Malaria Trends and Diagnoses in Rural Health Facilities in Mvomero, Tanzania

by

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Brian Pence

Thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Science in
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ABSTRACT

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Abstract

Malaria remains a significant global health challenge. In 2010, an estimated 660,000 people died from malaria and about 90% of all the deaths occurred in Africa. In Tanzania, malaria is the third most burdensome disease with 14 million cases and loss of 15,000 lives each year. This thesis investigates the trends, the diagnostic approaches and the methods of treatment of malaria in health facilities within the Mvomero district. In addition, this thesis examines the impact of environmental factors including precipitation, relative humidity and temperature on the number and burden of malaria cases in health facilities.

To answer the research questions, both quantitative and qualitative methods were employed. A total of 15 health facilities, including dispensaries, health centers and hospitals, were selected to collect data. In each facility, malaria data from 2002 to 2011, including monthly number of malaria cases and total diagnoses, were retrieved from government-required documents for all health facilities in Tanzania. Weather data, including monthly precipitation, average relative humidity and temperatures, recorded by a nearby weather station were collected from credible online resources. In addition, qualitative data were collected through in-depth interviews with health workers working in the facilities and with district officers. Statistical analyses, specifically, linear regression and ridge regression, were conducted to examine the trends in the number of malaria cases and the impact of weather on malaria. Qualitative analysis was conducted

to examine the common practices of malaria diagnoses and treatments in health facilities in the Mvomero district.

This study found that the burden of malaria in Mvomero district remained significant from 2002 to 2011. No significant increasing or decreasing trends in the number of malaria cases in health facilities were found during the past decade. Regarding the impact of weather on the number of malaria cases, the study found that increases in relative humidity and maximum temperature led to increases in malaria cases. However, precipitation seems to have dual effects. It decreases the number of malaria cases for the current month while it increases the number of cases in later months. From the qualitative analysis, the study showed that due to the lack of equipment and technicians, microscopy was not widely used in Mvomero district, though recommended by the government. Clinical diagnosis was still the major way used to diagnose malaria. Many health workers showed trust in clinical diagnosis. As for treatment, artemether-lumefantrine (ALU), which has been recommended as first-line antimalarial drug in Tanzania since 2007, has replaced sulfadoxine-pyrimethamine (SP) to become the most commonly used antimalarial drug in Mvomero district. Most of the health workers welcomed the use of ALU and considered it a safe and effective drug.

Dedication

This thesis is dedicated to my dear parents who supported my graduate study both spiritually and financially without asking anything for return.

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At last, thank you to those who have reviewed this thesis in part or in full.

1. Introduction

Malaria remains a significant global health challenge. According to WHO's latest estimate, there were about 219 million malaria cases in 2010 and the estimated number of deaths due to malaria was about 660,000. About 90% of all the malaria-related deaths occur in Africa, making Africa the most affected region (WHO, 2012). In the past decade, great progress has been made in the fight against malaria. Because of the implementation of effective interventions such as insecticide treated nets (ITNs) and indoor residual spraying (IRS) and improved case management strategies, between 2000 and 2010, the number of deaths due to malaria decreased by a third and the incidence of malaria decreased by 17% globally (Kendall, 2012).

In Tanzania, the percent of population potentially protected by ITNs increased from 5% in 2002 to about 90% in 2011. According to a national household survey, the percent of Tanzanian households that have at least one ITN was 63% in rural areas (WHO, 2012). In terms of the number of malaria cases and deaths due to malaria, the number of malaria cases in Tanzania decreased from more than 15 million in 2003 to about 14 million in 2011, and the related deaths decreased from 15,000 in 2003 to about 11,000 in 2011 (WHO, 2012). All of these facts show improvements in the malaria situation in Tanzania which parallels the global trends.

The effectiveness of the interventions such as ITNs, IRS and RDT on reducing infection has been demonstrated by many studies. However, controversy still exists on whether these approaches can effectively reduce disease episodes in addition to reducing infection (Makundi et al., 2007). Aiming at providing more information on malaria in the study area, this study was undertaken to investigate the trends of malaria cases, the diagnostic methods and treatments for malaria in rural health facilities in Tanzania in the context of an ongoing study of both vector control and early detection and treatment interventions. In addition, this study makes use of existing weather data to examine the relationship between environmental factors and the number and burden of malaria cases in a rural area of Tanzania.

This study builds upon a NIH-funded large cluster-randomized study aiming to evaluate the individual and combined effects of Larval Source Management (LSM) and early detection and treatment (rapid diagnostics testing for malaria by community health workers) interventions. The title of this project is *Implementation Science to Optimize Malaria Vector Control and Disease Management* (NIH RO1 AI 88009-01A1). The principal investigators are Dr. Randall A. Kramer from Duke Global Health Institute (DGHI) and Dr. Leonard Mboera from Tanzania National Institute of Medical Research (NIMR). This research is now underway in 24 villages in Mvomero district, Tanzania. To assess the individual and combined effect of larviciding and rapid diagnostic tests (RDT), 24 study villages were randomly assigned to four groups: Group 1 (No intervention); Group 2 (RDT Intervention); Group 3 (Larviciding Intervention); and Group 4 (RDT and Larviciding Interventions). The primary objective of this project is to estimate the individual and combined effects of larviciding and RDT interventions (Kramer, 2009). The longitudinal data in the R01 study includes household surveys, malariometric surveying, and entomological surveying.

This thesis is built upon and informs the ongoing research by developing and researching the health-facility based component of the study, including investigating the trends, the diagnostic approaches and the methods of treatment of malaria in health facilities within the Mvomero district. The study examines trends in the number of malaria cases over the decade from 2002 to 2011 and how the diagnosis and treatment of malaria have changed. In addition, this study examines how, if at all, the health facility data may differ across the study area, particularly with regards to potentially impactful factors such as facility type to the extent that the comparisons can be made. However, the opportunities to examine the specific relationship of the interventions to malaria infection at health facilities is precluded by the timing of the health facility research in the context of the broader study—the health facility data was collected just shortly after the first round of interventions and does not include the year in which the interventions started. Nonetheless, pre-intervention health facility data can be used to assess pre-existing patterns of infection and diagnosis across the study area. In addition to the quantitative analysis, in-depth interviews were conducted with staff of selected health facilities to explore their opinions on the trends, diagnosis and treatment of malaria in their facilities and their attitudes towards the impact of the diagnosis and treatment on malaria case management in health facilities. Additionally, the author uses existing weather data recorded by a weather station near Mvomero district to examine the potential impact of selected environmental factors on the number of malaria cases in facilities.

Based on the need of the ongoing research and a careful literature review, the specific research questions to be addressed by this study are:

(1) How has the number of malaria cases changed over the past decade from 2002 to 2011 in rural health facilities in Mvomero?

(2) What is the relationship between selected environmental factors, such as relative humidity, rainfall, and the temperature, and the number and burden of malaria cases presented at rural health facilities in Mvomero?

(3) How is malaria diagnosed and treated in health facilities in Mvomero, and what are health workers' attitudes toward malaria diagnosis and treatment in their facility?

2. Literature review

According to WHO's World Malaria Report, in 2010 about 660,000 people died from malaria, and about 90% of the deaths occurred in Africa (WHO, 2012). In Tanzania, malaria is the third most burdensome disease following HIV/AIDS and lower respiratory infection (WHO, 2006). In 2010, about 16,000 people died from malaria nationwide, accounting for 2.8% of total deaths in that year, and among all the deaths caused by malaria, more than 40% were children under 5 years of age (WHO, 2012; Tanzania National Bureau of Statistics, 2011; WHO 2006). In Mvomero, the problem of malaria is even worse. As an agricultural area, Mvomero has a high malaria transmission rate. In 2005, the annual average entomological inoculation rate (EIR) in Mvomero was 728 infectious bites per person per year (Mboera et al., 2010), more than 300 times higher than the annual EIR of 2.4 infectious bites per person per year in Lower Moshi located in Northern Tanzania in 2004 (Oesterholt et al., 2006).

However, during the past decade, a great amount of money has been spent on malaria control programs in Tanzania. From 2003 to 2010 the total funds money spent on malaria control increased from about $ 500,000 to more than $ 168,000,000 (WHO, 2012). Because of such a huge amount of input, progress has been made in fighting malaria. In 2009, although the whole country was still at high transmission risk of malaria according to the WHO definition, the incidence rate of malaria had dropped significantly from 17 per 1,000 to around 1 per 1,000 since 2009. This great progress was mainly due to multiple interventions introduced since 2004, including wide distribution of insecticide-treated nets (ITNs) and indoor residual spraying (IRS) (WHO, 2010).

It is undeniable that ITNs and IRS are very effective vector control interventions. They are highly regarded by both researchers and policy makers (Lengeler, 2004; WHO, 2005). In contrast, as a historic vector control intervention, larval source management (LSM) has not received a lot of attention although it has proved a very effective vector control intervention (Worrall & Fillinger, 2011). Recent studies in rural areas of western Kenya have shown that 1.5 years of LSM interventions, including weekly larviciding using microbial larvicide Bti, reduce adult female mosquitos by 90%. Furthermore, one study found that vector control interventions combining ITNs and LSM can be twice as effective as an intervention using ITNs alone (Fillinger & Lindsay, 2006; Fillinger et al, 2009). All these facts show the potential of LSM to be an effective vector control intervention.

Active case detection with RDT paired with treatment is another important intervention to control malaria. Since the introduction of effective yet expensive artemisinin- based combination therapies (ACT), accurate diagnosis of malaria has become more important than before (Allen et al., 2011). In Tanzania, it is a long-time tradition to diagnose malaria based mainly on clinical symptoms in health facilities in poor areas due to lack of laboratory equipment and trained technicians (Reyburn et al., 2004). This leads to over-diagnosis, which presents two problems. First, it leads to massive over-prescription of antimalarial drugs and promotes antimalarial drug resistance. Second, it results in higher mortality and morbidity because for some febrile patients, their true causes of the fever remain untreated (Reyburn et al., 2004). Therefore, as a cheaper alternative to laboratory tests, RDT, with its high sensitivity and specificity, becomes a particularly important intervention to control malaria in poor areas of Tanzania (Masanja, et al., 2010). In addition, compared with microscopy, the use of RDT is much easier and no laboratory technician is needed to use it, making it more suitable to be scaled up in resource limited settings (Hawkes, et al., 2009). Today, the most extensively used RDT is Para-Check Pf®, with sensitivity of more than 90% and specificity ranging from 52% to 99.5% (Allen et al., 2011).

In 2009, RDT, as an intervention, was recommended in all levels of care in Tanzania as a complement to microscopy (Masanja et al., 2012). However, after three years, the actual implementation of RDT in Tanzania, especially in rural areas, is still low. In addition, little research has been done to investigate the prevalence and diagnosis of malaria in health facilities in Mvomero. Therefore, considering the knowledge gaps listed above, this study is meaningful in that it provides useful information on malaria case management in rural health facilities in Tanzania and helps the ongoing research to obtain important background information on the trends, diagnosis and treatment of malaria in health facilities in Mvomero district.

3. Methods

3.1 Study Area

This study was conducted in rural area of Mvomero (latitudes 5°47’09’’-7°23’40’’S, longitudes 37°11’09’’-38°01’33’’E), Tanzania. Mvomero district is located in the Morogoro region of east-central Tanzania. Mvomero is a malaria endemic area with the prevalence of malaria among children under five years old being 15.7% (Tanzania Commission for AIDS et al., 2008), and the average rate of parasitemia among residents in seven villages in Mvomero being 34.5% (Mboera et al., 2007). More than 80% of the adult populations in Mvomero are involved in agriculture, and those from villages practicing rice irrigation have a higher malaria prevalence rate compared with those from other villages (Mboera et al., 2010). There are two rainy seasons. The longer one lasts from March to May and the shorter one lasts from October to December. The climate in the northern area is humid in contrast to the dry climate in the south (Randell et al., 2010). The primary malaria vectors in Mvomero are Anopheles *gambiae sl* and Anopheles *funestus* (Mboera et al., 2007). Puddles, sunlit swamps, hoof prints, rice fields, sunlit pools, and man-made containers are major breeding sites for the female mosquitos (Randell et al., 2010).

There are six levels of health facilities in Tanzania, namely Village Health Posts, Dispensaries, Health Centers, District Hospitals, Regional Hospitals and Referral Hospitals. The higher the level of the health facilities is, the more comprehensive the health services they provide (Tanzania National Website, 2011). Since 1996 there has been a steady decrease in the number of health facilities in Morogoro Region. The rate of decrease in the number of dispensaries, health centers and hospitals in Morogoro Region was 1.25%, 19.23% and 14.29%, respectively (Profile of Morogoro Region, 2007). In 2006, Mvomero had 43 dispensaries including 35 public dispensaries and 8 private dispensaries, and 4 public health centers (Profile of Morogoro Region, 2007). In Mvomero, the district hospital is the highest level of health facility. Three district level hospitals in Mvomero are Mtibwa Sugar Estate Hospital, a private-employers facility, Turiani Hospital, a private-religious facility, and Chazi Hospital, a public facility. The regional hospital and referral hospital serving Mvomero (but located some distance away) are Morogoro Regional Hospital in Morogoro Town and Muhimbili National Hospital in Dar es Salaam, respectively (Tanzania National Website, 2011; Tanzania Mobile Portal, 2011). In 2006, the total number of beds in hospitals and health centers in Mvomero was 428, tantamount to 655 persons per bed (Profile of Morogoro Region, 2007).

3.2 Ethics

This study obtained ethical clearance from the Duke Institutional Review Board (protocol number B0069). As part of the ongoing project in Mvomero, this study has also been ethically approved by Tanzania National Institute for Medical Research (NIMR).

This is a descriptive study, whose aim is to explore the trends, diagnosis and treatment of malaria in health facilities in rural area of Mvomero, Tanzania. Therefore, the nature of this study leaves no room for biological harm. The major potential risk of this study is the breach of confidentiality. Confidentiality is assured by collecting and using aggregate and de-identified data at the health facilities for the quantitative analysis. For the qualitative analysis, all the questions in the interview have been approved by Duke IRB and all participants are required to sign an informed consent form before they are interviewed. All the data that have been collected are kept in safe place and are only accessible to authorized project staff.

3.3 Quantitative Methods

3.3.1 Data Collection

This study employed a mixture of both quantitative and qualitative methods. The quantitative data include malaria data and environmental data.

3.3.1.1 Malaria data

In this study the malaria data include (1) the number of malaria cases presented at health facilities, (2) the total number of diagnoses, (3) the number of microscopies conducted at health facilities and (4) the number of positive test results (data # 1 to 4). These data were collected from health records in selected facilities across the study area.

The major health record used to retrieve these data is the MTUHA[1] BOOK No. 2 which is an official health record required to be filled and kept at each registered health facility by the Tanzanian government. The data are all recorded by month. Since the studied period lasts for 10 years (from 2002 to 2011), each of the four variables contains 120 observations.

In addition to MTUHA BOOK No.2, another health record that the author used is MTUHA BOOK No.10. Similar to BOOK No.2, BOOK No.10 is a government-required health record kept at each facility. Most of the data listed above (1 to 4) can also be found in BOOK No.10 except that they are all recorded by quarter in BOOK No.10. These aggregate quarterly data were used in cases where the monthly data in BOOK No.2 was missing or not currently available.

In total, 15 health facilities, including 3 hospitals, 2 health centers and 10 dispensaries, were visited between June 18th and July 11th in 2012 to collect these quantitative data. Because this study is part of the broader ongoing research mentioned above, the facilities selected in this study are facilities serving the villages which are selected for the ongoing project. Since the villages selected in the broader project are randomly selected from all the villages in Mvomero districts, the health facilities selected in this study, therefore, can be regarded as being randomly selected from all the health facilities in Mvomero district. Out of 100 villages in Mvomero (Profile of

[1] MTUHA is the abbreviation in Kiswahili language meaning "Health Management Information System"

Morogoro Region, 2007), the broader project randomly selected 24 villages or 24% of all the villages. In comparison, out of 61 health facilities (Spreadsheet from Dr. Mboera, 2010), this study selects 15 facilities or 24.6% of all the facilities. The similarity between the two percentages is further evidence of the appropriateness of the selection of the facilities in this study. A detailed list of the selected facilities in this study and their catchment areas (by village and by ward) is found in Appendix A.

A spreadsheet was created as a data collection tool to collect these quantitative data from the health records. This tool is listed as Appendix B at the end of this paper.

3.3.1.2 Environmental data

Since no weather data are recorded in the health facilities, the environmental data, such as data on rainfall, temperature and humidity, were retrieved from credible online resources. As mentioned above, the malaria data, such as the number of malaria cases, are recorded by month and to allow an exploration of the relationship between the number of malaria cases and selected environmental factors, such as rainfall, the environmental data also need to be recorded by month. After careful searching, data were obtained from the website http://www.tutiempo.net . Although there are no monthly weather data specifically for Mvomero district, there are monthly weather data, including data on temperature, precipitation and humidity, for Morogoro region for the past decades. These regional data can represent the weather condition in Mvomero district approximately.

The monthly weather data such on temperature, precipitation and humidity were collected from this website.

3.3.2 Data Description

3.3.2.1 Malaria data

All malaria data (data # 1 to 4) were collected for the past decade from Jan. 2002 to Dec. 2011. They are monthly data which are classified into two age groups, namely under 5 years old and 5 years old and above. Data on the number of malaria cases and number of diagnoses are available in all the health facilities that were visited. Data are recorded on a daily basis by health facility personnel and at the end of each month, the total number is summed and is recorded in the MTUHA BOOK No.2. The quality of the data is good and there are few missing data for these two types of data.

For the total number of microscopies conducted and the number of positive test results, the data are only available at health centers and hospitals because only these facilities have the equipment and technicians required to conduct microscopy. These data are not recorded in the health record books by age group. The quality of these data is not as good as the data on the case number because of more missing data.

3.3.2.2 Environmental data

As mentioned above, environmental data were retrieved from online resources. The data include data on monthly average relative humidity, monthly average precipitation and monthly average temperatures (both maximum temperature and minimum temperature). Although the weather data on the website are recorded on daily basis, only monthly average data were retrieved and used in the analysis due to the fact that all of the malaria data are monthly data.

3.3.3 Quantitative Data Analysis

3.3.3.1 Malaria trends over the whole period from 2002 to 2011 and within a year

The first research question of this study examines the trends of malaria during the past decade. To achieve this goal, the annual number of malaria cases is calculated by summing up all the monthly data within a year. The trends of malaria for the whole period from 2002 to 2011 are examined both graphically and statistically using these annual malaria cases. Graphs of the data are plotted to show the trends visually. In addition, tables are generated based on linear regressions of the annual numbers of malaria cases against years to reveal the trends statistically.

In addition to the trends of malaria for the whole period, trends of malaria within a year are also examined. To examine the trends within a year, the average number of malaria cases for each month is calculated given the data collected. For example, the average number of malaria cases for January is calculated by summing up all the malaria cases in Januarys for the past 10 years and dividing the total number by 10. After calculating the average number of malaria cases for all 12 months, a graph will be used to show the trends visually.

3.3.3.2 Relationship between environmental factors and number of malaria cases

The second research question is to explore the relationship between selected environmental factors and the number of malaria cases. Based on a literature review, three potential environmental factors selected for the analysis are relative humidity, precipitation and temperature (LabSpace, 2013; Ray, 2009; Elipe et al., 2007; Pampana, 1969).

The relationship between these environmental factors and the number of malaria cases is explored using linear regression. The dependent variable is the monthly number of malaria cases and the independent variables are monthly average relative humidity, monthly average precipitation amounts and monthly average temperature including both maximum and minimum temperatures. All the variables in the model are continuous variables. However, relative humidity is a truncated continuous variable ranging from 0 to 100. This analysis can provide some insight into how the environmental factors may affect the number of malaria cases presented at health facility in Mvomero district.

Before conducting these quantitative analyses, the issue of missing data needs to be properly dealt with because the missing data biases the sum of malaria cases, which is the most important data for all the analyses. To deal with the issue, when the number of malaria cases is missing, it is imputed using the existing data through linear regression. Considering the heterogeneity among different health facilities and different months, the imputation is conducted by facility and by month. For example, if the number of malaria cases in facility A in July of 2007 is missing, then the number of malaria cases in facility A in July of the other years is used to impute the missing data through linear regression. All the missing data are imputed using this method before the analyses are conducted.

3.4 Qualitative Methods

3.4.1 Data Collection

The qualitative data were collected from each health facility selected for this study using the semi-structured interview method. At each facility, the doctor in charge and/or a nurse were interviewed to obtain information on the trends of malaria in each facility, the health workers' perspective on environmental factors that affect the number of malaria cases, the common diagnosis and treatment of malaria and the health workers' attitude towards different malaria diagnoses and treatments.

In addition to the interviews that were conducted in the health facilities, two key informant interviews were conducted in the malaria control district office. The officer and his assistant were interviewed and useful information was obtained on malaria trends across the district, diagnoses and treatments of malaria, the malaria control policy and malaria intervention programs conducted in the district.

To collect these qualitative data, the detailed in-depth interview outlines were developed as data collection tools. Since most of the interviews were conducted in

Swahili, all the interviews were recorded and summarized, and some of them were transcribed and translated into English for analysis. Since some of the interviewees cannot read English, the informed consent is translated into Swahili for subjects to read and sign. The interview outlines including the informed consent form in both languages are attached in the appendices.

3.4.2 Interview Sample

In total, twenty three people were interviewed. Two of the interviewees were malaria control district officers and all the others were health workers working in the health facilities that we visited. In each facility, we interviewed at least one health worker. The in-charge of the facility was our first choice but if the in charge was not available on the day we visited, other health workers were invited to participate in the interview voluntarily given their availability. In a facility where more health workers were available, we interviewed more than one person paying attention to the diversity of the interviewees. Our interviewees include facility in-charge, medical officer (MO), assistant medical officer (AMO), clinical officer (CO), assistant clinical officer (ACO), nurses and laboratory technicians.

The two district officers are a man and a woman, both in their thirties. The male officer holds a bachelor degree and the female officer is a clinical officer. They have worked in the district office for three and seven years respectively. Among the 21 health workers, 7 (a third) are male and 14 (two thirds) are female. The age ranges from 21 to 61 with the average age of 42.6. The working experience of the interviewees ranges from 7 months to 39 years, and the average working experience is 18.1 years. Most of the interviewees hold high a school diploma or above.

3.4.3 Interview Process

To obtain the needed information more efficiently, the interviews were conducted in a semi-structured way. Separate interview guidelines were carefully prepared for health workers and district officers respectively. All the interviews were structured around three topics namely, malaria diagnosis, malaria treatment and malaria interventions. The interviews with district officers covered topics on the general trends of malaria in the whole district, district guidelines for malaria diagnosis and treatment, common practices for malaria diagnosis and treatment in the district and the malaria intervention programs conducted in the district. The detailed interview guidelines for district officers are provided in Appendix C. The interviews were conducted in the district office where the officers work. Each interview lasted for about 30 minutes.

The interviews with health workers working in the facilities covered topics on the overall trends of malaria in nearby villages, weather factors affecting the number of malaria cases, guideline for malaria diagnosis and treatment available in the facility, common practices of malaria diagnosis and treatment in the facility and their knowledge and opinion on malaria intervention programs conducted in their village, particularly the use of RDTs The interviews with health workers were conducted in the facility where they worked and each interview took approximately 30 minutes to finish. The interview was conducted after the interviewee signed the informed consent form.

To make the conversation easier for the respondents, most of the interviews were conducted in Swahili, the national language of Tanzania. Dr. Makenga, a Tanzanian researcher as well as a medical officer, conducted all the interviews. The interviews were recorded with the permission of the interviewees, and eight interviews were fully transcribed.

3.4.3 Qualitative Data Analysis

Qualitative data analysis is conducted mainly based on the transcribed interviews and a summary of all the interviews. Different themes and topics are identified and interviewees' responses are classified.

4. Results:

4.1 Quantitative Analysis Results

4.1.1 Trends of the Number of Malaria Cases Presented at Facilities

4.1.1.1 Overall trends

Out of 15 health facilities from which the data were collected, 2 facilities, namely Kanga dispensary and Matale dispensary, are excluded from the analysis because most of the data from these two dispensaries are missing. The Kanga dispensary experienced a severe flood in 2009 and lost all the documents they had. The Matale dispensary was established in 2011 and thus only had one year's data by the time we visited it. The total population of the villages where the rest of the 13 facilities are located is 154,090 (Dr. Mboera, personal communication, August 10, 2012).

The numbers of malaria cases from 2002 to 2011 are shown in Table 1. The largest number of cases is seen in 2008 with the total number of malaria cases reaching 76,138 in that year and the lowest number is seen in 2011 with 46,649 cases in that year.

Table 1: Number of Malaria Cases, Total and by Age Groups, from 2002 to 2011

Year	Total	5 years old and above	Under 5 years old
2002	47002	28077	18925
2003	65938	43436	22502
2004	70539	46469	24070
2005	53044	33317	19727
2006	50876	32951	17925
2007	70780	46531	24249
2008	**76138**	47916	28222
2009	69647	45071	24576
2010	59577	38359	21218
2011	**46649**	30392	16257

The graphs showing the overall trends are seen in Figure 1 below. From the graphs we can see that there is no significant increasing or decreasing trend in the total number of malaria cases and in the number of malaria cases by either age group from 2002 to 2011. Simple time trend regression models were estimated for each age group. The coefficients for "Year", its 95% confidence intervals and the P-values are shown in Table 2. Although the coefficients are all positive suggesting a mild increase of malaria cases in the past 10 years, both the broad confidence intervals and the large P-values indicate that the increases are not statistically significant. Interestingly, two peaks are observed in 2004 and 2008 both of which are followed by significant drop in the next couple of years making the overall trends emerges as an "M" shape. Possible explanations for this odd shape are presented in the Discussion Section below.

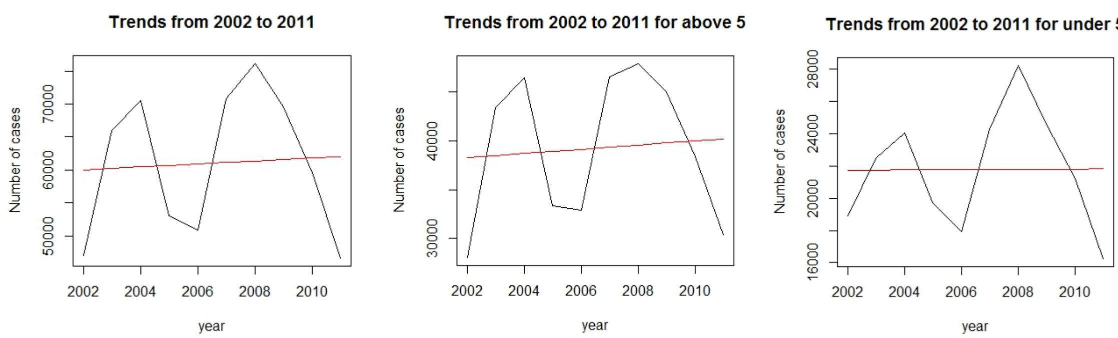


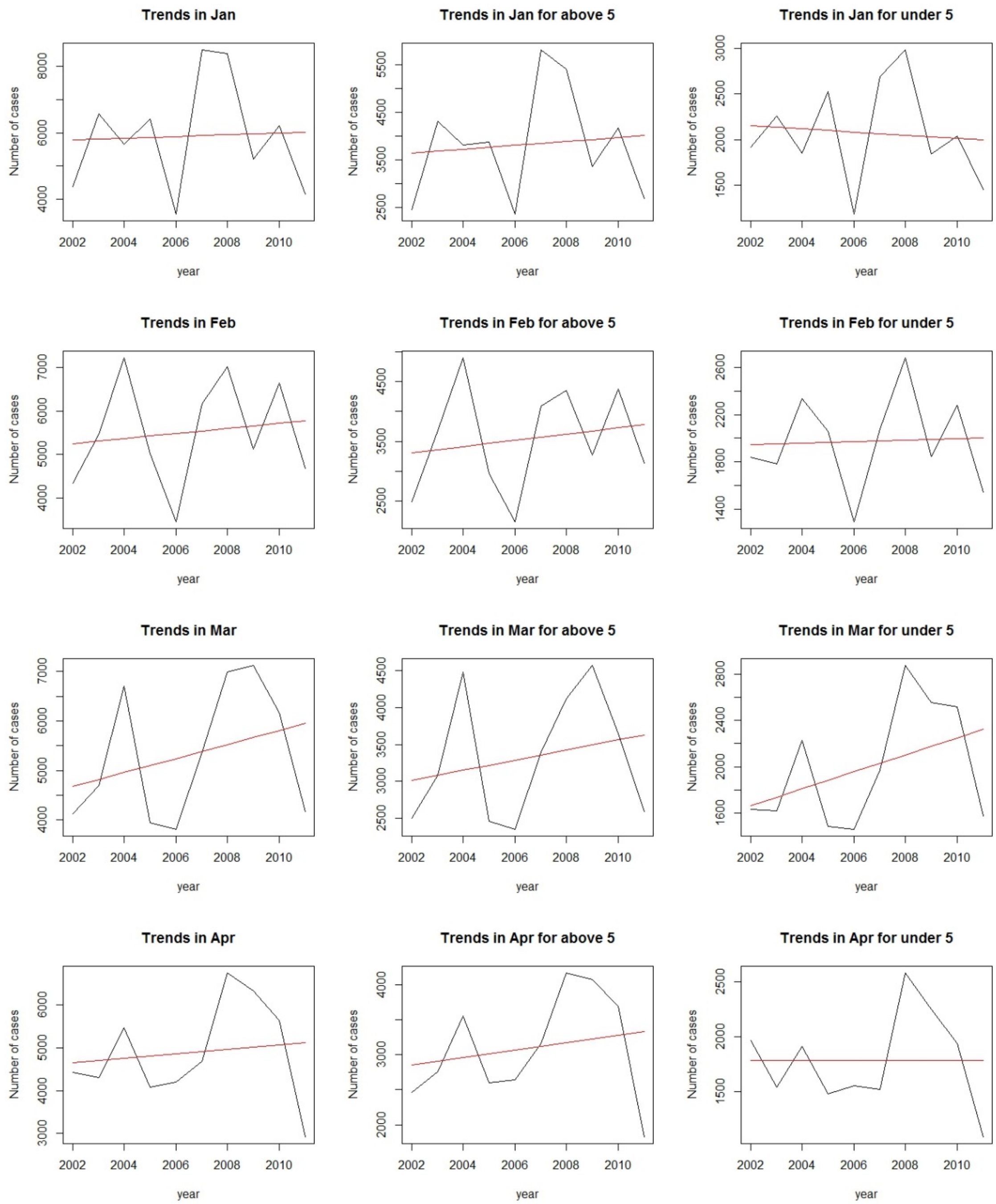
Figure 1: Graphs of the overall trends and the trends by age groups

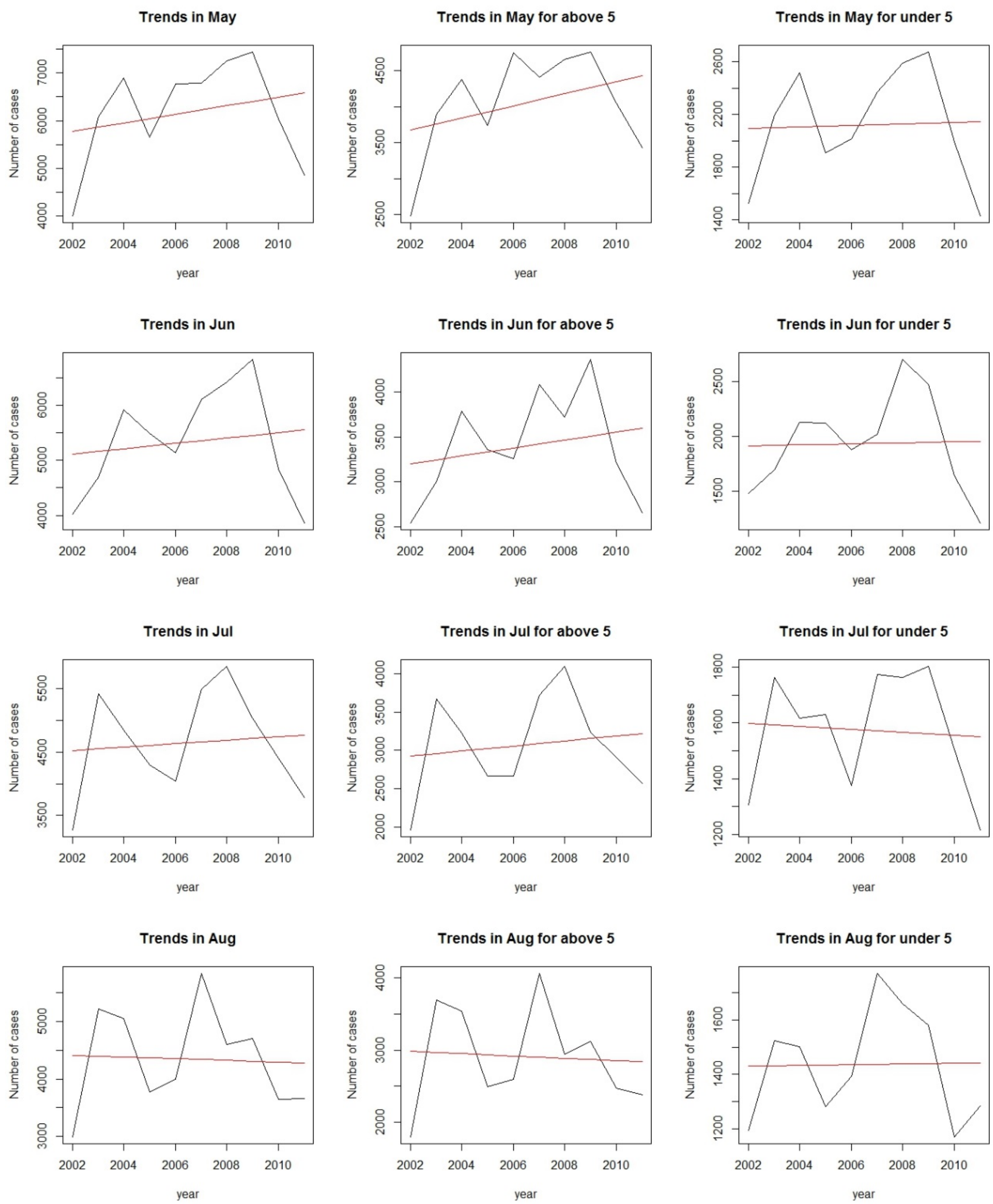
Table 2: Coefficients, 95% confidence interval and P-values for the time trend regressions

N=120	Coef (Year)	95% confidence interval	P-value
Overall Trends	224.4	(-2726.2, 3174.9)	0.87
Trends for above 5	216.3	(-1804.4, 2236.9)	0.81
Trends for under 5	8.1	(-972.0, 988.2)	0.99

4.1.1.2 Trends by month

Since the number of malaria cases in different months varies greatly, the trends of the number of malaria cases in different months is examined further. The graphs in Figure 2 showing the trends of the number of malaria cases in different months are presented below. The graphs indicate that the trends of the number of malaria cases in each month resemble the overall trends. None of the P-values in Table 3 is significant indicating that for any given month, there is no significant increasing or decreasing trend in the total number of malaria cases or in the number of malaria cases by either age groups during the past 10 years. Resembling the shape of the overall trends, the shapes of the trends in some months also look like an "M" with two peaks in 2004 and 2008, respectively.


Trends in Jan
Number of cases
4000 6000 8000
2002 2004 2006 2008 2010
year
Trends in Jan for above 5
Number of cases
2500 3500 4500 5500
2002 2004 2006 2008 2010
year
Trends in Jan for under 5
Number of cases
1500 2000 2500 3000
2002 2004 2006 2008 2010
year
Trends in Feb
Number of cases
4000 5000 6000 7000
2002 2004 2006 2008 2010
year
Trends in Feb for above 5
Number of cases
2500 3500 4500
2002 2004 2006 2008 2010
year
Trends in Feb for under 5
Number of cases
1400 1800 2200 2600
2002 2004 2006 2008 2010
year
Trends in Mar
Number of cases
4000 5000 6000 7000
2002 2004 2006 2008 2010
year
Trends in Mar for above 5
Number of cases
2500 3000 3500 4000 4500
2002 2004 2006 2008 2010
year
Trends in Mar for under 5
Number of cases
1600 2000 2400 2800
2002 2004 2006 2008 2010
year
Trends in Apr
Number of cases
3000 4000 5000 6000
2002 2004 2006 2008 2010
year
Trends in Apr for above 5
Number of cases
2000 3000 4000
2002 2004 2006 2008 2010
year
Trends in Apr for under 5
Number of cases
1500 2000 2500
2002 2004 2006 2008 2010
year


Trends in May
Trends in May for above 5
Trends in May for under 5
Trends in Jun
Trends in Jun for above 5
Trends in Jun for under 5
Trends in Jul
Trends in Jul for above 5
Trends in Jul for under 5
Trends in Aug
Trends in Aug for above 5
Trends in Aug for under 5
Number of cases
year
2002 2004 2006 2008 2010

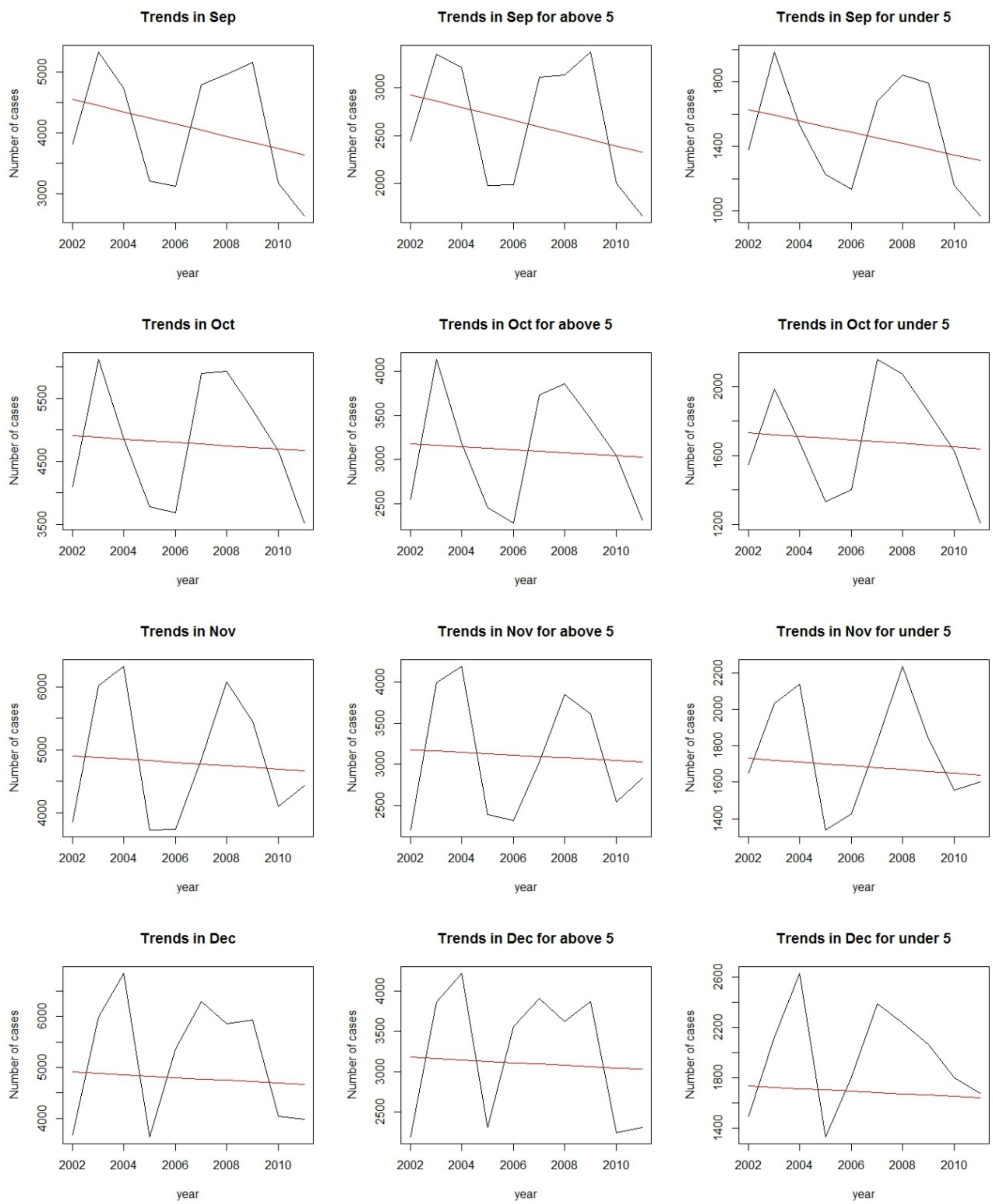


Figure 2: Graphs of the overall trends by month and by month and age groups

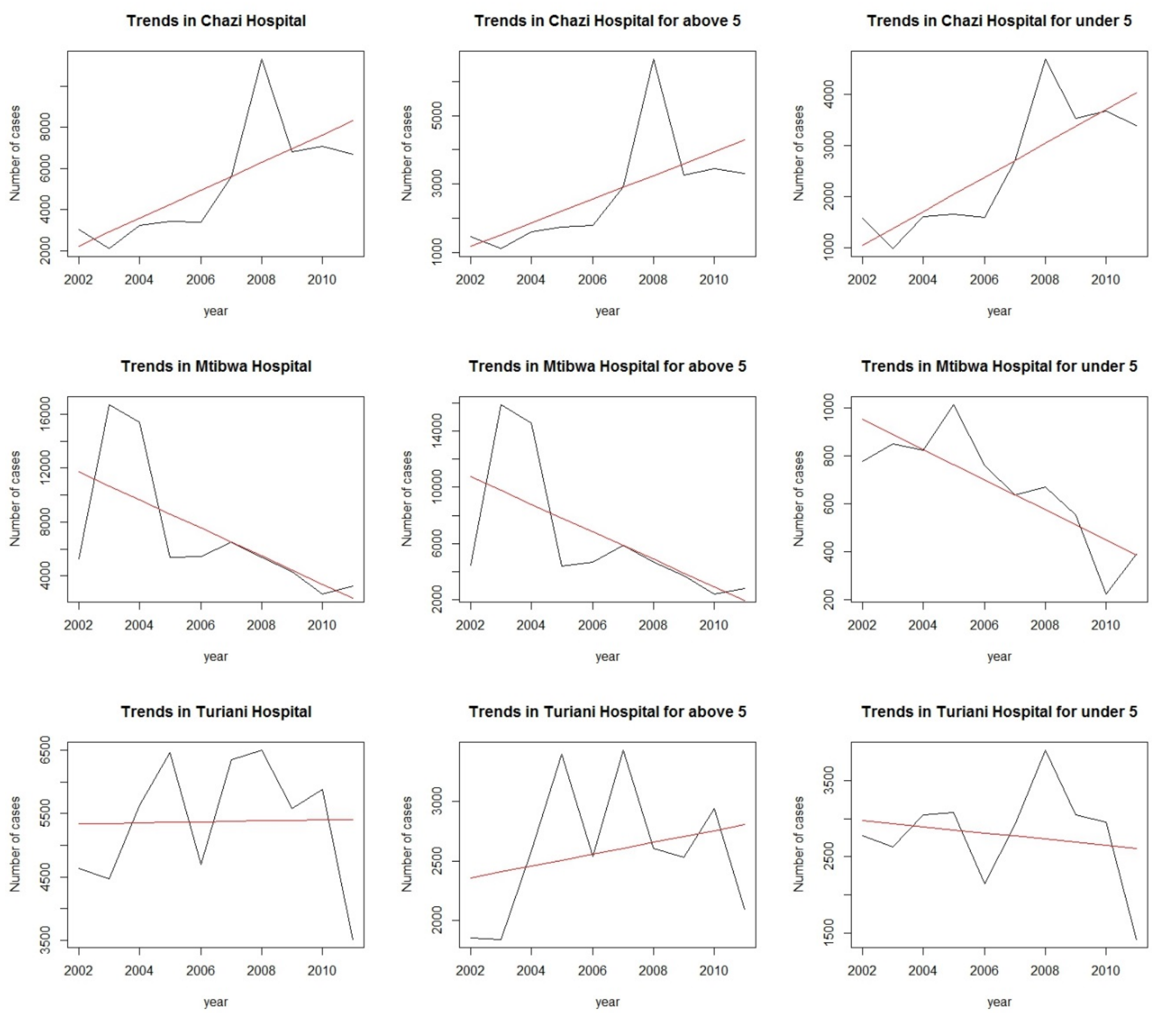
Table 3: Coefficients and P-values for the slope of the trends in each month

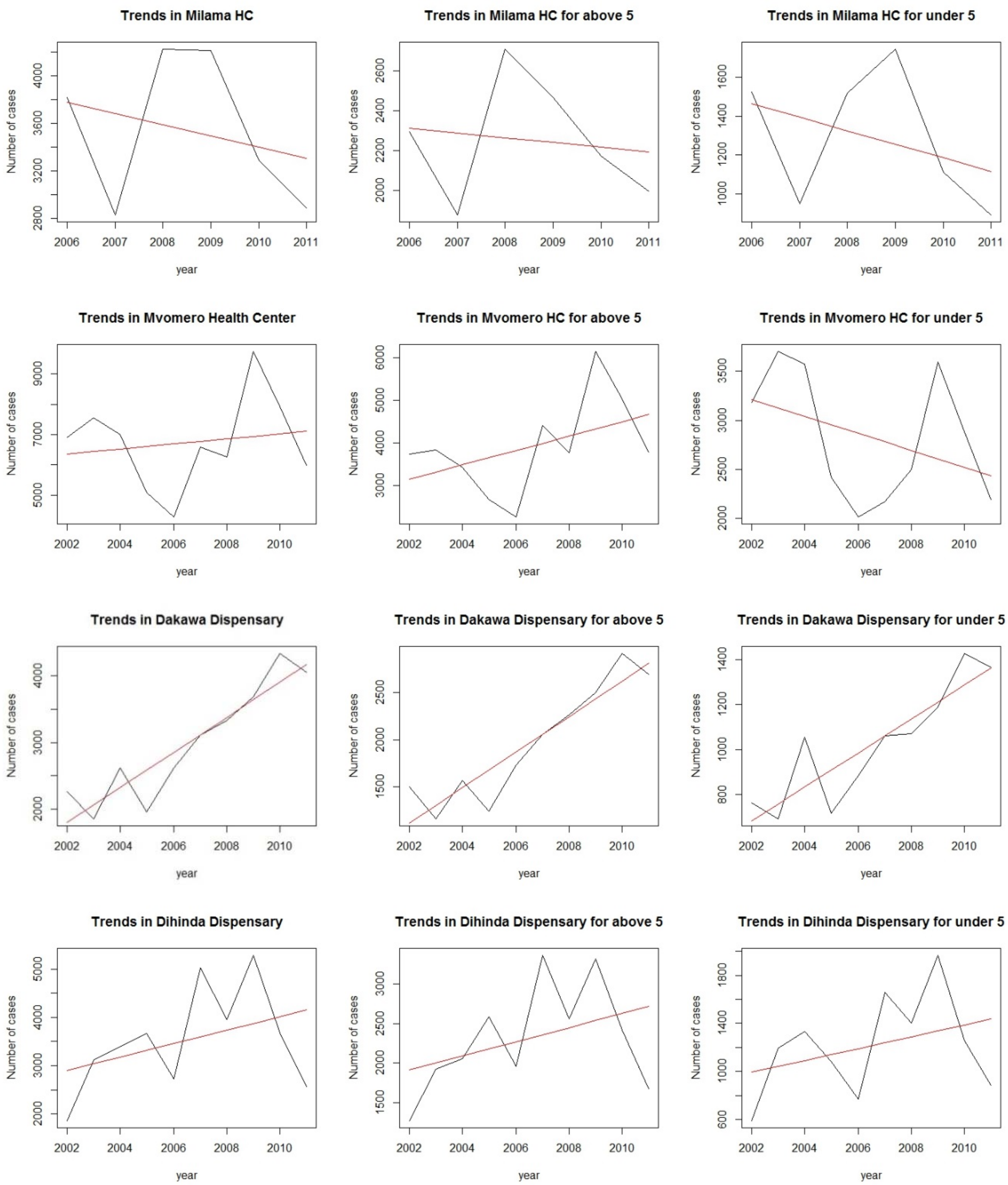
N=10	All age groups		5 years and above		Under 5 years	
	Coef	P-value	Coef	P-value	Coef	P-value
Jan	23.81	0.91	41.35	0.77	-17.53	0.79
Feb	58.11	0.69	51.97	0.62	6.14	0.90
Mar	142.00	0.36	68.69	0.50	73.26	0.22
Apr	52.17	0.71	52.73	0.56	-0.56	0.99
May	90.08	0.49	84.33	0.31	5.76	0.91
Jun	48.76	0.68	44.08	0.53	4.67	0.93
Jul	27.56	0.78	32.91	0.67	-5.35	0.84
Aug	-14.70	0.89	-16.07	0.85	1.37	0.96
Sep	-101.80	0.39	-66.86	0.40	-34.92	0.39
Oct	-26.53	0.82	-16.27	0.84	-10.26	0.79
Nov	-27.10	0.83	-13.76	0.88	-13.33	0.71
Dec	-47.96	0.74	-46.83	0.64	-1.13	0.98

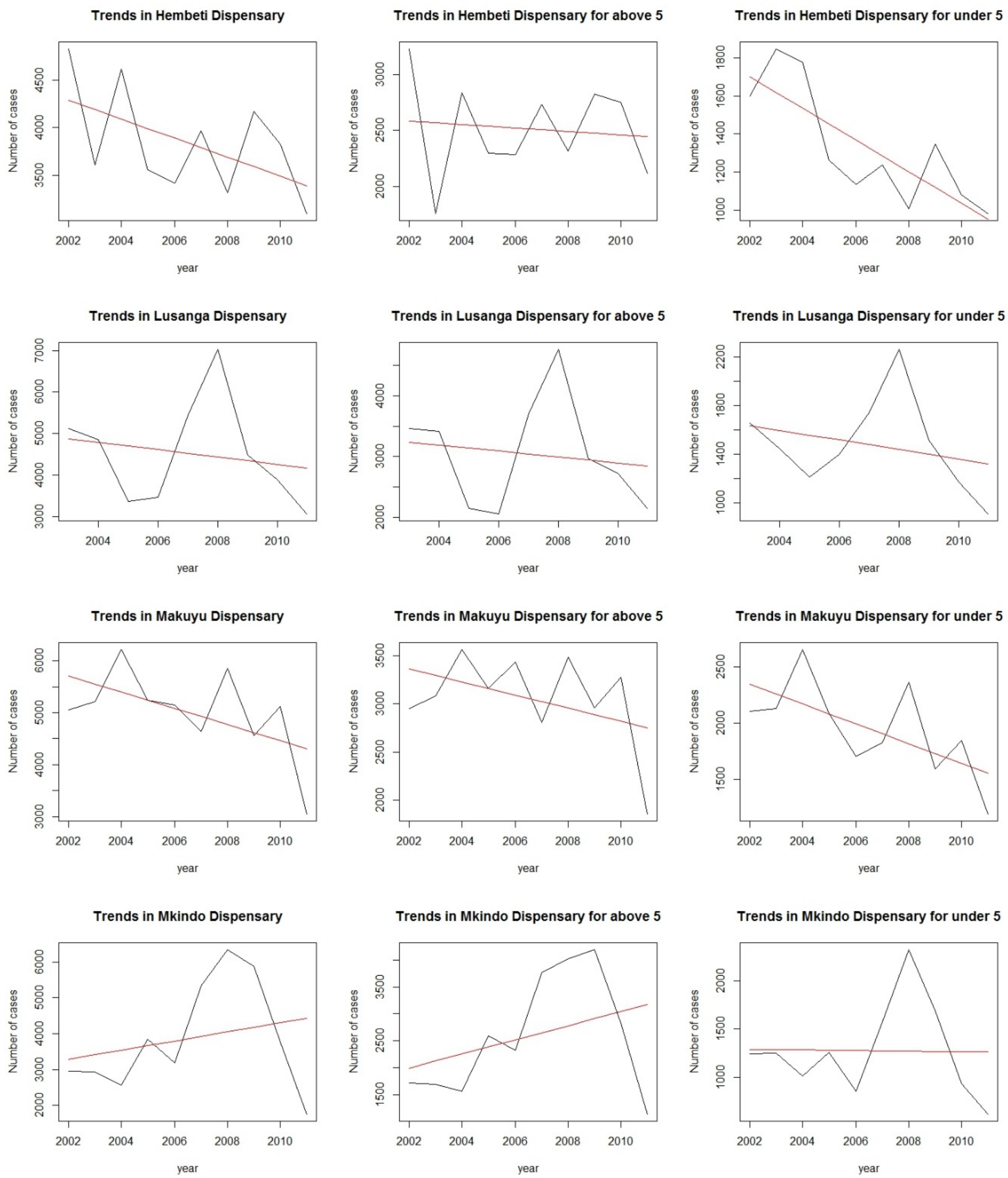
4.1.1.3 Time trends by facility

To examine whether the trends of the number of malaria cases varies among different facilities, the trends in each facility are studied. Figure 3 displays the overall trends in each facility. Different from the overall trends or the trends by month, the total number of malaria cases in certain facilities does demonstrate significant increasing or decreasing trends across years. For instance, there are significant increasing trends in Chazi Hospital and in Dakawa dispensary, and there is a significant decreasing trend in Mtibwa hospital. Heterogeneity in the trends among different facilities is observed. Table 4 shows the coefficients and the p-values for each facility. Out of 13 facilities, 7 facilities have negative coefficients. However, only Mtibwa Hospital’s coefficient is significant. The other six facilities have positive coefficients but only two of them, namely Chazi Hospital and Dakawa Dispensary, have significant positive coefficients.

Interestingly, compared with the above five population, children under five years old tend to have a more declining trends in terms of number of malaria cases. Ten out of thirteen facilities have negative coefficients for the trends for under 5 years old and four of the ten negative coefficients are significant suggesting that the number of malaria cases among children under 5 years old tend to decline in most facilities.




Trends in Milama HC
Trends in Milama HC for above 5
Trends in Milama HC for under 5
Trends in Mvomero Health Center
Trends in Mvomero HC for above 5
Trends in Mvomero HC for under 5
Trends in Dakawa Dispensary
Trends in Dakawa Dispensary for above 5
Trends in Dakawa Dispensary for under 5
Trends in Dihinda Dispensary
Trends in Dihinda Dispensary for above 5
Trends in Dihinda Dispensary for under 5
Number of cases
year



Trends in Hembeti Dispensary
Trends in Hembeti Dispensary for above 5
Trends in Hembeti Dispensary for under 5
Trends in Lusanga Dispensary
Trends in Lusanga Dispensary for above 5
Trends in Lusanga Dispensary for under 5
Trends in Makuyu Dispensary
Trends in Makuyu Dispensary for above 5
Trends in Makuyu Dispensary for under 5
Trends in Mkindo Dispensary
Trends in Mkindo Dispensary for above 5
Trends in Mkindo Dispensary for under 5
Number of cases
year

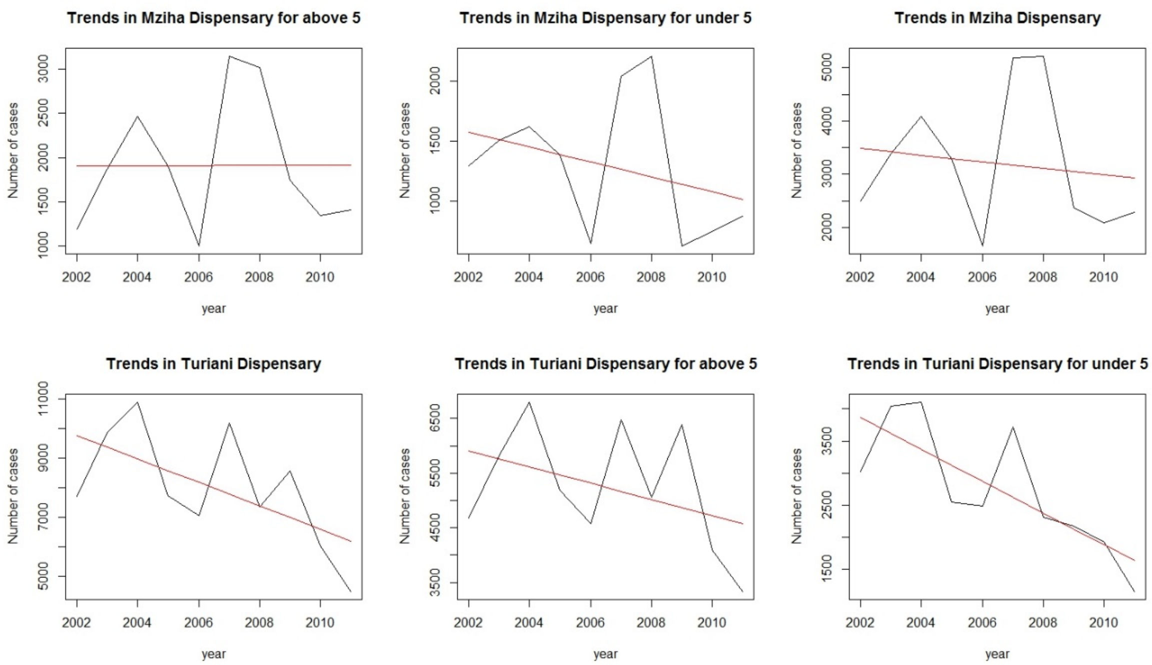


Figure 3: Graphs of the time trends by facility and by age groups

Table 4: Coefficients and the P-values for the slope of the time trends in each facility

	All age group		5 years and above		Under 5 years	
	Coef	P-value	Coef	P-value	Coeff	P-value
Chazi Hospital	676.8	0.0164	345.0	0.0452	331.8	0.0035
Dakawa Dispensary	263.2	0.0001	187.6	0.0001	75.7	0.0007
Dihinda Dispensary	138.7	0.2569	89.6	0.2498	49.2	0.3061
Hembeti Dispensary	-99.2	0.1100	-15.6	0.7630	-83.6	0.0048
Lusanga Dispensary	-88.1	0.6207	-48.8	0.7008	-39.3	0.4737
Makuyu Dispensary	-155.9	0.0957	-67.9	0.2300	-88.0	0.0433
Mikindo Dispensary	128.2	0.4760	131.3	0.3060	-3.1	0.9581
Milama Health Center	-94.1	0.5927	-24.4	0.7782	-69.7	0.4683
Mtibwa Hospital	-1039.6	0.0458	-976.8	0.0572	-62.8	0.0038
Mvomero Health Center	83.8	0.6456	169.4	0.1807	-85.6	0.2530
Mziha Dispensary	-61.1	0.6882	0.9	0.9920	-62.0	0.3508
Turiani Dispensary	-396.7	0.0605	-149.4	0.2490	-247.3	0.0084
Turiani Hospital	8.2	0.9460	49.3	0.4564	-41.1	0.5960

4.1.1.4 Time trends within a year

To examine the trends in the number of malaria cases within a year, further analysis was conducted. Figure 4 shows the trends. The average number of malaria cases peaks in January and May and reaches the bottom in September. The total average number of monthly malaria cases is between 4000 and 6000. A detailed listing of the average number of malaria cases is shown in Table 5.

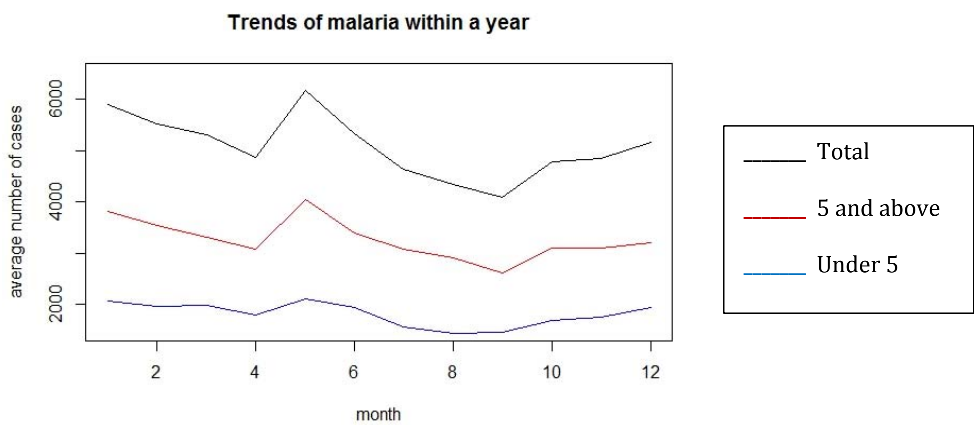


Figure 4: Trends in the number of malaria cases within a year

Table 5: Monthly average number of malaria cases within a year

	Total	5 years and above	Under 5 years
Jan	5899	3825	2074
Feb	5517	3543	1974
Mar	5314	3321	1993
Apr	4879	3092	1787
May	6178	4057	2121
Jun	5332	3398	1934
Jul	4648	3072	1576
Aug	4347	2911	1436
Sep	4094	2625	1469
Oct	4788	3102	1686
Nov	4860	3096	1765
Dec	5164	3210	1954

4.1.2 Trends in the Burden of Malaria Cases Presented at Facilities

To demonstrate the burden of malaria, two indicators are used, namely ratio of the number of malaria cases to the total diagnoses and the ratio of positive blood smears. The trends in the two indicators from 2002 to 2011 are examined.

4.1.2.1 Trends in the ratio of the number of malaria cases to the total diagnoses

The ratio of the number of malaria cases to the total diagnoses tells us what portion of total patients is diagnosed with malaria. Naturally, this indicator reflects the burden of malaria at the facility level. Figure 5 show the trends visually.

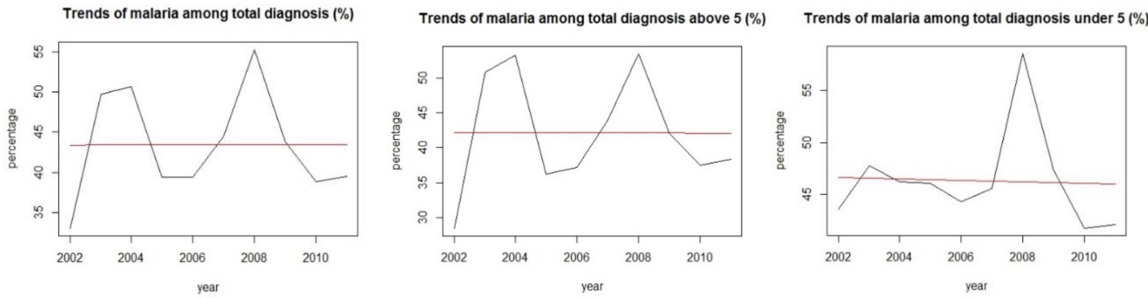


Figure 5: Trends in malaria cases among total diagnoses from 2002 to 2011

The regression lines in the three plots above are nearly horizontal, showing that overall there are no increasing or decreasing trends of this ratio from 2002 to 2011 although the ratio fluctuated greatly during this period. The overall trends and the trends for people above 5 years old demonstrate two peaks, one in 2003/2004 and the other is in 2008 resembling the trends of the number of malaria cases for overall population and population above 5 years old. However, the trends for people under 5 years old in Figure 5 only has one peak in 2008 which looks different from the trends of the number of malaria cases for people under 5 years old in Figure 1.

4.1.2.2 Trends in the ratio of the positive blood smear

Although the ratio of the number of malaria cases to total diagnoses would seem to reflect the burden of malaria, sometimes it is inaccurate because many patients are diagnosed with malaria based on their clinical symptoms, and the accuracy of clinical diagnosis is fairly poor (Hawkes et at., 2009). With many misdiagnoses, the percentage of malaria cases among total diagnoses falls short as a good measure of the burden of malaria. An alternative indicator is the ratio of the positive blood smears to the total blood smears conducted. In facilities where microscopy can be conducted, patients can be diagnosed more accurately with a blood smear examination. Besides, many diseases share the same symptoms with malaria such as fever, nausea and nausea. Therefore, the positive ratio of blood smears can be a better indicator of the burden of malaria compared with the ratio of the number of malaria cases to total diagnoses. Figure 6 below shows the overall trends of the ratio of positive blood smears from 2002 to 2011. Figure 6 demonstrates a slightly decreasing trend from 2002 to 2011 although the decreasing trends are not significant (Table 6). There are two peaks in 2005 and 2008 and a valley in 2006. What is noteworthy is that the positive ratio has been declining dramatically since 2008, and it reached 19.1% in 2011, the first time this number has ever been below 20% over the decade. The next lowest number is 26.6% in 2006. The detailed data are seen in Table 7.

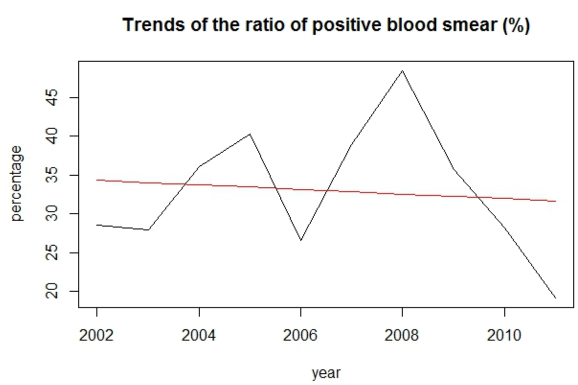


Figure 6: Overall trends in the ratio of positive blood smear

Table 6: Coefficients, 95% confidence interval and P-values for the time trends in the ratio of malaria cases to total diagnoses.

	Coef (Year)	95% confidence interval	P-value
Ratio of Malaria Cases to Total Diagnoses			
Overall Trends	-0.01	(-1.81, 1.82)	0.99
Trends for 5 and above	-0.01	(-2.24, 2.22)	0.99
Trends for under 5	-0.07	(-1.35, 1.22)	0.91
Ratio of positive Blood Smear			
Overall Trends	-0.30	(-2.57, 1.98)	0.77

Table 7: Yearly average ratios from 2002 to 2011

Year	Ratios of malaria cases to total diagnoses			Ratio of positive blood smear
	Overall	5 and above	Under 5	Overall
2002	33.0	28.4	43.6	28.5
2003	49.7	50.8	47.7	28.0
2004	50.7	53.3	46.2	36.1
2005	39.4	36.3	46.1	**40.3**
2006	39.4	37.2	44.3	26.6
2007	44.5	44.0	45.6	38.9
2008	55.3	53.5	58.6	48.5
2009	43.8	42.1	47.3	35.7
2010	38.9	37.5	41.7	28.1
2011	39.6	38.3	42.1	**19.1**

4.1.2 Impact of Environmental Factors on Malaria in the Study Area

4.1.2.1 Impact of environmental factors on the number of malaria cases

Based on the earlier literature review in section 3.3.3.2, the environmental factors considered for the analysis include precipitation, relative humidity and temperature (LabSpace, 2013). Since precipitation may have a delayed effect on the number of malaria cases, meaning that the number of malaria cases in one month may be influenced by the amount of rainfall in the previous month, therefore a “lag” analysis matching the number of malaria cases to previous month precipitation is conducted.

To conduct the “lag” analysis, both current month’s precipitation and previous month’s precipitation are included in the model. A variable named Prev_PP is created by moving all the original precipitation data one month ahead. In terms of temperature, both minimum and maximum temperature are used to examine which one has more impact on the number of malaria cases.

To examine the relationship between the environmental factors and the number of malaria cases, a linear model is proposed. The dependent variable in the linear model is the monthly number of malaria cases in the whole region. Figure 7 and Table 8 show the distribution and the quantiles of the dependent variable, respectively.

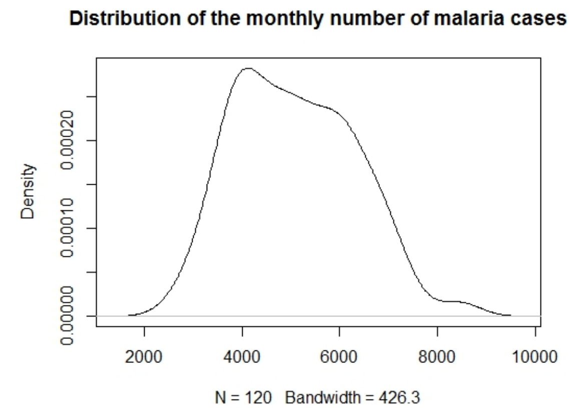


Figure 7: Distribution of the monthly number of malaria cases

Table 8: Quantiles of the monthly number of malaria cases

Quantiles	0%	25%	50%	75%	100%
Quantities	2632.0	4042.5	5000.5	6030.0	8501.0

To use a linear model, the dependent variable should be normally distributed. The above figure and the table show that the distribution of the dependent variable is approximately normal validating the use of linear model.

The potential independent variables or predictors include monthly precipitation (mm), last month precipitation (mm), monthly average relative humidity (%), and monthly average maximum and minimum temperature (C^o).

To run a linear model, collinearity among the independent variables can be problematic. Intuitively, weather variables are strongly correlated with each other. For example, relative humidity is believed to strongly correlate with precipitation. Therefore, the correlation between independent variables is carefully examined. Table 9 contains a correlation matrix for the independent variables.

Table 9: Correlation matrix of the independent variables

	H	PP	Prev_PP	Tmax	Tmin
H		0.48	0.53	-0.26	0.26
PP	0.48		0.28	0.19	0.43
Prev_PP	0.53	0.28		-0.11	0.23
Tmax	-0.26	0.19	-0.11		**0.74**
Tmin	0.26	0.43	0.23	0.74	

H: monthly average relative humidity (%),
PP: monthly average precipitation (mm)
Prev_PP: last month average precipitation (mm)
Tmax: monthly average maximum temperature (C^o)
Tmin: monthly average minimum temperature (C^o)

The correlation matrix shows that the correlation between maximum and minimum temperature is very strong, greater than 0.7. Since the two temperatures are strongly correlated and either of them can represent the factor of temperature appropriately, therefore, only one of them will be included in the regression model. In the analysis, the maximum temperature is chosen to be used to fit the model. However, when the best model has been found, the maximum temperature will be replaced by the minimum temperature to see which one fits the model better. There is a moderate positive correlation (around 0.5) between precipitation/last month precipitation and relative humidity. The effect of these correlations is examined by comparing the results of models containing each of the three variables (H, PP and Prev_PP) with the results of the model containing all of the three variables. If the results vary greatly, collinearity is a threat to the model and thus need to be carefully dealt with.

The models that are considered for the analysis are listed in the table below. First, the potential predictors are examined individually and then combinations of the potential predictors are examined. The goal is to find the model which fits the data best. As mentioned above, special attention is paid to potential collinearity between predictors.

Table 10: Models considered for the environmental analysis

No.	Models
1	Total= $\beta_0 + \beta_1$*H+ ε
2	Total= $\beta_0 + \beta_1$*PP+ ε
3	Total= $\beta_0 + \beta_1$*Prev_PP+ ε
4	Total= $\beta_0 + \beta_1$*Tmax+ ε
5	Total= $\beta_0 + \beta_1$*H + β_2*PP+ β_3*Prev_PP + β_4*Tmax + ε
6	Total= $\beta_0 + \beta_1$*H + β_2*PP+ β_3*Tmax + ε
7	Total= $\beta_0 + \beta_1$*H + β_2*Prev_PP+ β_3*Tmax +ε
8	Total= $\beta_0 + \beta_1$*PP + β_2*Prev_PP+ β_3*Tmax + ε
9	Total= $\beta_0 + \beta_1$*H + β_2*PP+ β_3*Prev_PP + β_4*Tmin + ε

Total: monthly total number of malaria cases for all facilities
H: monthly average relative humidity (%),
PP: monthly average precipitation (mm)
Prev_PP: last month average precipitation (mm)
Tmax: monthly average maximum temperature (C^o)
Tmin: monthly average minimum temperature (C^o)

Software R is used to estimate the linear models using Ordinary Least Squares, and the results of the models are shown in Table 11 below. Based on criteria such as adjusted R^2, mean squared residuals (MSR) and signs and significance levels of the coefficients, the model that fits the data best is model 5 with humidity, precipitation, last month precipitation and maximum temperature as the predictors. The coefficients of the predictors in this model are all significant at the 95% confidence level showing that all the predictors are important. In addition, model 5 has the highest adjusted R2 and the lowest MSR indicating that this model has the best performance in terms of fitting the data. The coefficient of relative humidity is 70.48 suggesting that each additional percent increase in monthly average relative humidity increases the monthly number of malaria cases by about 70. The coefficients for monthly precipitation and last month precipitation are -5.60 and 3.62 respectively, suggesting that each additional millimeter precipitation in a month decreases the number of malaria cases in that month by about 6, and increases malaria cases in the next month by about 4 cases. The coefficient for monthly average maximum temperature is 176.67 meaning that each additional Celsius degree increase in the average maximum temperature leads to 177 more malaria cases in that month.

In terms of collinearity, the most troublesome issue is the correlation between relative humidity and last month average precipitation. With the monthly precipitation and maximum temperature in the model, model 5 contains both relative humidity and last month precipitation while model 6 and model 8 contain only relative humidity and only last month precipitation respectively. Comparing model 5 with model 6, it seems that dropping last month's precipitation does not change the coefficients of other variables or the overall model performance (suggested by adjusted R^2) very much.

However, comparing model 5 and model 8, dropping relative humidity from the full model seems to have a large impact on the coefficients and overall model performance. Given these facts, it is difficult to draw conclusion on whether collinearity is problematic so far.

Therefore, linear ridge regression, a technique dealing with collinearity, is used to further examine this issue. The basic idea of this method is to add a penalty parameter λ into the model to adjust for the collinearity between predictors. With the increase of the parameter λ, the coefficients are shrinking towards 0. The relationship between the parameter λ and the coefficients can be shown using a trace plot which is usually called "ridge trace" (Brown, 1994). The ridge trace for model 5 is shown below.

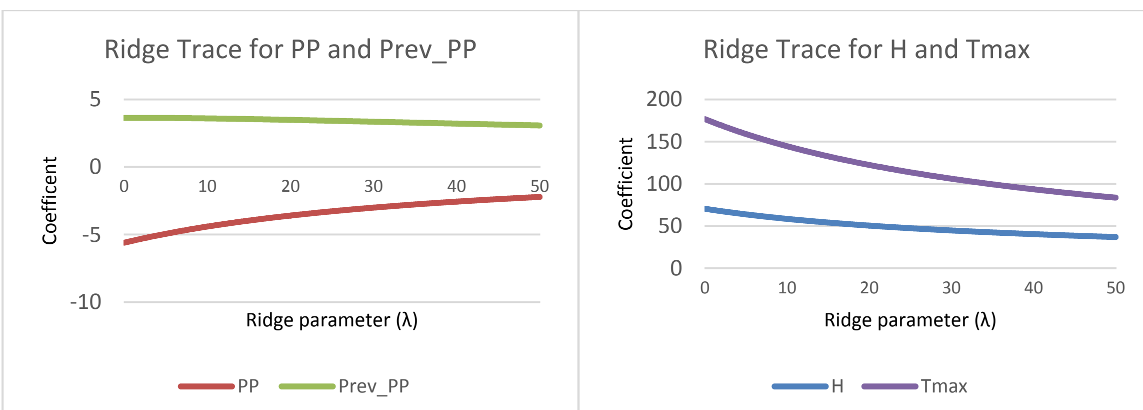


Figure 8: Ridge Trace for the coefficients

Table 11: Results for the Environmental Analysis

	Model (N=120)								
	1	2	3	4	5	6	7	8	9
Coefficients (95% CI)									
H	51.58 ***				70.48 ***	87.12 ***	42.59 *		49.49 **
	(23.30, 79.86)				(33.43, 107.53)	(53.38, 120.87)	(9.17, 76.00)		(14.36, 84.63)
PP		0.14			-5.60 **	-5.51 **		-2.20	-4.92 **
		(-3.18, 3.45)			(-9.25, -1.95)	(-9.20, -1.81)		(-5.56, 1.16)	(-8.63, -1.21)
Prev_PP			5.629 ***		3.62 *		3.48 .	6.56 ***	3.27 .
			(2.44, 8.81)		(0.09, 7.15)		(-0.18, 7.13)	(3.21, 9.91)	(-0.35, 6.90)
Tmax				54.7	176.67 **	178.27 **	110.75 .	95.35 .	
				(-60.63, 170.03)	(61.08, 292.26)	(61.15, 295.38)	(-0.31, 221.8)	(-17.98, 208.7)	
Tmin									111.97 *
									(3.61, 220.33)
Adjusted R^2	0.092	-0.008	0.086	-0.001	**0.191**	0.169	0.133	0.099	0.157
MSR	1359434	1509636	1367847	1498517	**1180419**	1222773	1275347	1229706	1229706

*p-value <0.001 "***", <0.01 "**", <0.05 "*", <0.1 "."*
H: monthly average relative humidity (%), PP: monthly average precipitation (mm),
Prev_PP: last month average precipitation (mm), Tmax: monthly average maximum temperature (C^o)
Tmin: monthly average minimum temperature (C^o)

From the ridge trace, we can see that with the increase of the penalty parameter λ, the coefficients are moving towards 0. The coefficients in the linear ridge model are the same with the coefficients in the linear model when λ=0. In most cases, when λ is small, the coefficients shrink rapidly with the increase of λ; however, when λ is big enough, the coefficients become stable and will not change rapidly with λ anymore. The penalty parameter is not used at zero cost. In fact, the introduction of penalty parameter λ introduces bias into the model; the bigger the λ is, the bigger the bias is but the higher the precision is. Compared with the OLS coefficients, the coefficients from ridge linear model is biased but with better precision. Therefore, the choice of λ is actually a tradeoff between bias and precision. A commonly used way to choose an optimal λ is call generalized cross validation (GCV) (Hoerl, 1975; Lawless, 1976). The optimal λ is chosen at the smallest value of GCV. Using R, the optimal λ for linear ridge regression on model 5 is 6.1. The coefficients of the predictors when λ = 6.1 are shown in table 12 along with the coefficients for the linear model.

Table 12: Results of linear ridge and linear versions of model 5

	Model (N=120)	
	Linear ridge model	Linear model
Coefficients (95% CI)		
H	62.526 *** (30.35, 94.70)	70.48 *** (33.43, 107.53)
PP	-4.816 ** (-8.07, -1.56)	-5.60 ** (-9.25, -1.95)
Prev_PP	3.615 * (0.41, 6.82)	3.62 * (0.09, 7.15)
Tmax	155.55 ** (50.34, 260.76)	176.67 ** (61.08, 292.26)

Table 12 shows us that the results of linear ridge model and the results of the linear model are very similar, indicating that the collinearity between predictors is not a big issue for this analysis. Notice that the 95% confident intervals of the linear ridge model are narrower than those of the linear model indicating that the precision of the estimators in the linear ridge model is better.

In the above analysis, only the last month's precipitation is included. However, based on the literature, it may take a longer time to see the impact of precipitation on the number of malaria cases presented at health facilities. Therefore, the length of the "lag" may need to be extended.

As mentioned above, the major malaria vector in Mvomero district is Anopheles mosquitoes. Usually, depending on the temperature, it takes 11 to 21 days for Anopheles mosquitoes' eggs to develop into adults mosquitos (Cross, 2004). Anopheles mosquitoes are not born with malaria parasites; they need to ingest infected blood from the host of malaria parasites in order to transmit malaria. However, even assuming a newly hatched mosquito bites a malaria patient immediately, it takes the lucky mosquito another 8 to 15 days for the parasites to develop in its body and appear in its saliva (NIAID, 2012). Once the malaria parasites are present in its saliva, the mosquito becomes infectious and it will transmit malaria to humans when it bites them. However, it takes some time for the infected person to develop the disease due to the incubation period of malaria. Usually the incubation period lasts for 10 to 15 days (Easmon, 2009). However, though rarely, the incubation period could be four months or even longer under certain circumstances such as the use of antimalarial drugs (WHO, 2013). All the facts indicate that the precipitation may have a much longer impact on the number of malaria cases. Therefore, to refine the "lag" analysis above, precipitation in the previous four months should also be considered. Built upon the full model above (Model 5), the results of three additional models (Model 10, 11 and 12) are shown below in Table 13. The results suggest that precipitation has a long impact on the number of malaria cases and that the longer the lag is, the weaker the impact becomes.

In Mvomero district, hospitals and dispensaries (including health centers) are extremely different. Compared with most of the dispensaries visited, the hospitals have better equipment and more skilled health professionals. Hospitals thus may attract more patients and the health seeking behaviors between the patients visiting hospitals and those visiting dispensaries may vary greatly. Therefore, it is worthwhile to conduct the analysis on the impact of weather factors on the number of malaria cases in hospitals and in the dispensaries separately to examine whether there are systematic differences. Table 14 below shows the results of the comparison.

Table 13: Results of the lag impact of precipitation on the number of malaria cases

	Model (N=120)							
	5		10		11		12	
	Coefficients	P-values	Coefficients	P-values	Coefficients	P-values	Coefficients	P-values
H	70.48	0.0003	58.69	0.0024	58.60	0.0024	58.76	0.0025
Tmax	176.67	0.0030	195.99	0.0009	217.78	0.0006	220.60	0.0014
PP	-5.60	0.0029	-4.93	0.0079	-4.94	0.0077	-4.94	0.0080
Prev_PP	3.62	0.0445	3.02	0.0891	3.17	0.0752	3.19	0.0760
Prev_PP2			4.11	0.0137	3.78	0.0266	3.79	0.0272
Prev_PP3					1.60	0.3434	1.58	0.3578
Prev_PP4							0.18	0.9141
Adjusted R^2	0.1910		**0.2264**		0.2257		0.2189	
MSR	1180419		1118909		1110016		1109900	

H: monthly average relative humidity (%)
Tmax: monthly average maximum temperature (C^o)
PP: monthly average precipitation (mm)
Prev_PP: last month average precipitation (mm)
Prev_PP2: average precipitation two months ago (mm)
Prev_PP3: average precipitation three months ago (mm)
Prev_PP4: average precipitation four months ago (mm)

Table 14: Results of the impact of weather factors on the number of malaria cases presented in hospitals and in dispensaries

	Model (N=120)			
	Hospitals		Dispensaries	
	Coefficients	P-values	Coefficients	P-values
H	5.62	0.452	53.14	0.0004
Tmax	30.90	0.244	189.71	0.0003
PP	-0.49	0.494	-4.45	0.0017
Prev_PP	-0.45	0.516	3.64	0.0081
Prev_PP2	0.43	0.514	3.36	0.0102
Prev_PP3	-0.10	0.875	1.68	0.1966
Prev_PP4	0.29	0.665	-0.10	0.9356
Adjusted R^2	-0.0404		0.3241	

H: monthly average relative humidity (%)
Tmax: monthly average maximum temperature (C^o)
PP: monthly average precipitation (mm)
Prev_PP: last month average precipitation (mm)
Prev_PP2: average precipitation two months ago (mm)
Prev_PP3: average precipitation three months ago (mm)
Prev_PP4: average precipitation four months ago (mm)

The results in Table 14 clearly show that the impact of environmental factors on the number of malaria cases presented in hospitals and in dispensaries are systematically different, which is a very interesting finding.

4.1.2.2 Impact of environmental factors on the burden of malaria

As mentioned before, in this paper the burden of malaria is measured by the ratio of positive test results to all tests conducted (PTR) and by the ratio of malaria cases to total diagnoses (MCR). Therefore, for these analyses, the dependent variables become a percentage ranging from 0 to 1. To make the number easy to read, the dependent variable is multiplied by 100. Figure 9 and Table 15 show the distribution and quantiles of the monthly ratio of positive tests and monthly ratio of malaria cases

Table 15: Quantiles of the monthly ratio of positive tests and ratio of malaria cases

Quantiles	0%	25%	50%	75%	100%
Positive Test Ratio (%)	10.8	25.8	30.9	40.3	63.8
Malaria Case Ratio (%)	16.6	38.7	43.3	46.5	63.5

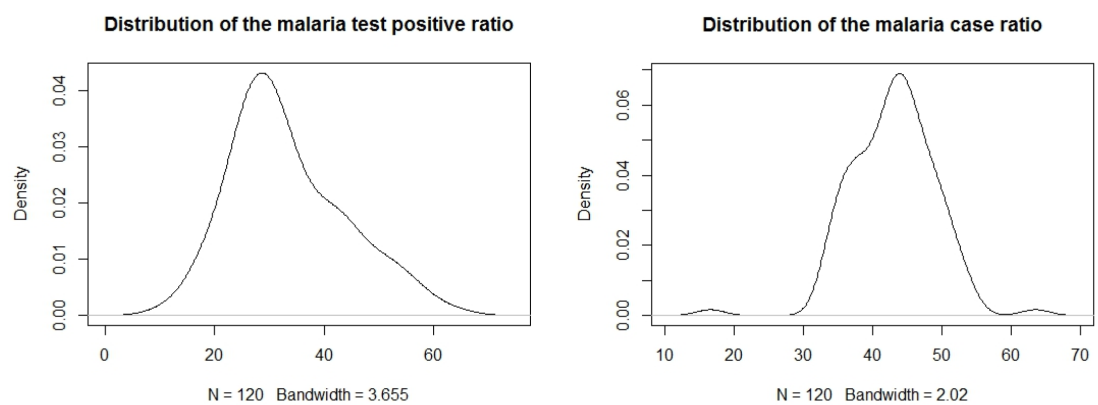


Figure 9: Distribution of the monthly ratio of positive tests and the ratio of malaria cases

Table 15 and Figure 9 show that both PTR and MCR are approximately normally distributed and both of them are densely concentrated between 20% and 60% indicating that a linear model is appropriate for both of the two dependent variables. The results of the regressions are shown in Table 16 and Table 17.

Table 16: Results of the PTR analysis

PTR	Model (N=120)				
	1	2	3	4	5
Coefficients (95% CI)					
H	0.15 (-0.11, 0.40)				0.07 (-0.29, 0.43)
PP		0.01 (-0.02, 0.03)			0.00 (-0.03, 0.04)
Prev_PP			0.02 (-0.01, 0.05)		0.01 (-0.02, 0.04)
Tmax				-0.45 (-1.44, 0.54)	-0.35 (-1.46, 0.76)
Adjusted R^2	0.003	-0.007	0.003	-0.002	-0.016
MSR	109.75	110.84	109.77	110.23	108.98

Table 17: Results of the MCR analysis

MCR	Model (N=120)				
	1	2	3	4	5
Coefficients (95% CI)					
H	0.14 * (0.00, 0.29)				0.20 * (0.01, 0.40)
PP		0.01 (-0.01, 0.02)			-0.01 (-0.03, 0.01)
Prev_PP			0.01 (-0.01, 0.03)		0.00 (-0.02, 0.02)
Tmax				0.27 (-0.29, 0.83)	0.53 (-0.08, 1.15)
Adjusted R^2	0.024	-0.003	0.004	-0.001	0.024
MSR	201.42	202.50	201.64	203.84	203.23

*p-value <0.001 "***", <0.01 "**", <0.05 "*", <0.1 "*"*
H: monthly average relative humidity (%), PP: monthly average precipitation (mm),
Prev_PP: last month average precipitation (mm),
Tmax: monthly average maximum temperature (C^o)

Table 16 suggests that none of the environmental factors have much impact on the monthly positive test ratio. All the coefficients are close to 0 and are not significant. The adjusted R2 for all the models are small indicating that none of the models fit the data well.

Table 17 indicates that monthly relative humidity may be the only factor that affects the ratio of the number of malaria cases to the number of total diagnoses. The coefficient of relative humidity is the only coefficient which is significant under a 95% confidence level. The coefficient of relative humidity is 0.14 suggesting that each additional percent increase in the relative humidity could increase the ratio of the number of malaria cases to the number of total diagnoses by 0.14%.

Again, as demonstrated in the section 4.1.2.1 the impact of the weather factors on the burden of malaria may vary between hospitals and dispensaries. Since MCR is the only indicator of malaria burden available in both hospitals and dispensaries, only MCR analysis will be conducted for the comparison. Table 18 below shows the results of this analysis.

Table 18: Results of the impact of weather factors on the burden of malaria presented in hospitals and in dispensaries, an MCR analysis

MCR	**Model (N=120)**			
	Hospitals		Dispensaries	
	Coefficients	P-values	Coefficients	P-values
H	-0.08	0.778	0.20	0.008
Tmax	-0.11	0.906	0.83	0.002
PP	-0.01	0.714	-0.01	0.408
Prev_PP	0.00	0.848	0.00	0.628
Prev_PP2	0.01	0.628	0.01	0.110
Prev_PP3	-0.02	0.406	0.01	0.145
Prev_PP4	-0.02	0.391	0.01	0.189
Adjusted R^2	-0.03975		0.1332	

Similar to the Table 14, Table 18 above clearly shows that there are systematic differences between hospitals and dispensaries. Similar to the previous results in Table 14, none of the weather factors seems to have significant impact on MCR in hospitals. However, it seems that humidity and temperature have significant impacts on MCR in dispensaries while the precipitation seems to have neither short nor long term impact on MCR in dispensaries as well.

4.2 Qualitative Analysis Results

4.2.1 Malaria trends

Malaria trends within a year in Mvomero vary from site to site, but in most places the incidence of malaria is higher during rainy and hot seasons. Usually, the rainy season in Mvomero is from March to May and from October to December and the hot season is from October to April. Almost all the interviewees agreed that there are more malaria cases during the rainy and hot season.

"During the rainy and hot season, we have the most malaria cases. The number of malaria cases increases from December to March and it begins to decrease in April." (doctor and officer's category, male, 10 years' working experience)

However, only a few of the health workers acknowledged the impact of land type on the number and the trends of malaria cases. A district malaria control officer is one of the few who acknowledged the impact.

"Within a year, we have a lot of cases during the hot season. It starts from October and last till April. During the rainy season, it depends, sometimes it is true. We have different climatic areas. In the mountainous areas we don't have many cases because it's a cold climate and we don't have mosquito breeding sites. However, in the lowland, we have many cases." (doctor and officer's category, male, 3 years' working experience)

Concerning the overall trends of malaria during the past decade (from 2002 to 2011), opinion varied greatly among the interviewees. Two district officers expressed different opinions on this. One district officer thought that there was a reduction in the number of malaria cases in the past decade while another officer insisted that the number of malaria cases was increasing.

"We found that the number of cases is lowering…..Yes, there is a reduction. Now malaria cases are being reduced because of interventions. However, people are being educated on health seeking behavior and reporting altitude and the number of facilities is increasing. So in some areas the decreasing trends may not be significant." (doctor and officer's category, male, 3 years' working experience).

"Malaria is increasing, especially in the warm season from August to December. The winter season is less… malaria prevails in rainy season." (doctor and officer's category, female, 7 years' working experience)

Among the health worker interviewees, about 40 percent of 23 interviewees commented that compared to the previous years, malaria was currently decreasing in severity and prevalence at their facility.

"Malaria is a major problem in the village. In the past, many people were suffering from malaria but right now malaria has decreased dramatically… Malaria is not severe because the community is struggling to use the nets… we offer discounted nets to pregnant women… Compared with nowadays, malaria was much higher when I started working here." (doctor and officer's category, female, 17 years' working experience)

However, another 40 percent argued that there were no significant changes in the prevalence of malaria at their facility.

"Malaria is still there… It is declining and yet increasing meaning it is regular on some level and it has stood on one point. It is still there…" (nurse and technician's category, female, 21 years' working experience)

More interestingly, about 20 percent of the interviewees believed that the number of malaria cases had been increasing in the past decade from 2002 to 2011.

"Malaria is in fact a bigger problem now, the number one problem in this area. Malaria is the first disease among the top ten diseases and it appears every day and each week in our report… Malaria leads to many patients." (doctor and officer's category, male, 34 years' working experience)

The heterogeneity of the responses suggests that the trends of malaria may differ from one area to another within the district. The variety of the responses is also consistent with the insignificant slope of the overall trends of malaria in the previous quantitative study because the overall trends are in essence the average effect of trends across facilities.

In some villages like Dihinda, Mkindo and Hembeti, where there are many rice paddies, it was reported that in May and June there were many malaria patients because some people who had shifted to their farms returned back to their home while they were sick. This may explain why a health worker at Dihinda claimed that malaria was at peak during the cold and dry seasons from June to September.

"In the winter season, there are more malaria cases… Even if there is a difference between cold season and hot season, it is very small, malaria is high all the time." (nurse and technician's category, female, 21 years' working experience)

Among all the facilities, the Mtibwa Hospital had a peculiar annual trend for malaria. This was attributed to the fact that the hospital served the Mtibwa factory workers who were employed seasonally during the hot and rainy season in each year, which helps explain the result of the quantitative analysis where there was a peak in January and February. These workers mostly came from Iringa region where the malaria prevalence was low and when they came to a malaria-endemic area such as Mvomero, they frequently got sick with malaria. Furthermore, as they arrived at Mtibwa, they were not accommodated immediately, so they might sleep outdoors for a week or so, which increased their exposure to malaria. In addition, the area was surrounded by sugarcane plantations, which provided ideal breeding sites for mosquitoes. This was claimed by an officer at Mtibwa Hospital (doctor and officer's category, male, 34 years' working experience).

4.2.2 Malaria diagnoses

All respondents claimed to have the malaria treatment guideline from the Ministry of Health, although some were unable to show the guidelines to the interviewer. Nearly all the respondents reported that they diagnosed malaria based on patients' clinical symptoms such as convulsions, severe headaches, vomiting and fever.

About half of 23 interviewees trusted their ability to correctly diagnose malaria based on patients' clinical symptoms. Although most respondents believed that microscopy is better and more appropriate than clinical diagnosis, a few respondents still claimed to trust clinical diagnosis more than laboratory tests.

"The recommended diagnosis is microscopy. When there is a laboratory in the facility, patients should be diagnosed by microscopy. But, few facilities have a laboratory and in this case, patients are mainly diagnosed clinically." (doctor and officer's category, female, 7 years' working experience)

"We use clinical diagnosis most of the time because we don't have a laboratory. I believe in clinical diagnosis in some ways because when someone comes here telling that they have a fever. Then you give them malaria drugs, and they get better…. But I think the method of microscopy is actually better because you can see the real parasites without speculation." (doctor and officer's category, female, 17 years' working experience)

"We normally use clinical diagnosis only… I trust it at a high percentage more than that of testing… We don't have a laboratory nor a microscope anyway…" (nurse and technician's category, female, 21 years' working experience)

A major reason why patients were diagnosed clinically was that the facilities did not have the equipment to conduct microscopy. This fact contradicts the claim from a district officer that many facilities now have a laboratory (doctor and officer's category, male, 3 years' working experience). In addition to equipment, lack of qualified laboratory technicians was another major reason why microscopy could not be conducted. Chazi hospital, which had a functional laboratory, did not conduct a single microscopy from 2004 to 2008 just because there was no technician to do the job (doctor and officer's category, male, 16 years' working experience). Another factor affecting the use of microscopy was electricity. The nurse in charge in Lusanga dispensary claimed that they had a laboratory but it had been inoperative from time to time due to lack of electricity.

"When there was power, we used to take blood samples from patients to test for malaria. But now the electricity has been cut so we come back to clinical diagnosis… The power has been gone for three months and even when the power was there, there was no one in the lab." (nurse and technician's category, female, 11 years' working experience)

Almost none of the dispensaries had laboratories and hence clinical diagnosis was their major approach. Some respondents in the dispensaries doubted the accuracy of microscopy tests although they would like to have it available in their facilities. They were skeptical because some patients whose previous test results were negative came back with severe cases of malaria and their test results became positive for malaria. Other patients whose test results were negative might respond well to anti-malarial drugs prescribed to them empirically.

"The results are mostly negative even for a person who is convulsing or another with a severe headache and fever. However, if you treat with using antimalarial drugs, he recovers. That

is how it is to most patients… Therefore, you should fasten the treatment and you decrease severity of the disease." (nurse and technician's category, female, 21 years' working experience)

"…Microscopy may be more appropriate yet sometimes can be incorrect too because the parasites may not reach the capacity to be seen on the blood smear." (doctor and officer's category, male, 10 years' working experience)

All the hospitals and some health centers had laboratory facilities. Therefore, patients in these health facilities were diagnosed using the microscopy technique most of the time. However, the laboratories were not open after daytime working hours or during the weekends making the doctors use clinical diagnosis in such cases. The clinicians in the hospitals wanted both microscopy and clinical techniques to be used; some of them still relied on the clinical method despite the presence of microscopy because they sometimes doubted the abilities of the slide readers (doctor and officer's category, male, 35 years' working experience).

Most of the respondents, including doctors and nurses claimed to have heard about RDTs from the earlier ISOMCO seminar held at Turiani hospital, although some heard about it during earlier ministerial seminars held at Morogoro town. Only a few of them had seen RDTs in practice but most of them trusted the tests and would like to see this employed at their facilities because they ran short of laboratory technicians as well as the laboratory equipment from time to time. Most respondents preferred RDTs to microscopy because RDTs do not require special expertise or electricity but few claimed that this approach was superior to clinical diagnosis.

"I heard about RDTs first on a conference held in Morogoro city… We were also called at Turiani hospital and your people told us how to use it to test malaria… I think RDTs can help us more than microscopy because microscopy requires expertise while RDT doesn't." (doctor and officer's category, male, 10 years' working experience)

"RDTs can really help us because it does not require electricity and it can help us confirm the clinical diagnosis that we've made." (nurse and technician's category, female, 11 years' working experience)

In the public hospital of Chazi, it was noted that the cost of microscopy malaria testing was high (1,500Tsh) as compared to the patients' income. Therefore, many patients received at this hospital might already have severe forms of the disease due to concerns about diagnostic costs at initial stage of the disease (doctor and officer's category, male, 26 years' working experience).

4.2.3 Malaria treatments

The most commonly used antimalarial drug dispensed in all health facilities was Artemether-lumefantrine or ALU, an artemisinin-based combination therapy (ACT), for uncomplicated malaria and Quinine for severe cases. Pregnant women were always given Quinine according to the treatment guidelines. About 80 percent of the respondents felt that the drugs were effective and had little or no side effects. About 20 percent of the respondents claimed that the effectiveness of ALU had been decreasing because they had seen frequent recurrences among the treated case. Some respondents reported mild side effects of Quinine such as tinnitus and headaches.

Most dispensaries in the study area experienced serious drug stock outs of ALU, varying from two to six months. In these occasions, the patients were advised to purchase the drug at the nearby pharmacies after being given the prescription note, although some patients could not afford to buy ALU that was sold between 1000 to 2000 Tsh at local pharmacies.

"Drug stock outs are common and they usually last for a long time. Sometimes they could last for more than three months… we experienced stock out of ALU this year from January to May… In such periods, we write the patients the prescription and ask them to buy the drugs elsewhere." (nurse and technician's category, female, 21 years' working experience)

Sometimes, the drug stock outs can last for 4 to 5 months. We experienced severe ALU stock out from last September to this February… If we don't have the drug, we explain to the patients and ask them to purchase the drug from the chemists. ALU costs about 1500 to 2000 shillings in the drug store… but here we provide the drug free of charge." (doctor and officer's category, male, 10 years' working experience)

The Turiani and Mtibwa hospitals did not have as much difficulty with drug stock outs for they usually cooperated with each other to manage the stock fluctuations.

"When the drugs are going to be used up, we go to the nearby Turiani hospital to borrow some drugs and when they experience drug stock outs, they also turn to us for help." (nurse and technician's category, female, 26 years' working experience)

The drug supply in the dispensaries followed the quarterly order from the government through the Medical Stores Department (MSD), and in most cases, these dispensaries did not receive the drugs in the same quantity as they order. Therefore, their supplies might only last for a month or two, and after that they had to wait for the next quarter's supply. It was also noted that in some dispensaries patients presented with fake symptoms of malaria in order to get the drugs when they knew the MSD car had supplied the drugs to their dispensaries.

"Sometimes people see the car of MSD come and they will come to my clinic pretending they have malaria just to get the free drugs from us. In fact, so many will come and the drug stock declines dramatically." (doctor and officer's category, male, 10 years' working experience)

4.2.4 RDT and Other Interventions

Most of the respondents were aware of the ISOMCO project by NIMR only. Some of them referred to other health projects in the areas. However, most respondents could only mention the activities without naming the projects.

All respondents from the intervention villages reported receiving a few referral letters from patients they treated. They were aware that the letters were written by the ISOMCO community health workers (CHWs) in their village. They were happy to work with the CHWs in such manner because the CHWs reduced their workload by treating patients at home though only a few households were targeted by the program. They claimed the referral letters had helped them in changing their clinical view of the symptoms presented by these patients; for example, the in charge at Dihinda dispensary changed the diagnosis from malaria to pneumonia for one of the referred cases to her facility (nurse and technician's category, female, 21 years' working experience).

In addition, in villages like Dakawa where larviciding was implemented, it was noted that the number of mosquitoes had decreased and people were happy that they could stay outside without much concern of getting malaria (doctor and officer's category, female, 22 years' working experience).

5. Discussion:

5.1 Discussion on the number of malaria cases

According to the previous analysis, there are no significant increasing or decreasing trends in the yearly number of malaria cases for the period spanning 2002 to 2011. However, the yearly number of malaria cases is by no means unchanged. In fact, there are significant fluctuations throughout the studied period making the graphs of the yearly number of malaria cases have an "M" shape. Two significant peaks are observed in 2004 and 2008 with one valley between 2005 and 2006. Finding the reasons which have caused these fluctuations is not the purpose of this paper. However, it would be interesting and helpful to explore the possible reasons because these reasons may have important policy implications and shed light on directions for future research.

A number of factors could be linked to the fluctuations, including intervention programming, drug resistant and climate changes. Based on the literature, insecticide treated nets (ITNs) were promoted as an important malaria control intervention by the Tanzanian government in 2005 (WHO, 2010; Khatib et al., 2008). According to one of the district malaria control officers, they began to promote the use of ITNs in Mvomero district in 2005 and ITNs were widely distributed in the district from 2005 to 2006. The distribution of ITNs in Mvomero district in 2005 is evidenced by Mlozi et al.'s (2006) paper published in 2006. In a study conducted in Mvomero in 2007 above 90% of the respondents claimed to own at least one ITN and the average ratio of ITNs per capita was 0.27, or about one ITN for every four people (Dickinson et al., 2012), which evidences the success of ITNs distribution in the district between 2005 and 2006. Therefore, the promotion of this highly effective type of intervention in 2005 and 2006 might have contributed to the sharp decrease in the number of malaria cases during this period. However, after 2006, the number of malaria cases increased rapidly in 2007 and reached the top in 2008.

The reason for this dramatic rebound is unknown but there are several possible explanations. One explanation is drug resistance. In 2007, Tanzania began to use a new artemisinin drug "ALU" to supplement and to gradually replace the use of sulfadoxine-pyrimethamine (SP), which has been gradually resisted by malaria parasites (Alba et al., 2010). The SP resistance (SPR) results in prolonged and recurrent parasite infection thus fueling the transmission of malaria (Yaro, 2009). Before the introduction of ALU in 2007, SPR in Tanzania was very sever. A study conducted in north-eastern Tanzania reported 45% failure rate of SP treatment (Yaro, 2009). In fact, the severe SP resistance was the major reason for the introduction of ALU to replace SP in Tanzania in 2007 (Alba, 2010). However, it could take some time for SP to be replaced by ALU in the clinics and private drug shops. In a study conducted in Kilombero, a district nearby Mvomero, the availability of ALU was only 7% and 29% in 2007 and 2008 respectively. Meanwhile, the sales of SP remained very high all the time. In 2005, SP accounted for 64% of all anti-malarial sales and in 2008 this number was 51%, only 13% decrease from 2005. In addition, the introduction of ALU in 2007 led to sever stock-outs of SP in both health facilities and drug stores due to delayed introduction of ALU without additional SP orders to compensate (Alba, 2010). All these factors might help explain the rapid increase of the number of malaria cases in 2007 and the subsequent decrease of the number after 2008.

Another possible reason is that the ITNs that were distributed in 2005 and 2006 might have been worn out or become less effective after being used for more than a year. According to WHO's guideline, ITNs need to be re-treated at least once a year or after three washes to ensure its insecticidal effect (WHO, 2008). A study conducted in Ethiopia from 2009 to 2011 found that having worn out bed nets was the most frequent reason for not using ITN (Loha et al., 2013). Therefore, without timely replacement of these worn-out ITNs, the risk of getting malaria for those who were using or stopped using these worn-out ITNs increased and thus the number of malaria increased. Starting in late 2008, two ITNs promotion campaigns aiming to provide ITNs to children and to every household were implemented in Tanzania (USAID, 2011). These programs might have helped replace the worn-out ITNs with new ones and increase the number of nets per household, thereby number of people sleeping under nets, which may help explain the dramatic decrease of malaria cases since 2008.

Intuitively, another possible explanation for the fluctuations in the number of malaria cases is the change in weather conditions such as annual average humidity, annual average temperature and annual total precipitation during the past decades. However it seems that weather loses its power to predict in this case. Figure 10 shows the trends of these weather data visually. The annual average relative humidity peaked in 2007 reaching more than 70%. Interestingly, the number of malaria cases in 2007 increased dramatically compared with the number in 2006. However, the annual average relative humidity in 2006 was also high yet the number of malaria cases in 2006 was low. Therefore, no convincing relationship has been found. The same is true for temperature and precipitation, although the valley in annual average maximum temperature in 2006 coincides with the valley in the number of malaria cases in 2006. However, the high temperature in 2010 matches with a low number of malaria cases, which cannot be explained. For precipitation, since the lag effect can be appropriately ignored in a long term such as a year, we expect more malaria cases when there is more annual total precipitation. However, a peak in annual precipitation in 2006 leads to a valley in the number of malaria cases, which contradicts our hypothesis.

While weather conditions may have impacts on the number of malaria cases, their impacts are overwhelmed by human factors such as intervention programming.

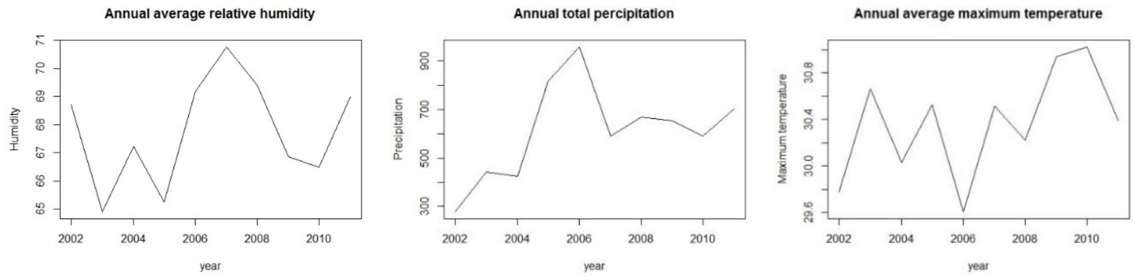


Figure 10: Trends in weather data from 2002 to 2011

As for the trends of malaria within a year (Figure 4), as expected, there are more cases in the hot and rainy season. The two rainy seasons are from October to December and from March to May. The 10 years' average data show that the number of malaria cases reaches the lowest valley in September and begins to increase in October and reaches a peak in January. The case number then begins decreasing moderately from January to April mostly during the dry season and it starts increasing and reaches the top peak in May. Interestingly, we can observe a moderate lag effect of the rain fall on the number of malaria cases, which is also in a line with the quantitative analysis results.

Another interesting finding is the heterogeneity among the trends in the number of malaria cases in different health facilities. Figure 3 demonstrates the heterogeneity clearly. In Figure 3, each facility demonstrates a trend which is different from the others'. In some facilities, namely, Chazi hospital and Dakawa dispensary, there is a significant increasing trend in the number of malaria cases in the past decade. However, in other facilities such as Makuyu dispensary, Mtibwa hospital and Turiani dispensary, a decreasing trend in the number of malaria cases has been observed for during the past decades. Besides the different trends among the facilities, the shape of the trends in each facility also differs from each other. Although the overall trend in the number of malaria cases demonstrates an "M" shape, except for Mziha dispensary, none of the other facilities has the same "M" shape for their trends. In addition, great heterogeneity has also been observed for different age groups. The trends for the under-five population are very different from the trends for five and above population. In some facilities such as Mvomero health center and Turiani hospital, the two groups even demonstrate the opposite overall trends.

Although the underlying reasons for the heterogeneity observed are still unknown, many factors such as the location of the facility, the qualification of the health workers in the facility and the accessibility of the facility may all have contributed the heterogeneity. Another important explanation for the heterogeneity among the facilities is that the study period (from 2002 to 2011) is too short to observe stable trends in the number of malaria cases in each facility.

5.2 Discussions on the burden of malaria.

As mentioned before, the burden of malaria is measured by the positive test ratio (PTR) and by malaria case ratio (MCR). Figure 5 and Figure 6 show that the overall trends of MCR and PTR are similar to each other and both of them resemble the trends of the number of malaria cases which demonstrates an "M" shape. As shown in Figure 1, the number of malaria cases decreased dramatically from 2008 to 2011. The same trends are observed for PTR but the decreasing trends ended in 2011 for MCR. From 2010 to 2011 the MCR increased from 38.9% to 39.6%. The reason for such difference is unknown, but a potential reason may lie in the clinical diagnosis of malaria, which is more likely to misclassify patients than microscopy. With decreasing burden of malaria, the risk of misdiagnosing patients with malaria using clinical diagnosis increases. This might help explain why the MCR does not decrease further in 2011 along with PTR.

The PTR and the MCR are two different indicators to measure the burden of malaria. Based on the analysis, it seems that both indicators are consistent with each other. The shape of the trend in the PTR is similar to the shape of the trend in the MCR suggesting that both indicators reflect the change in the burden of malaria consistently. In addition, although the PTR is lower than the MCR in general due to the misdiagnosis of malaria by clinical diagnosis, the difference between the PTR and the MCR is small, suggesting that the misdiagnosis of malaria by clinical diagnosis may not be a severe problem in Mvomero district.

5.3 Discussion on the impact of environmental factors on malaria case numbers and malaria burden

In Table 13, based on criteria such as adjusted R^2, coefficients and the p-values, model 10 has been shown to have the best performance. Model 10 not only captures the impact of all relevant environmental factors but also captures the lagged effect of precipitation on the number of malaria cases. As expected, the relative humidity (H) and the maximum temperature (Tmax) have positive coefficients meaning that increase in relative humidity and temperature lead to an increase in the number of malaria cases (Elipe et al., 2007). However, what seems interesting is that the monthly precipitation (PP) has a negative coefficient while the previous months' precipitation (Prev_PP1 and Prev_PP2) has significant positive coefficients. As discussed in section 4.1.2.1, the impact of precipitation on the number of malaria cases may have a very long lag (usually 21 to 51 days). Therefore, it is intuitive that the coefficients of previous months' precipitation (Prev_pp1, Prev_pp2, etc.) are positive because the precipitation in the previous months increases the number of stagnant water collections where mosquitos breed. However, interestingly, according to the results of the analysis, the impact of precipitation on the number of malaria cases in the current month (PP) is negative. Although this result is a little counter-intuitive, it may not be difficult to explain. Firstly, the major way precipitation affects the number of malaria cases is by creating more stagnant water collections which in turn leads to increase in mosquito population. However, as discussed in section 4.1.2.1, this process may take at least 1 to 2 months meaning that the positive impact of precipitation on the number of malaria cases can hardly be observed in the current monthly. In addition, Silver (2008, p543), in his book *Mosquito Ecology: Field Sampling Methods*, says that an increase in rain can decrease or even stop the mosquito biting activity. In another study, Korgaonkar et al. (2012) found that heavy rainfall may reduce the mosquito biting activity due to the flushing effect on the immature population. These findings in the literature may help explain why the results in this study show that precipitation has a negative impact on the number of malaria cases in the current month. Another possible explanation is that heavy rainfall may make access to the health facilities difficult, thus preventing patients from going to the facilities. This is particularly relevant in Mvomero district where the transportation infrastructure is very poor. Some of the facilities, such as the Matale dispensary, are located in the mountainous area and are difficult to reach even on the good weather days. Sometimes, these facilities are almost unreachable during the rainy season because of road conditions. All these facts indicate that it is sensible for the precipitation to have a negative impact on the number of malaria cases presented at facilities in the current month In addition, Table 14 and Table 18 indicate that the impact of weather factors on the number of malaria cases and on the MCR are significantly different in dispensaries and in hospitals. The weather factors seem to have significant impacts on the number of malaria cases in dispensaries while have little or even no impact on the number of malaria cases presented in hospitals. What is noteworthy is that the impact of precipitation on the number of malaria cases decreases significantly as the length of the lag increases, with the PP having the smallest p-value and Prev_PP4 having the biggest p-value. Also, in the previous analysis, except for humidity, none of the other factors have a significant impact on MCR. However, in Table 18, it shows that both humidity and temperature demonstrate very significant impacts on the MCR in dispensaries while the precipitation shows neither current nor lag effects on the MCR in dispensaries. Although this study is not designed to be able to explain the underlying reasons for these interesting findings, several possible reasons are suggested here to lead future research. One possible explanation might be that the severity of the diseases is different between the patients who go to the hospitals and those who go to the dispensaries. For example, the newly developed malaria case tends to have less severe symptoms and thus the patient may go to the nearby dispensary to seek for simple treatment. However, after some time, if not healed, the patient may develop a severe form of malaria and thus needs to be referred to a hospital. Intuitively, the impact of weather factors is mostly on the number of the newly developed malaria cases, therefore, the number of malaria cases presented at the dispensaries may be more affected by the weather factors. On the other hand, only part of the malaria cases, namely, the more severe cases, present to the hospitals. It usually takes the patients some time to develop more severe symptoms and be referred to the hospitals, meaning that the weather factors have little impact on the number of malaria cases in the hospitals. Another possible reason is that since there are very few hospitals in rural areas, the patients outside study area may also come to the three hospitals in the study area for treatment. Therefore, the impact of the weather factors on the number of malaria cases in the hospitals may be obscured by the fact that the weather data collected in this study is specifically for the study area. The third reason may lie in the misdiagnosis of malaria due to practice of clinical diagnosis in dispensaries. For instance, when there is more rain, in addition to the number of malaria cases, the number of other fever-symptomized, malaria-like diseases such as diarrhea, phenomena and common cold may also increase dramatically and because of the practice of clinical diagnosis, these cases may be misdiagnosed to be malaria cases, therefore making the impact of weather factors on the number of malaria cases in the dispensaries appear to be more significant. Since microscopy is usually used to confirm malaria cases in the hospitals, there are fewer misdiagnosed malaria cases reducing this over-predictive effect caused by misdiagnosis. In addition to the three major explanations mentioned above, other possible reasons that might explain the findings may be the difference in health seeking behaviors and social economic status between people who go to hospital and who go to dispensary. Since all the hospitals are located in the more developed "urban" area and most dispensaries are located in the more rural areas, the difference in location and accessibility may also be relevant to this finding.

Although the underlying reasons why only precipitation has no impact on the MCR in the dispensaries are unknown, some possible explanations are provided here. As for the long-term "lag" effect of precipitation, the hypothesis to explain this finding is that rain can cause diseases other than malaria compared with humidity and temperature. Therefore when there is more rain, the number of total diagnosis increases by the same percentage as the number of malaria cases does. However, the increase in humidity and in temperature increases malaria cases more than other diseases. As for the short-term "current" effect of precipitation, the hypothesis is that heavy rainfall can prevent malaria patients as well as other patients from coming to the dispensaries. Therefore, the short-term impact of precipitation on the MCR is also limited.

However, all the reasons and possible explanations cannot be backed up by this study. Therefore, future research is l called for to provide more evidence to answer these questions.

5.4 Limitations of the study

Although this is a carefully designed and conducted study, there are still several limitations that may affect the quality of this study.

First of all, the quality of the malaria cases data may not be completely reliable. Although the data are collected from MTUHA book No.2 the quality of the data may vary because the data are recorded and calculated manually by hand. When entering the data, the author found that more than 20% of the calculations made by the staff in the facilities such as adding up the number of malaria cases are incorrect. To solve this problem, the author entered the original data into excel and redid all the calculations again. However, this cannot fix the errors that resulted from inaccurate data entry.

Another limitation of this study is that there are some missing data due to the loss of MUTHA Books and people's negligence. Interestingly, in some facilities, the MUTHA Books for 2005 and 2007 are missing. To fix this problem, the author used linear regression to impute these missing data. However, the results are still affected by these missing data.

In addition, the weather data used in this study were recorded by a weather station in Morogoro city which is about 40 miles away from the study area. Therefore, the weather data may not capture the weather conditions in the study area precisely.

Lastly, the variables used to indicate malaria burden in this study, namely, PTR and MCR, have their own limitations. In theory, PTR is a better indicator for the burden of malaria because the microscopy is an accurate diagnostic method for malaria. However, in this study, the data on PTR are only available in three hospitals because only the hospitals have the equipment to conduct microscopy in the district. Therefore, for this study, the PTR may not be broadly representative. One the other hand, the data for MCR are available in all the health facilities making it more representative. However, MCR is not a very accurate indicator for the burden of malaria because clinical diagnosis is the primary diagnostic method for malaria in Mvomero district. Patients without malaria may be misdiagnosed with malaria by clinical diagnoses making the MCR an over estimate for the burden of malaria. Luckily, based on the findings in this study, the PTR and the MCR measure the burden of malaria similarly. It seems that the impact of this limitation on the quality of this study is limited.

6. Conclusions

As one part of a broader ongoing project in Mvomero district, this study aims to provide useful background information on trends, diagnoses and treatment of malaria at health facilities and to examine the impact of environmental factors on the number of malaria cases presented at health facility. Based on the aims of this study, three specific research questions are (1) how the number of malaria cases has changed over the past decade from 2002 to 2011 in rural health facilities in Mvomero, (2) what impact the selected environmental factors, relative humidity, rainfall, and temperature, have on the number of malaria cases presented at rural health facilities in Mvomero and (3) how malaria is diagnosed and treated in health facilities in Mvomero, and what health workers' attitudes are toward malaria diagnosis and treatment in their facility?

Despite the high malaria prevalence in Mvomero district, the trends in malaria cases presented at health facilities in this area of Tanzania have not been previously studied. Therefore, to answer the first research question, malaria data were collected from selected health facilities for the period spanning 2002 to 2011. Both graphical and statistical methods were employed to examine the trends of malaria at facilities in the district.

The results indicate that the number of malaria cases presented at health facilities in Mvomero district had neither increasing nor decreasing trends in the study period. This was in contrast to the decreasing trends in national and global data over the same time period. The number of malaria cases from 2002 to 2011 demonstrated an "M" shape with two peaks in 2004 and 2008 respectively and two valleys in 2005 and 2006. The valleys might be due to the distribution of ITNs in Mvomero district in 2005. The increase in the number of malaria cases from 2006 to 2008 might have resulted from drug resistance of sulfadoxine-pyrimethamine (SP), which was the first-line antimalarial drug used widely in Tanzania before 2007. In contrast, the sharp decrease in the number of malaria cases since 2008 might be explained by the introduction of a new antimalarial drug, Artemether-lumefantrine (ALU) in 2007, and its widespread use in treating malaria after 2008.

The burden of malaria in Mvomero district measured by positive test ratio (PTR) and malaria case ratio (MCR) had neither increasing nor decreasing trends from 2002 to 2011 as well. The graphs of PTR and MCR showed a similar "M" shape to the graph of the number of malaria cases.

To examine the impact of environmental factors on the number of malaria cases, monthly weather data on relative humidity, precipitation and temperature from 2002 to 2011 were collected from online government agency websites. Linear regression was employed to statistically examine the relationship between the weather factors and the number of malaria cases.

The findings show that relative humidity, temperature and precipitation all have significant impacts on the number of malaria cases presented in health facilities. The first two factors have a positive impact, while the last factor, precipitation, has dual effects on the number of malaria cases: the current month effect of precipitation is negative while the lagged effect of precipitation is positive.

To explore the diagnoses and treatment of malaria in Mvomero district, qualitative data were collected through in-depth interviews with health workers working in the facilities and with district malaria control officers. Qualitative analysis was conducted using the data collected from the interviews.

The health workers' interviews show that clinical diagnosis is still the major way used to diagnose malaria. Many health workers showed trust in clinical diagnosis. Microscopy is the recommended diagnosis for malaria according to the national guidelines. However, in Mvomero district, only hospitals had the equipment and personnel to conduct microscopy. Most of the health centers and dispensaries did not have the equipment or personnel, thus the workers in those facilities were unable to use microscopy to diagnose malaria. In addition, although most health workers believed that microscopy is more accurate than clinical diagnosis, some of them still preferred to use clinical diagnosis or both methods. Many health workers had heard about RDTs and believed that RDTs are more accurate and effective than clinical diagnosis. Although they would like to have access to RDTs at their facilities, no facility had used RDTs to diagnose malaria in practice.

Regarding the treatment of malaria, since 2007 when ALU was first introduced, it has replaced SP and become the mostly commonly used drug to treat malaria in Mvomero district. The major second-line antimalarial drug is quinine, commonly used to treat malaria for pregnant women. Given the high malaria prevalence in Mvomero district, the demand for antimalarial drugs and particularly ALU, is very high. However, most of the health facilities experienced ALU stock-outs very often, indicating that drug availability in Mvomero district is still an issue that needs to be resolved.

Based on the findings of this study, future research is needed to provide more evidence on how and why the number of malaria cases during the period spanning 2002 to 2011 demonstrates an "M" shape, to explore the prevalence of misdiagnosis of malaria and its possible impact on people's health, to examine the impact of other environmental factors especially geographical factors on malaria and to keep an eye on potential drug resistance of ALU.

Appendix A: Health Facilities List

Ward	**Village**	**Health Facilities**
Dakawa	Wami Dakawa	Dakawa
Dakawa	Wami Sokoine	Dakawa
Dakawa	Wami Luindo	Dakawa
Diongoya	Lusanga	Lusanga
Diongoya	Kwadoli	Lusanga
Diongoya	Digoma	Lusanga/Turiani Hosp
Hembeti	Dihombo	Hembeti/Mkindo
Hembeti	Mkindo	Mkindo
Hembeti	Hembeti	Hembeti
Kanga	Bwage	Kanga/Mziha
Kanga	Dihinda	Dihinda
Kanga	Kanga	Kanga
Kanga	Mziha	Mziha
Mtibwa	Madizini	Mtibwa Hosp/Lusanga/Turiani Hosp
Mvomero	Mvomero	Mvomero
Mvomero	Makuyu	Makuyu
Mvomero	Dibamba	Mvomero
Mvomero	Milama	Milama/Mvomero
Mvomero	Matale	Matale
Sungaji	Komtonga	Turiani Disp
Sungaji	Kigugu	Chazi Hosp/Mkindo
Sungaji	Mbogo	Chazi
Sungaji	Kilimanjaro	Turiani Disp/Turiani Hosp
Sungaji	Kisala	Turiani Disp/Turiani Hosp

Appendix B: Quantitative Data Collection Tool

Implementation Science to Optimize Malaria Vector Control and Disease Management in Mvomero, Central Tanzania: Malaria Trends and Diagnoses in Rural Health Facilities

Data Collecting Tool for the Quantitative Survey

The proposed study will investigate malaria prevalence, diagnosis and treatment in health facilities throughout the study areas by collecting relevant malaria data from available de-identified or aggregate facility statistics at the involved health facilities. Collected information may include number of cases of fever/malaria overall and by age cohorts, as well as information related to malaria status, diagnosis methods, and treatment. No personal identifying information will be collected (e.g. names).

Data need to be collected in health facilities: (in the past five years?)

1. Number of cases of fever

2. Number of cases of malaria (diagnosed cases)

3. Patients’ age (confined to malaria cases)

4. Patients’ symptom (including body temperature)

5. Diagnosis method and its result (clinical diagnosis, microscopy or RDT)

6. Treatment received

7. Geographic data of the facility (using GPS to record the location of the facility)

I hope this table below will be useful in getting quantitative data, all inputs are measurable. The geographic data of the facility can be put above as one of the identifying titles. It is difficult to count and rely on patient's symptoms rather we can get to measure temperature above 37.4^{o}C. This is measurable as long as we find temp has been recorded. Otherwise we will have to visit and see one dispensary just to know what information they fill in. (MTUHA books)

YEAR	MONTHS	# FEVER CASES	#MALARIA DX	AGE GROUP		# TEMP >37.4	DX METHOD (# IN EACH DX METHOD)			RX RECEIVED	
				ADULT	UNDER FIVE		CLINICAL	MICROSCOPY	RDT/OTHER	ALU/QUININE (#)	OTHER (#)
	JANUNARY										
	FEBRUARY										
	MARCH										
	APRIL										
	MAY										
	JUNE										
	JULY										
	AUGUST										
	SEPTEMBER										
	OCTOBER										
	NOVEMBER										
	DECEMBER										
TOTAL											

NB: DX= diagnosis
RX= treatment

Appendix C: Informed Consent Form

Implementation Science to Optimize Malaria Vector Control and Disease Management in Mvomero, Central Tanzania: Malaria Trends and Diagnoses in Rural Health Facilities

INFORMED CONSENT FORM

I am ________Xiaochen Dai__________________________ from Duke University of the United States working in collaboration with the National Institute for Medical Research.

This is part of the on-going large study titled "Implementation Science to Optimize Malaria Vector Control and Diseases Management in Mvomero District which started in 2010. The purpose of this part of the study is to investigate the changes in malaria trends, diagnoses, and treatment in health facilities.

Participation in the study involves participating in an interview lasting 30-45 minutes. Through the interview, we hope to better understand the opinions of health care workers about the diagnosis and treatment of malaria, and their impact on malaria case management in health care facilities.

In order to have an accurate record of your comments, with your permission, we will audio record the interview. We will later transcribe the recording and then destroy it. Your responses will be held confidential and no harm will happen on your side. When we report our research results, no individual participant will be identified.

You may skip questions or end the interview at any time. Your participation in this study is completely voluntary.

If you have any questions regarding this research, you may ask the research staff or contact Dr. Leonard Mboera, Chief Research Scientist at the National Institute of Medical Research, at 255 75431701.

If you have questions about your rights as participant in this research, please contact the chairperson of the National Health Research Ethics Review Committee of the National Institute of Medical Research, at 255 22 2121400.

____

Statement of Consent

I have read the above information. I have asked questions and have received answers. I consent to participate in the study.

Print Name: ____________________________Signature ________________________ Date ____________

Signature of Investigator ____________________ Date __________

I agree to allow my interview to be audio recorded: YES________ NO_____________

Appendix D: Interview Outline for District Officers

General information

Name of the Facility: ______________________________________ Type of Facility: _________________

Name of Village: _________________________

Name of respondent: ___________________________

Qualification: ___________________________

Position: ___________________________

Age: ___________________________

Sex: ___________________________

How long has you worked as a medical personnel? _______ Year(s)

How long has you worked in this facility? _______ Year(s)

Malaria diagnoses

Q1: In your opinion, what is the overall trends of malaria in Mvomero district?

Q2: Do you have Standard Case definition of malaria? Are there any guidelines or job aides available to health workers?

Q3: What is the recommended diagnosis? What is the most commonly used diagnosis? If the most commonly used diagnosis is not the recommended diagnosis, what do you think is the major barrier to the recommended diagnosis?

Q4: In your opinion, what is the most reliable diagnosis of malaria? How reliable is RDT?

Q5: How many RDT projects are/were going in Mvomero?

Malaria treatments

Q6: What is(are) the recommended drug(s) of malaria? What is the most commonly used drug? If the most commonly used drug is not the recommended drug, what do you think is the major barrier to the recommended drug?

Q7: Have stock outs of anti-malaria drug ever happened in this district? How often? How long did the last stock-out last? What is the measurement to this situation?

Intervention

Q8: What are the malaria interventions in Mvomero (ITNs/IRS/RDT/ACT/LSM)? When each of these interventions is implemented?

Appendix E: Interview Outline for Health Workers

General information

Name of the Facility: ____________________________Type of Facility: __________________

Name of Village: _________________________

Name of respondent: ___________________________

Qualification: ___________________________

Position: ___________________________

Age: ___________________________

Sex: ___________________________

How long has you worked as a medical personnel? _______ Year(s)

How long has you worked in this facility? _______ Year(s)

Malaria diagnoses

Q1. In your opinion, what is the general trend of malaria in this village? Within a year which period (hot season/rainy season/months) has the most number of cases?

Q2. Do you have Standard Case definition of malaria? Are there any guidelines or job aides available?

Q3. In your facility, what techniques are used to confirm malaria cases? Among all these techniques, which technique is the most used?

Q4. Do you trust clinical diagnosis?

Q5. In your opinion, how accurate are the confirmatory diagnoses? How do you think the accuracy of diagnosis varies according to the diagnostic techniques available at this facility? (RDT/Microscopy). If they had the equipment, are they able to conduct the test and maintain the facilities? Who runs the dispensary in terms of maintenance of the facility? (Mostly, the village government are the one who runs the dispensaries)

Q6. (If the staff mentioned microscopy, then ask) How often are patients diagnosed by microscopy? Do you trust microscopy's result? What do you think about the cost of microscopy (Many do not know it, the health services are provided free of charge)?

Q7. (If the staff did not mention RDT, then ask) Have you ever heard of Rapid Diagnostic Test (RDT) for malaria? If you know about RDT, where have you heard about it (probe for all sources)? What do you think about RDT (accuracy, cost etc.) (Many do not know the cost)? Do you trust the result of RDT?

Q8. (If the staff mentioned RDT, then ask) How often are patients diagnosed by RDT in your facility? Do you trust RDT's result? What do you think about the cost of RDT?

Malaria treatments

Q9. What antimalarial drugs are dispensed in this facility? What is the most dispensed antimalarial drug? What do you use for pregnant women? If patients require for certain drug, what do you do with this situation? How many patients will do this (the patients' opinion towards ALU)?

Q10. Are the drugs effective? Do patients report any complaints about the drug? E.g. side effects, effectiveness, or other issues.

Q11. Do you experience malaria drug stock outs at this facility? (Verify with the register) Which drugs? How often? How long did the last stock-out last? What do you advise patients to do for treatment of malaria during a stock out? Do you receive the same amount of drug as you ordered or need? When is the last time you received the drugs? (When the new drugs arrive, there will be a lot of patients in the following days… confounders: time of the drug arrive)

RDT Intervention

Q12. Are you aware of any malaria research project been implemented in this area? Can you name the projects or its activities?

Q13. Have any patients reported to this facility with a referral written by CHWs related to this project? If yes, did you find the referral(s) to be helpful? Why or why not? Did they have any impact on the diagnosis or treatment of the patient? (This question is only asked in intervention areas: 12 villages)

Q14. What is your biggest concern about malaria in this village/ What do you think still need to be done to combat malaria in your village.

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