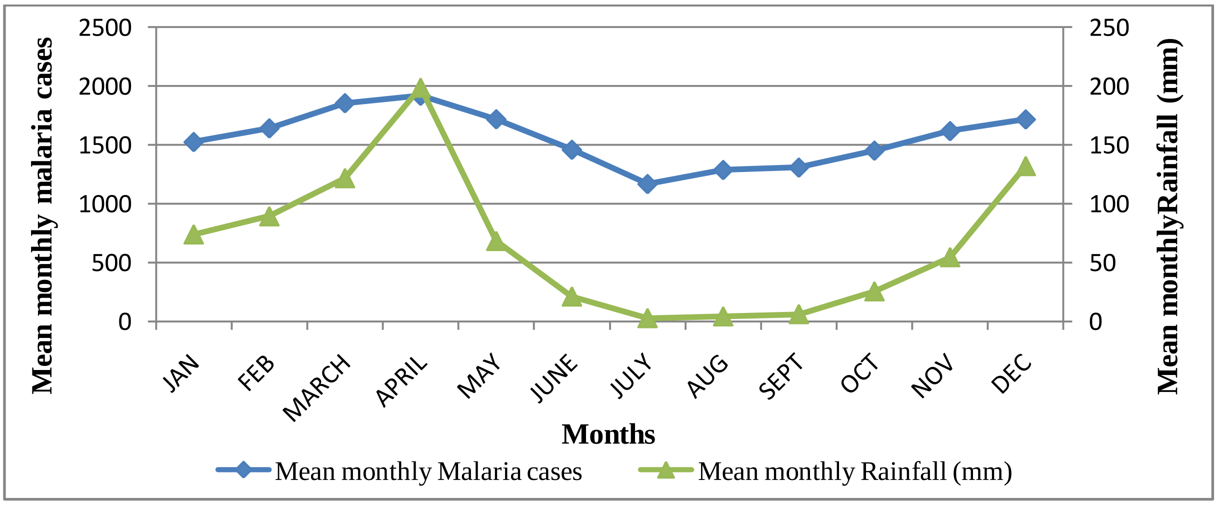

Figure 12: Mean monthly malaria cases and rainfall over Morogoro Municipality (2007-2011).

4.3.1.2 Patterns of Malaria cases and Temperature (◦c)

In general the seasonal increase in temperature was associated with increase of malaria cases as shown in figure 13 below. Here it seen that the increase in minmum temperature was related with increase of malaria cases. The highest peak of malaria cases in April was coincided with high value of minimum temperature. Therefore the pattern of monthly malaria cases and minimum temperatures showed a general correspondence, but was no clear relationship with maximum temperature. On other hand the lowest peak of malaria incidence occurred in July which coincided with the lowest value of minimum temperature.

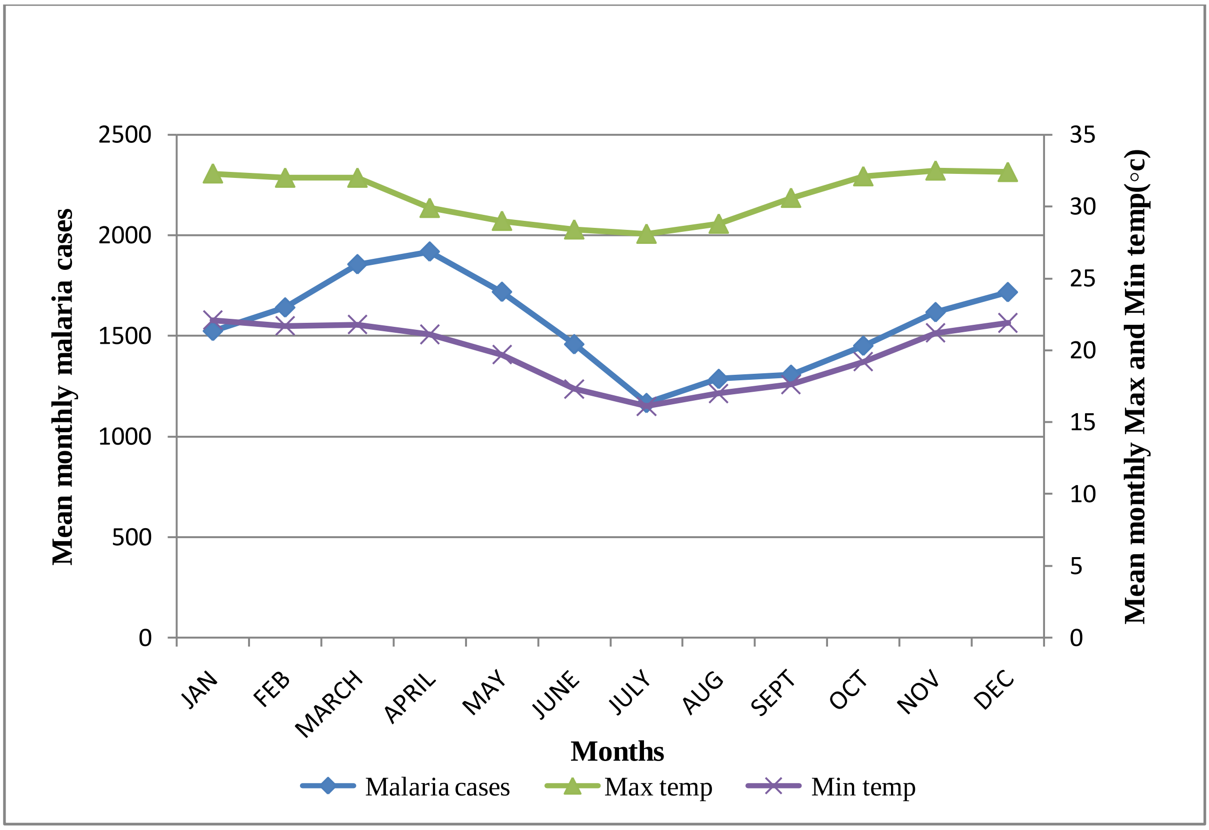

Figure 13: Mean monthly malaria cases and temperature over Morogoro Municipality (2007-2011).

4.3.1.3 Patterns of Malaria cases and Relative Humidity (%)

Comparison of malaria cases and relative humidity (%) at 0300Z, 0600Z, 0900Z and 1500Z was depicted in figures 14 to 17 below. Two peaks of high malaria cases were observed on April and December, each peak coinciding with a peak of relative humidity pattern. Both malaraia cases and relative humidity tend to increase from February to May as well as November to December. Also the lowest peak of malaria cases coincided with lowest value of relative humidity in month of July. The highest relative humidity in month of April supported much mosquitoes' life cycle due to wet condition. On other hand month of July was dry which didn't support much mosquitoes' life cycle. Hence relative humidity at 0300Z, 0600Z, 0900Z and 1500Z in the figures below showed similar relationship with malaria cases.

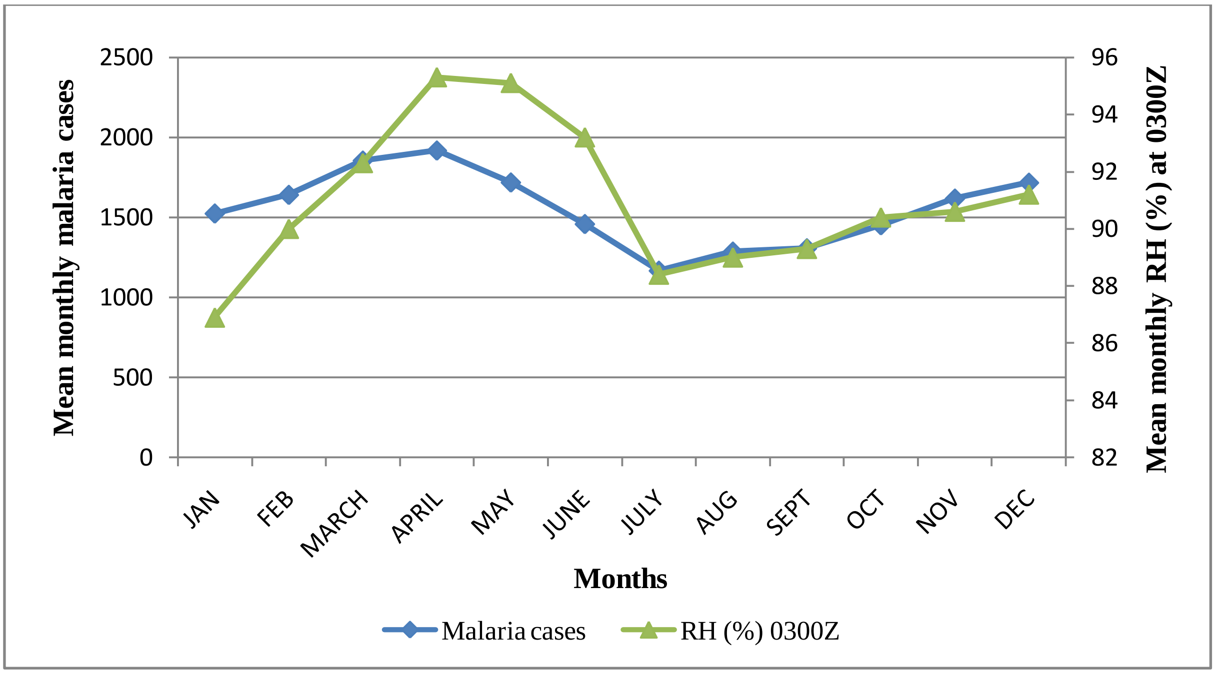

Figure 14: Mean monthly malaria cases and Relative humidity (%) at 0300Z over Morogoro Municipality (2007-2011).

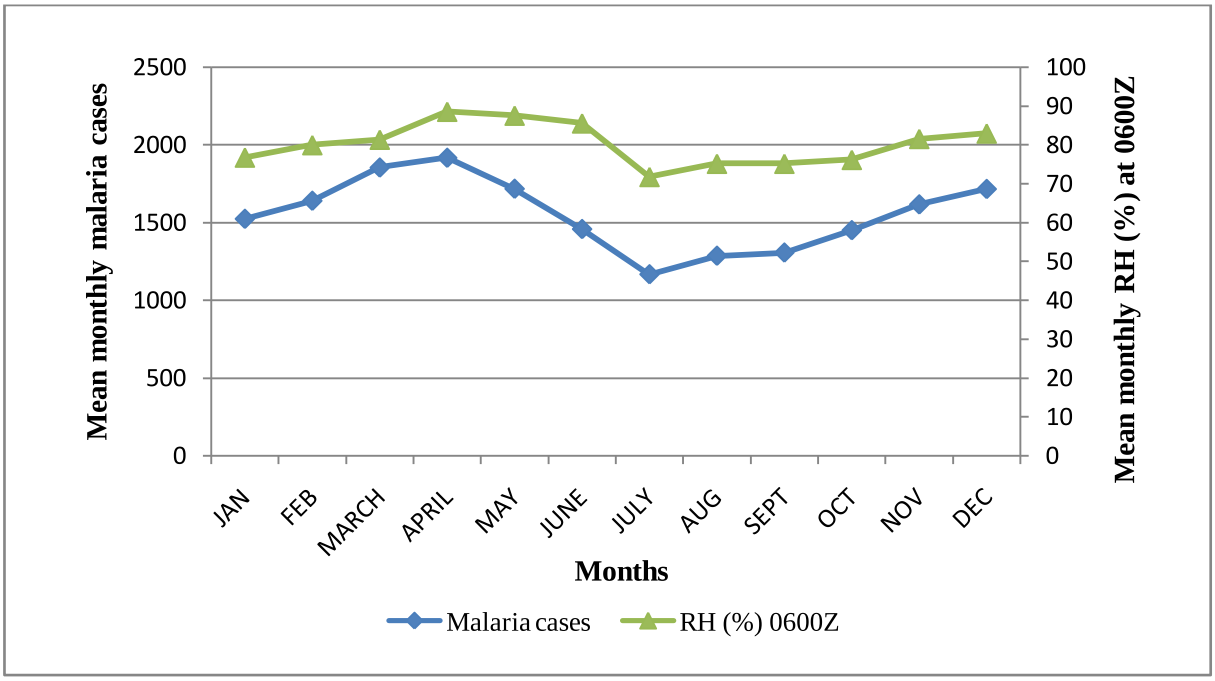

Figure 15: Mean monthly malaria cases and Relative humidity (%) at 0600Z over Morogoro Municipality (2007-2011).

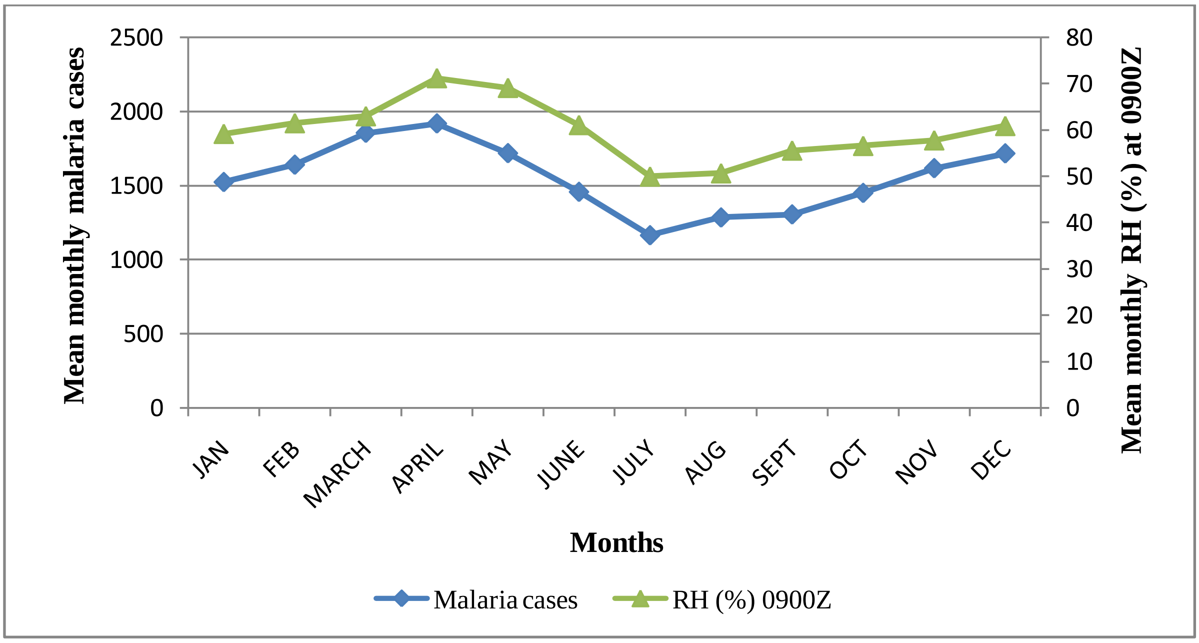

Figure 16: Mean monthly malaria cases and Relative humidity (%) at 0900Z over Morogoro Municipality (2007-2011).

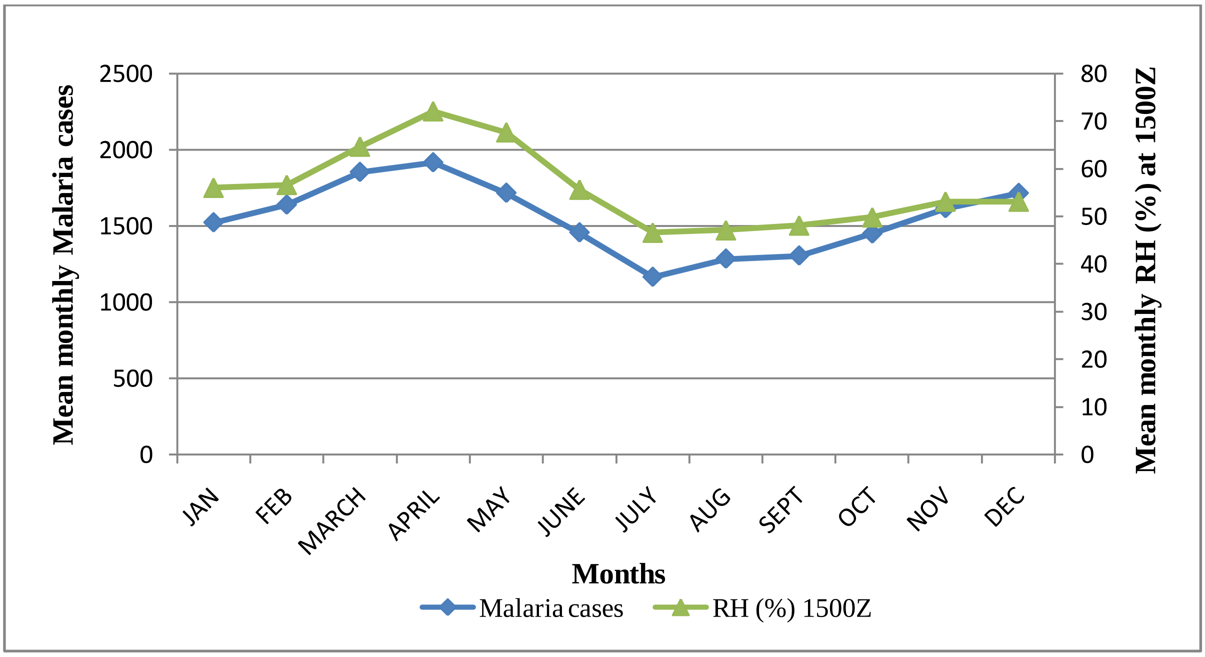

Figure 17: Mean monthly malaria cases and Relative humidity (%) at 1500Z over Morogoro Municipality (2007-2011).

4.3.1.4 Hourly patterns of Relative humidity (%)

Figure 18 below indicated hourly variation of relative humidity at 0300Z, 0600Z, 0900Z and 1500Z over Morogoro Municipality. It is evident from the figure that relative humidity was high in early morning (0300Z) and start to decrease as day advances to a lower value in evening (1500Z).

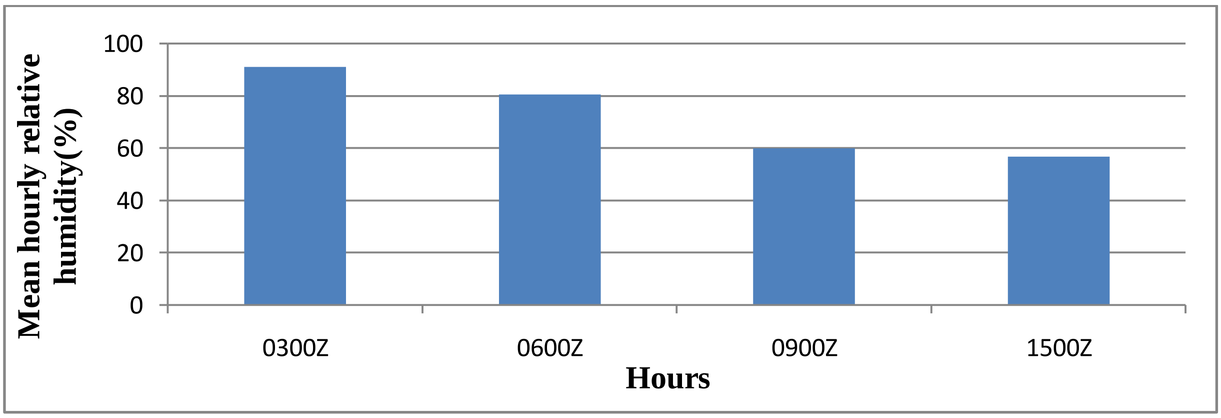

Figure 18: Hourly patterns of Relative humidity (%) at 0300Z, 0600Z, 0900Z and 1500Z over Morogoro Municipality (2007-2011).

4.3.2 Simple linear regression

A simple linear regression describes the relationship between one independent variable (weather parameter) and dependent variable (malaria cases) as a straight line. The coefficient of determination (R^2) value indicates how much of the dependent variable, can be explained by the independent variable. So simple linear regression was performed as follows;

4.3.2.1 Patterns of Malaria cases against Rainfall (mm)

Figure 19 below depicted that malaria cases and rainfall (mm) had strong positive linear correlation, which mean that as rainfall increase also malaria cases increase. The coefficient of determination (R^2) seemed to be about 65% and implies that rainfall influenced malaria incidences for about 65%. Furthermore the figure below showed the intercept at 1350 and prove that there was malaria even in the absent of rainfall. This was influenced by other factors like stagnant water on ponds and growing grass that surround the environment. These factors could generate mosquito's life cycle even during a month when there was no rainfall.

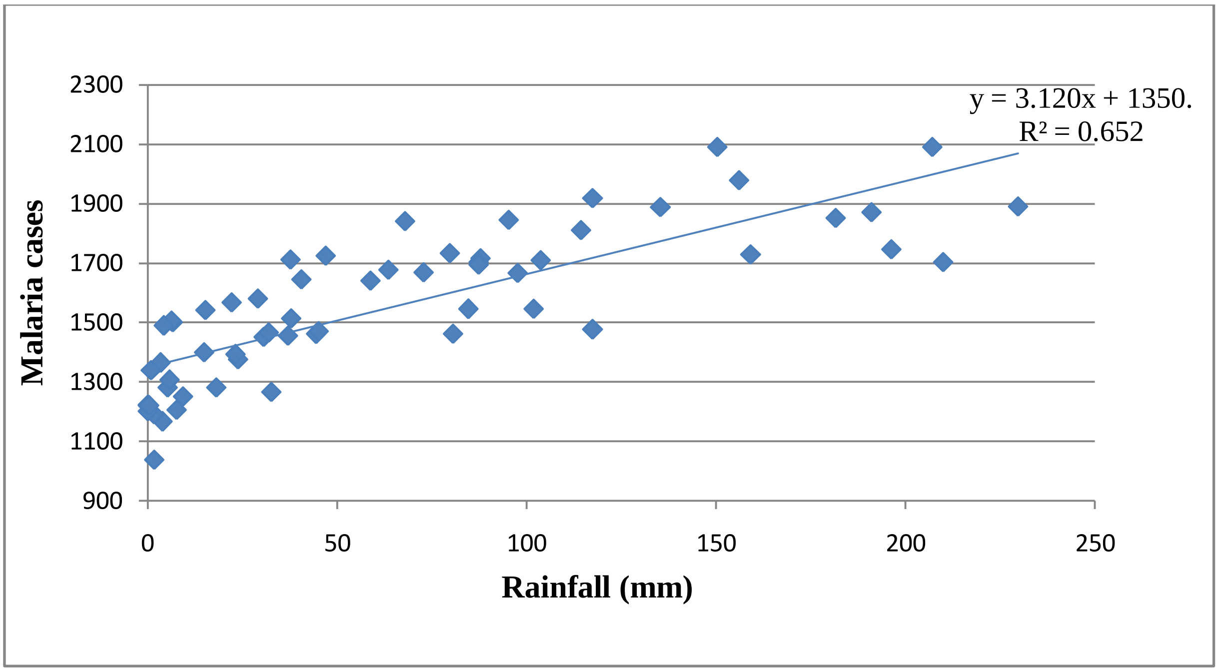

Figure 19: Linear correlation between malaria cases and rainfall (mm) over Morogoro Municipality (2007-2011).

4.3.2.2 Patterns of Malaria cases against Temperature (◦c)

The results of regression analysis from figures 20 and 21 below showed that malaria cases and temperature had positive linear correlation. This indicates that when temperature increase also malaria cases increase. Moreover coefficient of determination for maximum temperature was about 13 percent. This showed that maximum temperature had weak linear correlation with malaria cases. On other hand coefficient of determination for minimum temperature was 50 percent. This implies that minimum temperature had good correlation with malaria cases. Thus when minimum temperature increase mosquitoes are happier because their development rate increase.

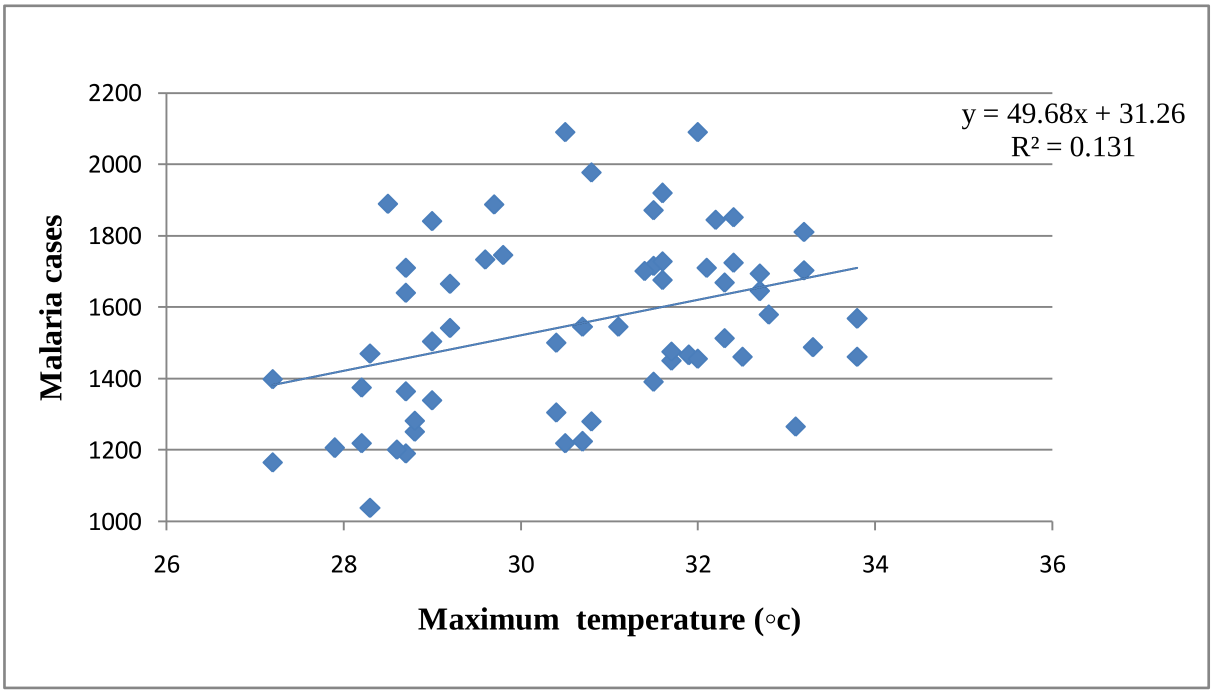

Figure 20: Linear correlation between malaria cases and maximum temperature (◦c) over Morogoro Municipality (2007-2011).

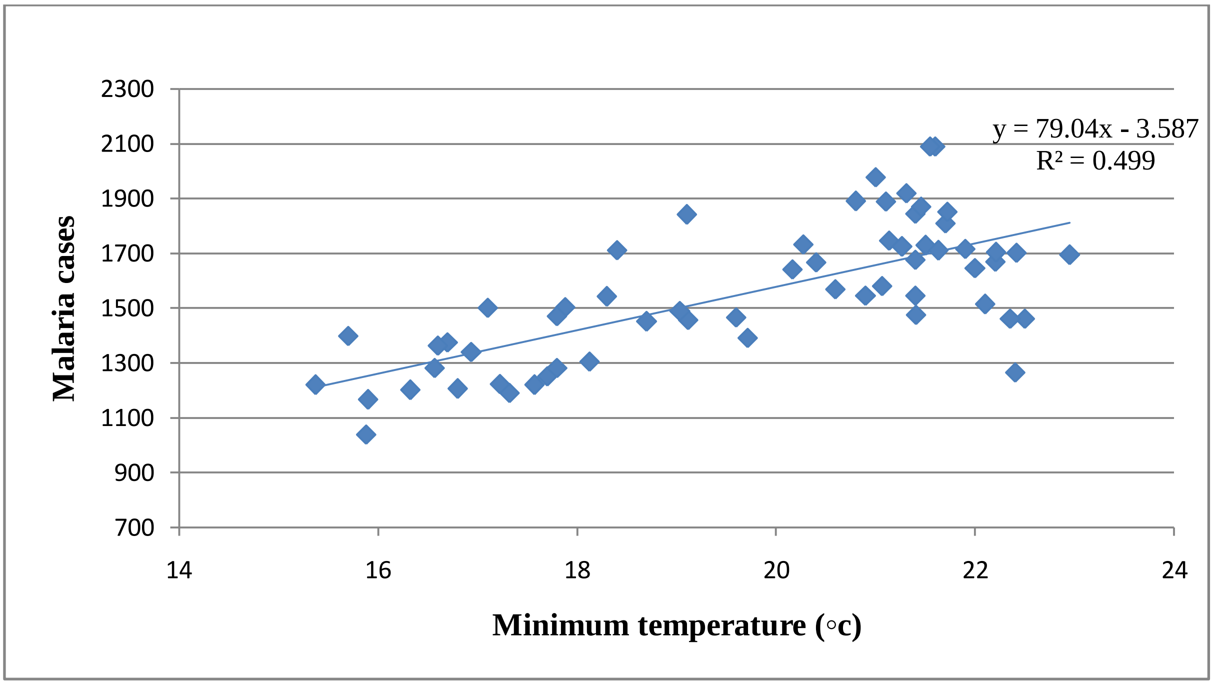

Figure 21: Linear correlation between malaria cases and minimum temperature (◦c) over Morogoro Municipality (2007-2011).

4.3.2.3 Pattern of Malaria cases against Relative humidity (%)

The results from figures 22 to 25 below indicated that malaria cases and relative humidity at 0300Z, 0600Z, 0900Z and 1500Z had positive linear correlation. This implied that as relative humidity increase also malaria cases increase. Furthermore the coefficients of determination (R^2) in figures 22 to 25 below were 18% early in the morning (0300Z), 45% late morning (0600Z), 29% in afternoon (0900Z) and 41% in the evening (1500Z). The coefficients of determination were fluctuating as a day advances.

By considering figure 18, relative humidity was highest early in the morning (0300Z) and decreasing as time goes up to lowest value in the evening (1500Z). Thus when relative humidity was highest early in the morning the coefficient of determination (R^2) was low may be due to cold condition in the morning when temperature was at minimum point which favor little life of mosquitoes. Also in late morning coefficient of determination appeared to be high perhaps due to warm condition after sunrise that make mosquitoes happy and easily bite human. Again in afternoon coefficient of determination (R^2) seemed to be low compared to late morning may be for the reason of warmer situation when temperature approached maximum point which did not support much the survival of mosquitoes. In the evening coefficient of determination was higher than afternoon although relative humidity was low may be due to heat lost by ground which cause warmer condition that favor development of mosquitoes.

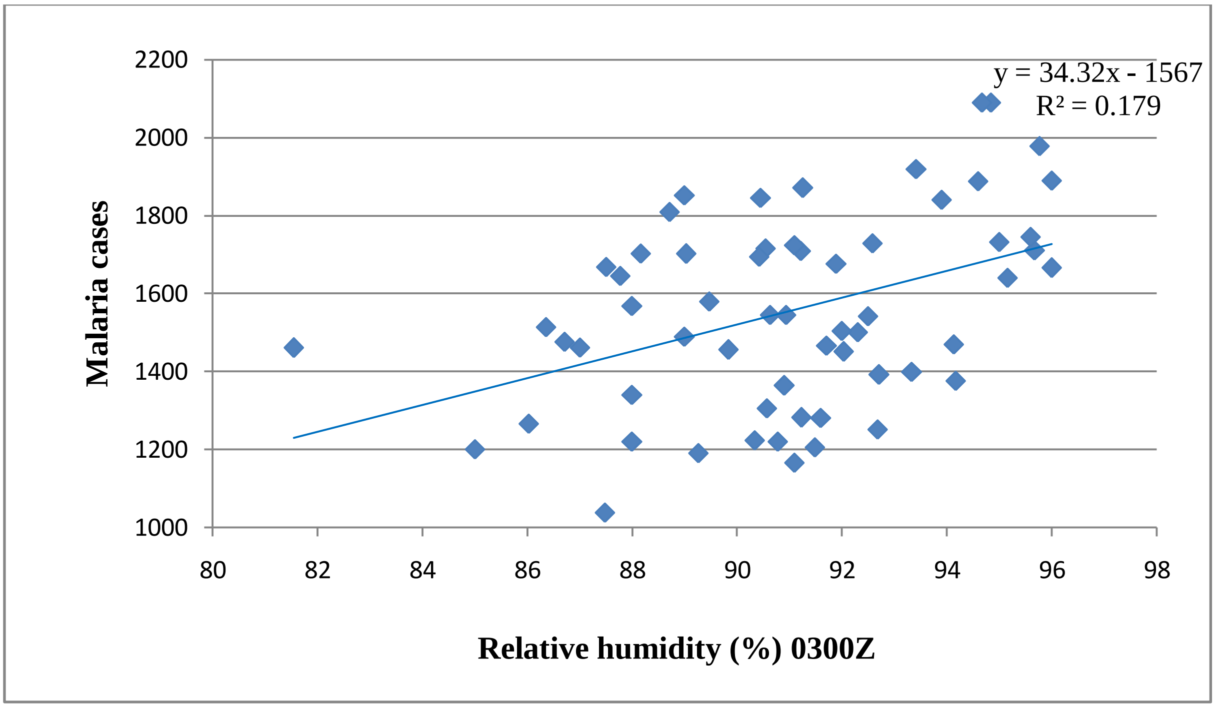

Figure 22: Linear correlation between malaria cases and Relative humidity (%) at 0300Z over Morogoro Municipality (2007-2011).

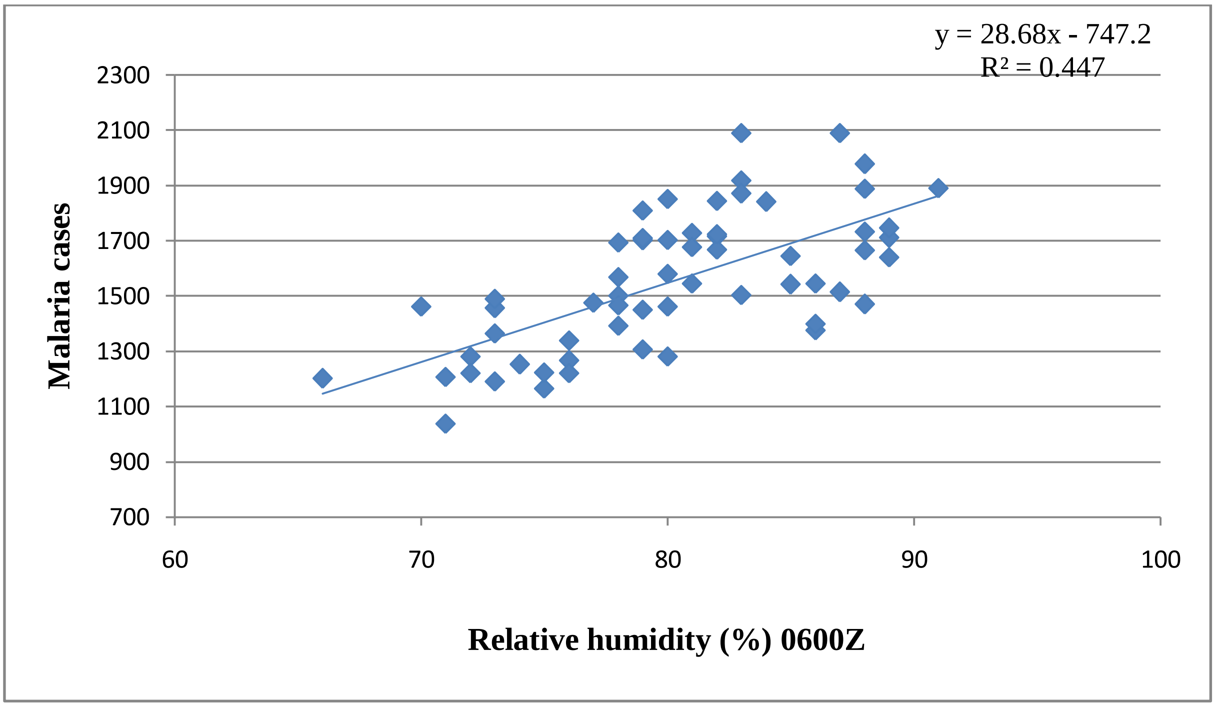

Figure 23: Linear correlation between malaria cases and Relative humidity (%) at 0600Z over Morogoro Municipality (2007-2011).

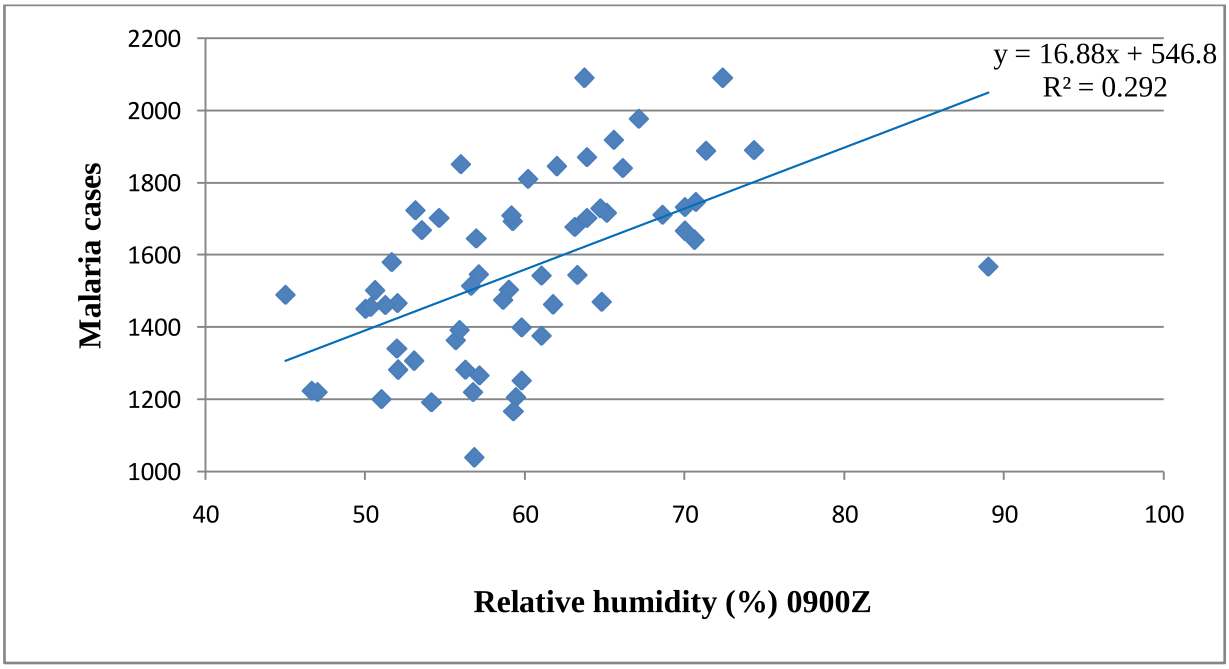

Figure 24: Linear correlation between malaria cases and Relative humidity (%) at 0900Z over Morogoro Municipality (2007-2011).

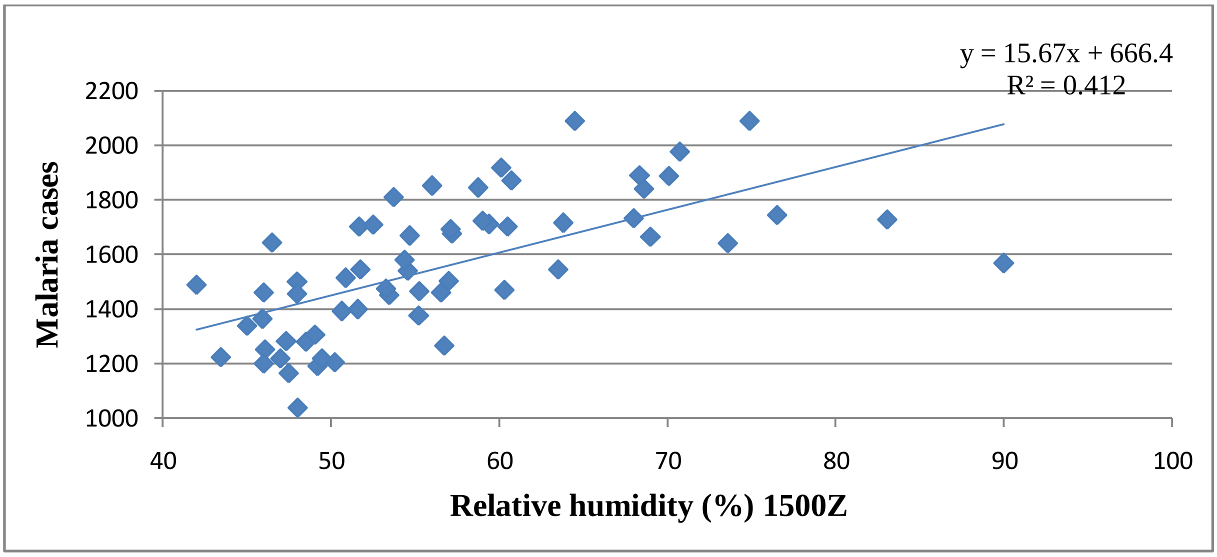

Figure 25: Linear correlation between malaria cases and Relative humidity (%) at 1500Z over Morogoro Municipality (2007-2011).

4.3.3 Correlation between malaria cases and weather parameters

Table 1 below indicated correlation coefficients of weather parameters from Lag 0 to Lag 3. This identified that weather parameters and malaria cases have relationship. Furthermore single parameter can influence malaria cases for a certain amount of percentage while other weather parameters have been fixed. For instance at Lag 0, rainfall alone seemed to influence malaria cases by 65% (r = 0.81). This outcome of malaria cases is expected to happen for the next 14 days after rainfall, because mosquito life cycle takes about two weeks to complete its cycle from egg to adult mosquito. In addition, mosquitoes are most active during late evening and night hours. Also after a mosquito bites a person, it takes three to four days for a person to show malaria symptoms.

Table 1: Correlation output

PARAMETERS / MALARIA	RAIN	TMAX	TMIN	RH0300Z	RH0600Z	RH0900Z	RH1500Z
Lag 0	0.810	0.321	0.638	0.432	0.692	0.630	0.730
Lag 1	0.624	0.634	0.699	0.005	0.113	0.207	0.450
Lag 2	0.120	0.673	0.544	-0.445	-0.242	-0.160	-0.006
Lag 3	-0.259	0.493	0.295	-0.730	-0.443	-0.435	-0.450

4.4 Prediction of malaria outbreaks using meteorological parameters

Prediction of malaria outbreaks was achieved by using multiple linear regressions and also statistical accuracy of the model was done by error analysis.

4.4.1 Multiple linear regressions

Multiple linear regression analysis is a technique used for predicting the unknown value (dependent) of a variable from the known value (independent) of two or more variables. So in this project, multiple linear regression anaylsis was performed by using SYSTAT program to formulate a model equation for predicting malaria cases from weather parameters.The following regression output at Lag 1 and Lag 2 were obtained from SYSTAT program;

Table 2: Regression output at Lag 1

```
Data for the following results were selected according to:
      (SMONTH=< 40)

Dep Var: MALARIA   N: 40   Multiple R: 0.826   Squared multiple R: 0.683

Adjusted squared multiple R: 0.647   Standard error of estimate: 152.759
```

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-1691.275	1217.981	0.000	.	-1.389	0.174
RAIN	1.077	0.658	0.261	0.355	1.637	0.111
TMIN	93.618	19.329	0.830	0.309	4.843	0.000
RH0300Z	36.325	12.997	0.451	0.348	2.795	0.008
RH0600Z	-24.737	6.412	-0.550	0.446	-3.858	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1758423.726	4	439605.932	18.839	0.000
Residual	816730.674	35	23335.162		

```
Durbin-Watson D Statistic     1.384
First Order Autocorrelation   0.297
```

From the results above the equestion was then developed to predict malaria cases by combination of rainfall, minimum temperature and relative humidity at 0300Z, and 0600Z.

The equation (4) below is prediction model obtained at Lag 1 and can predict malaria cases when given minimum temperature, rainfall and relative humidity. Also coefficient of determination (R^2) from regression results was 0.683

M= -1691.275+1.077R+93.618TMIN+36.325(RH0300Z)-24.737(RH0600Z) ....(4)

Where, M= Malaria cases reported,

R= Rainfall,

TMIN= Minimum temperature,

RH0300Z= Relative humidity at 0300Z,

RH0600Z= Relative humidity at 0600Z.

Table 3: Regression output at Lag 2

```
Data for the following results were selected according to:
      (SMONTH=< 40)

Dep Var: MALARIA   N: 40   Multiple R: 0.745   Squared multiple R: 0.555

Adjusted squared multiple R: 0.518   Standard error of estimate: 176.438
```

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-930.463	663.381	0.000	.	-1.403	0.169
TMAX	104.022	16.423	0.756	0.868	6.334	0.000
RH0600Z	-19.468	6.895	-0.438	0.514	-2.824	0.008
RH0900Z	14.402	6.236	0.376	0.467	2.309	0.027

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	1396554.453	3	465518.151	14.954	0.000
Residual	1120689.447	36	31130.262		

```
Durbin-Watson D Statistic     1.676
First Order Autocorrelation   0.086
```

From the results above the equestion was then developed to predict malaria cases by combination of maximum temperature and relative humidity at 0600Z, and 0900Z.

The equation (5) below is prediction model obtained at Lag 2 and can predict malaria cases when given maximum temperature, and relative humidity. Also coefficient of determination (R^2) from regression results was 0.555

M= -930.463+104.022TMAX-19.468(RH0600Z)+14.402(RH0600Z) ....(5)

Where, M= Malaria cases reported,

TMAX= Maximum temperature,

RH0600Z= Relative humidity at 0600Z,

RH0900Z= Relative humidity at 0900Z,

4.4.2 Investigation of the predictability of the model

The investigation of the model was done by applying malaria cases at **Lag 1** and **Lag 2**. The first 40 months were selected as training of the model and last 20 months as testing of the model. A graph of malaria cases reported and predicted was plotted on the same graph against time to show development of the model. Since the values of malaria cases reported and predicted in the figures below were fluctuating in the same direction therefore model equation observed to be accurate. Model equation at **Lag 1** can be used to predict malaria cases for one month ahead and Model equation at **Lag 2** can be use to predict malaria cases for two months ahead.

At Lag 1

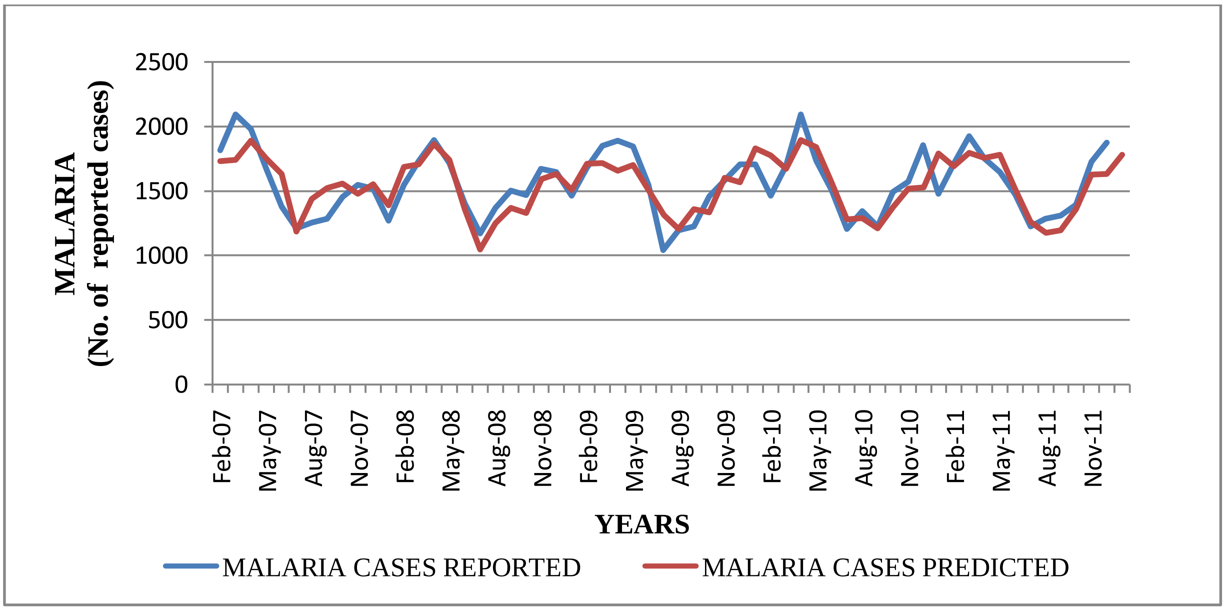

Figure 26: Relationship between malaria cases reported and predicted at Lag 1 over Morogoro Municipality (2007-2011).

At Lag 2

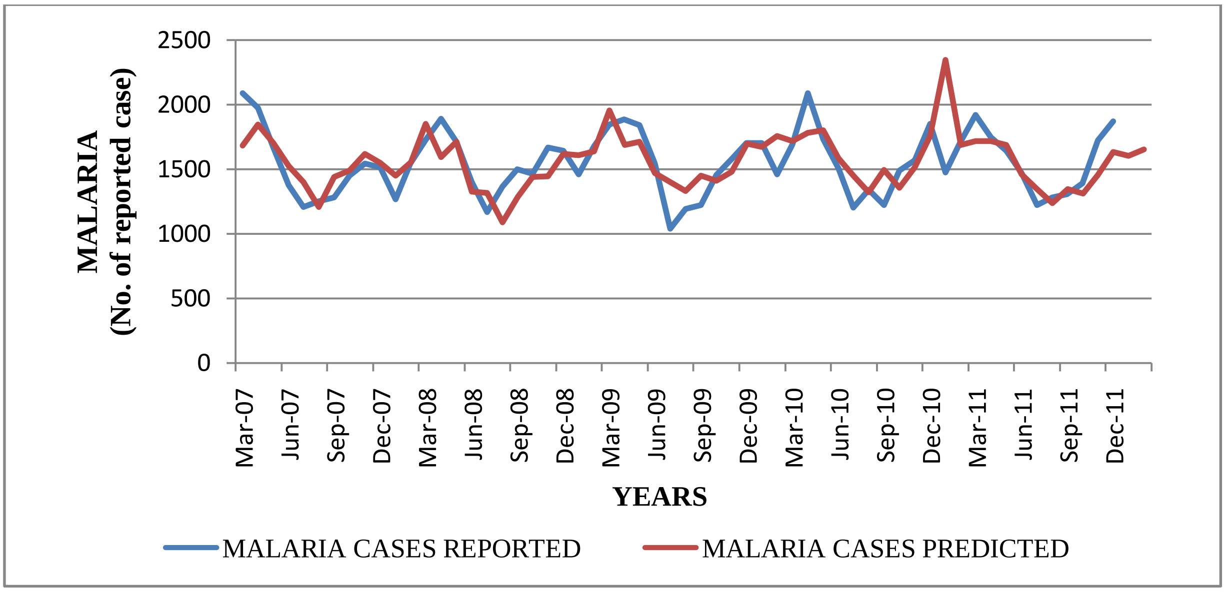

Figure 27: Relationship between malaria cases reported and predicted at Lag 2 over Morogoro Municipality (2007-2011).

4.4.3 Error analysis

The root mean square error (RMSE) obtained from prediction model was 269 at Lag 1 and 356 at Lag 2. So when these values are compared with mean malaria cases (1500) it seems to be almost zero. This means that errors from Lag 1 and Lag 2 deviate very little from mean malaria cases. Thus errors obtained assess statistically the accuracy of the model as well as help government to know extra amount of medicine can add from mean when need to provide health services (e.g. treatment of malaria cases) over Morogoro Municipality.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter gives the summary of the results, conclusions and recommendations drawn from the study.

5.1 Summary

In Tanzania malaria is the leading health problem where it accounts for the most outpatients and inpatients hospital attendances and is among the leading causes of hospital deaths for all ages in the country, and the most vulnerable groups are children under five years and pregnant women.

Therefore, this study sought to investigate the relationship between malaria (number of malaria cases) and weather parameters (temperature, rainfall and relative humidity) over Morogoro Municipality based on data spanning the period from 2007 to 2011. The specific objectives were aimed to determine temporal pattern of malaria cases, relationship between malaria outbreaks and weather parameters and investigation of predictability of malaria incidences using meteorological parameters.

Data quality control using single mass curve indicated that all meteorological parameters used in the study were homogeneous. The rainfall, temperature and relative humidity data were homogenous and consistent for analysis. Although malaria cases prevailed throughout the year, seasonal variations noted that high malaria cases were reported during February to May period and November to December period with highest peaks on month of April.

Time series analysis of both malaria cases and weather parameters were increasing from February to May and November to December period. This attributed to the coinciding of highest peaks of malaria cases and rainfall, minimum temperature and relative humidity in April and December and lowest peak during the month of July.

Simple linear regression related with increasing trend of malaria cases and increase of rainfall, maximum and minimum temperature and relative humidity. Furthermore, simple linear regression showed that malaria cases had strong positive relationship with meteorological parameters as indicated by coefficient of determination between malaria cases and rainfall, maximum and minimum temperature of 65%, 13%, and 41% respectively. Relative humidity showed a coefficient of determination of 18% at 0300Z, 45% at 0600Z, 29% at 0900Z and 41% at 1500Z.

Prediction model was based on multiple regression analysis. Graphical presentations indicated that the model performed well. However, accuracy assessment of the model using root mean square error (RMSE) showed that the model overestimated 269 malaria cases at Lag 1 and 356 malaria cases at Lag 2.

5.2 Conclusions

The study showed that cases of malaria reported over Morogoro Municipality were associating with weather parameters. Malaria outbreaks and seasonal rainfall, minimum temperature and relative humidity indicated significant relationship but was no clear relationship with maximum temperature. The highest cases of malaria reported were found during the MAM season with peaks in April and coincided with the highest peak of rainfall and relative humidity while the lowest peak of malaria cases was observed on July and coincided with lowest peak of rainfall, minimum temperature and relative humidity.

The main weather parameters that significantly contributed to developed model were rainfall (65%), minimum temperature (50%) and relative humidity (45%). Moreover, assessment of the accuracy of the model showed that the model performed well.

5.3 Recommendations

Since the study showed relationship between malaria cases and weather parameters so Morogoro Municipality and its health sectors is recommended to be aware with rainy season in order to take care of malaria cases by preparing enough medicine and providing education to people on how to control malaria.

The study noted that the five years data was very short to give conclusive evidence on the accuracy of the model and thus further research should be done using data of many years so as to make possible verification and testing of model accuracy in predicting malaria cases over study area. Moreover, data from private hospitals should be included in model development.

Relevant policies should also be enacted to ensure that comprehensive databases of malaria cases from both private and public hospitals are achieved for research and representativeness. This will enable extensive research and provide strategies that will help to eradicate malaria over Morogoro Municipality.

In addition, government needs to provide enough funds over study area during rainy season and after rainy season so as to facilitate achievement of strategies that can reduce malaria.

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