IMPACT OF CLIMATE CHANGE ON THE SPREAD OF MALARIA AMONG CHILDREN UNDER FIVE YEARS IN VIHIGA COUNTY, KENYA

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DECLARATION AND CERTIFICATION

Declaration by the candidate

This Thesis is my original work prepared with no other than the indicated sources and support and has not been presented elsewhere for a degree or any other award.

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

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Certification by the Supervisors

The undersigned certify that they have read and hereby recommend for acceptance of Masinde Muliro University of Science and Technology a thesis entitled: ***Impact of climate change on the spread of malaria among children under five years in Vihiga County, Kenya.***

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DEDICATION

I dedicate this thesis to: my Mum Patricia Musinzi, Sisters Sylvia Nakhumicha and Lucy Musinzi; my little brother Michael Wafula and my wife Faith Litunda. They have always offered encouragement and support in my endeavours.

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ABSTRACT

Vihiga County for a long time has been known to be an endemic malaria region. The presence of many rivers and high temperatures, is ideal for mosquitoes breeding and maturity. However, the impact of changing climate and increasing malaria prevalence in the region have received little attention. Temperatures have increased over the past decades and rainfall decreased. Mosquitoes are temperature sensitive whereby high temperatures exacerbate their breeding. Therefore, this study aimed at investigating the changes in climate trends to increased malaria prevalence in the region especially among children under five years. The specific objectives were; to determine the changes in the rainfall and temperature trends for the past forty years in Vihiga County; to examine the impact of rainfall and temperature changes on the spread of malaria among the children under five years in Vihiga County; to develop a malaria spread map of Vihiga County. Instruments of data collection that were employed included the questionnaires, interviews, content analysis, focus group discussion (FGD) and downloaded digitized maps of the region. Purposive sampling was adopted. This was to target children under five years and health centres. A sample size of 300 households was sampled. The study used both qualitative and quantitative methods to analyse the data. Qualitative analysis tools, predictive analytic software (PAS) was used to analyse the responses from the questionnaires, interviews and FGD while Microsoft Excel was used to analyse the quantitative data from the surveys on malaria prevalence, district hospital information system (DHIS) data from hospital and climatic data from the metrological station. Digitized Earth Map was downloaded from the internet for generating a slope map while others drawn maps were collected from the statistical department of Vihiga. The results revealed that temperatures have increased by 2°C for the past forty years with annual increase of 0.04°C while rainfall has decreased by 50 mm for the same period of time. The rainfall patterns have also changed with increased rainfall during shorter season with short rains during the longer season. Report reviled higher malaria prevalence during three months preceding rainy season (May, June, and July). It was noted that the reported cases of malaria prevalence are still high among children under five years. Population in the lower grounds was most affected as depicted on the sentinel map. From the results, it was concluded that temperature and rainfall have changed in the region. These changes have aided in the increase of malaria prevalence in the region. The study generated slope and sentinel maps to site the key sentinel health canters for early malaria predictions. This is important to the community as it will assist in monitoring the future malaria outbreak and easy accessibility to the affected area. From the study, it was recommended that the county government should work with international bodies like World Bank to enforce policies on land use and safe energy to mitigate the impacts of climate change. The county government to work with the national government in the war against malaria by implementing the policies of making Kenya a malaria-free country. However, further studies need to be conducted on how malaria immunization will be effective in war against malaria among children under five years and how climate change will affect mosquitos' survival as they are likely to mutate to the drugs after vaccination on children under five years.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACT	-	Antenatal Care and Treatment
AMMA	-	African Monsoon Multidisciplinary Analysis
DEM	-	Digital Earth Map
DHIS	-	District Hospital Information System
GHG	-	Green House Gases
GIS	-	Geographical Information System
GoK	-	Government of Kenya
GIS	-	Geographical Information System
IPCC	-	Intergovernmental Panel on Climate Change
I**PCCAR**	-	Intergovernmental Panel on Climate Change's Annual Report
IRS	-	Indoor Residual Spraying
ITN	-	Insecticide Treated Nets
IMF	-	International Monetary Funds
KEMRI	-	Kenya Medical Research Institute
KMIS	-	Kenya Malaria Indicator Survey
LLINs	-	Long Lasting Insecticide Nets
MARA	-	Mapping Malaria Risk in Africa
MDGs	-	Millennium Development Goals
MOPHS	-	Ministry Of Public Health and Sanitation
NCCRS	-	National Climate Change Report Strategies
NGO	-	Non-Governmental Organization
PAS	-	Predictive Analysis Software
RDT	-	Rapid Diagnostic Test
RS	-	Remote Sensing

SDG - Sustainable Development Goals

SPSS - Statistical Package for the Social Science.

WHO - World Health Organization

DEFINITION OF OPERATIONAL TERMS

1. **Climate change-** The changes that are thought to be affecting the world's weather so that it is becoming warmer. In this study when this term is used, it refers to the changes in temperature and rainfall. The two elements of weather the only one selected as they direct impact on the mosquitoes breeding.

2. **Climate variability-** it is the short term fluctuations on seasonal or multi-seasonal time scale of the climate. It's the fluctuation of the climate of an area locally without causing the long-term average to change.

3. **Sentinel sites-** These are sites and health centres that are selected to be used a monitoring unit for changes in malaria prevalence in the region to alert the concerned state holders to take precaution before it becomes an epidemic.

4. **Hotspot**- these are areas where transmission intensity exceeds the average level, become more pronounced as transmission declines. Targeting hotspots may accelerate reductions in transmission and could be pivotal for malaria elimination.

5. **Malaria surveillance-** these are programs organized to support the dissemination, adoption and implementation of the policy guidance by the national malaria control programmes.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

There has been a malaria prevalence reduction of 62% in the past 15 years (WHO, 2016) as a result of global efforts. In the year 2000, malaria accounted for 70% of the death of children under five years globally, 17% of this deaths occurring in sub-Saharan Africa where malaria was presumed to be the leading cause of mortality (WHO, 2017). In 2015, malaria accounted for 5% of under-five years death mortality globally and 10% of under-five years in sub-Saharan Africa, where it is now the fourth highest cause of death (Mbodj, 2000). A similar report by Velema *et al., (*2014) indicates that of the 429,000 people that died of malaria in 2012, the majority of them were young children under the age of five. Even though globally, the under-fives malaria death rate fell, malaria remains a significant killer, claiming the lives of children under five years in every two minutes globally (Crawley *et al.,* 2010).

The impact of climate change on human health globally is high. However, there is little-documented information on how climate change affects the spread of malaria. Temperature affects vectors life-cycle that significantly influences the spread of vector-borne diseases, malaria being one of them (Oliver & Brooke, 2017). Mosquitoes, vectors that spread malaria are sensitive to external changes in temperature as they do not have their internal thermodynamic system of temperature regulation. Diurnal temperature fluctuation around the mean of<21°C slows parasite development compared with temperature ranging between 21°C and 31°Cwhich speeds development cycle of the mosquitoes.

Reproduction of *Plasmodium vivax* in mosquitoes takes 55 days at 16°C, 29 days at 18°C and only seven days at 28°C. *Plasmodium falciparum* which causes the majority of severe malaria, at 16- 18°C is the required minimum temperature for development. There is high mortality in mosquitoes from 32°C. At the 40°C, their survival becomes zero (Oliver *& Brooke*, 2017). Table 1.1 below, gives the summarised influence of temperature on the mosquitoes' survival.

Table 1.1: The effect of temperature Sporogenic Development of Mosquito

T(°C)	Duration of sporogony (days)	Daily vector survival (%)	Vector survival after period required for sporogony (%)	Larval development (days)
16	-	89.3	0	47
17	111	89.7	0.001	37
18	56	90	0.28	31
20	28	90.3	5.9	23
22	19	90.4	15	18
30	7.9	88.1	37	10
35	5.8	80.8	29	7.9
39	4.8	38.9	1.1	6.7
40	4.6	0	0	6.5

Source: Jon Cox (19) pg10

Globally, analysis by the Intergovernmental Panel on Climate Change (IPCC) using the global circulation models, projects that Eastern African will likely become wetter, particularly during rainy seasons (Ebi *et al.*, 2006). These models also anticipate rainfall patterns becoming less uniform over time, with possible increases in sporadic and intense precipitation. By the end of the century, the number of extreme wet seasons may increase by 5-20% (Kjellstrom *et al.,* 2016). These changes in climate will lead to malaria transmission associated with increased rainfall in dry regions and increased temperatures in high altitude, typically cool regions. The increased rain produces the moisture conditions and surface water that facilitate the breeding of malaria-transmitting mosquitoes.

Warmer temperatures promote faster development of mosquito larvae and survival of adult mosquitoes. In summary, warmer temperatures allow the malaria vectors, mosquitoes, to multiply more quickly hence high malaria prevalence.

Kenya is expected to experience higher temperatures all the year round though uncertainty remains regarding how much warming will occur. In the medium term, projections suggest that annual temperature in Kenya will rise by 1.0°C to 3.5°C from 2046 to 2065 (Weiss *et al.,* 2014). However, other studies project a less dramatic increase in temperature in the medium term; a rise of 1.0°C to 2.8°C by the 2060s and by 1.3°C to 4.5°C by the 2090s. This will manifest through increased frequency of hot days and nights. This is likely to be a scenario expected to be witnessed across the country hence an anticipated increase in malaria rates (Hay *et al.*, 2000).

In the Western region, especially in Vihiga County, there is limited available literature on the spread of malaria based on rainfall and temperature changes. Researchers who have carried out the study mostly focused on non-climatic factors that affect the spread of malaria; the use of the domestic spray, Insecticide Treated Nets (ITN), media campaign, socio-economic levels of the population and treatment level of the patients(Zhou *et al.,* 2012). Regardless of using these methods, there are reported cases of increased malaria prevalence in the area especially among children under five years.

Therefore, the purpose of this study is to investigate how changes in temperature and rainfall have influenced the spread of malaria among the children under five and how a malaria spread map will help to predict the future occurrence of the disease. The generated map will also assist the health stakeholders at all levels to come up with mitigation measures for malaria prevention and treatment.

1.2 Statement of the Problem

Malaria is one of the leading global killer diseases whereby one million people die per year globally. Africa is one of the most hit in malaria prevalence due to lack of preparedness and misuse of funds allocated for prevention and malaria treatment according to the World Health Organisation report (WHO, 2017). This has led to a high economic strain on population especially women who care for the children. Countries in the Sub-Saharan region; Kenya, Uganda, Tanzania are most affected. Kenya is the leading country in malaria prevalence. This has been attributed to various factors both including the high temperatures and rainfall that facilitates the breeding of mosquitoes (Cairns *et al.,* 2015). High temperatures shorten the incubation period of mosquitoes larva to a few days unlike when the temperatures are low while high rainfall experienced in the area provides breeding grounds for the mosquitoes.

The recent studies carried out in Vihiga County by the various researchers have revealed declining rainfall amounts, changing rainfall patterns and with increasing temperature (Amegah *et al.,* 2016). These changes in climate trends are likely to have a significant impact on the mosquitoes' life-cycle which will directly impact on the level of malaria prevalence in the area especially on children under the age of five. This is because mosquitoes are temperature sensitive with high temperature favoring their breeding unlike low heat (Garke *et al.,* 2013). The changes in climate have received minimal attention as the cause of increasing malaria prevalence in the region. There is a need to investigate how climate change has impacted the spread of malaria especially among children under five years.

This study therefore aimed at filling the gap that currently exists that links the rainfall and temperatures changes to malaria prevalence. The region also has a varied land terrain with low, medium and high areas that are likely to indicate variation in malaria prevalence when mapped. The changes in rainfall and temperature beyond a certain threshold can be used as a warning for future malaria outbreak. Also, both county and national government can use the information from sentinel health centers as malaria epidemic detection to prepare for emergency prevention and treatment measures which will help to reduce the cost of malaria treatment especially on children under five years who are most affected.

1.3 Objectives of the Study

1.3.1 General Objective

The research was aimed at investigating the impacts of climate change on the spread of malaria among children under the age of five in Vihiga County, Western Kenya.

1.3.2 Specific Objectives

i. To determine the changes in the rainfall and temperature trends for the past forty years in Vihiga County.
ii. To examine the role of rainfall and temperature changes on the spread of malaria amongst the children under five years in Vihiga County.
iii. To develop a malaria spread map for Vihiga County.

1.4 Research Questions

i. How have temperature and rainfall trends changed for the past forty years in Vihiga County?

ii. What are the impacts of temperature and rainfall changes to the spread of malaria amongst children under five years in Vihiga County?

iii. What is the significance of malaria spread map on malaria control in Vihiga County?

1.5 Scope of the Study

The study focused on temperature and rainfall trends in Vihiga for the past forty-seven years using meteorological data from Kakamega and Kaimosi weather stations. The study used malaria statistical data from District Hospital Information System (DHIS) and from various health centers for the past five years to validate the malaria prevalence in the region. The range of five years (2012-2016) was ideal as beyond this period; there could have been inadequate data available in some health centers owing to insufficient data records as some health centers were opened recently. The study focused on children under the age of five years (1-month old-5 years old). This is because they are the most vulnerable as compared to other members of the population. They have low body immunity and low environmental adaptability.

With this in view, the malaria slope map and malaria sentinel map were generated, they were then overlaid to create a malaria spread map to show high, middle and low areas. The region's altitude ranges between 1300-1500m. Therefore, the lower ground 1300-1365, the middle ground 1366-1430m and higher ground between 1431-1500m. It was hypothesized that children from the lower areas and away from the health centers might have high malaria prevalence unlike children from the upper regions and close to the health centers.

The study relayed on the information gathered from other respondents like health personals, malaria coordinators, parents and local leadership on malaria prevalence. Focus group discussion was used to collect the data from them.

The study was carried out in the five sub-counties (Vihiga, Emuhaya, Sabatia, Luanda, and Hamisi). Five health centers were picked from each county for mapping.

1.6 Significance of the Study

The study aims at strengthening the health system by improving malaria outbreak prediction through intensive monitoring, and routine surveillance of climate changes. This can be enhanced by developing of malaria early warning systems that will combine both local peoples' knowledge of weather changes with scientific and improving data flow across all levels in the county.

The report will help to improve communication and increase awareness of climate and health risks, especially in communities living within nether regions, swampy areas and along the rivers. The information will be strengthening cross-sectorial collaboration among actors engaged in malaria control and disaster risk reduction; to come up with adaptation and mitigation measures to climate change in the region.

Kenya's Vision 2030, aims at transforming this country into a newly industrialized "middle- income country." To achieve this, the state is expected to have realized the Sustainable Development Goals (SDG) that aims at improving each area based on its diversity. The regions differ concerning altitude, social; economic activities carried out by the people in the area. This will have different impact and will require different mitigation and adaptation strategy for sustainable development. This help to reduce the aspect of generalization of the regions due to geographical location.

On climate change, the government promises to enhance disaster preparedness in all disaster-prone areas and improve the capacity for adaptation to global climate change. The results will provide essential information for both the national and county government. As mapping the field, it will be easy to locate regions that are likely to be malaria hotspots during high rainfall season.

1.7 Justification of the Study

This study was essential as tends to relate the increasing malaria prevalence in the Vihiga County due to changing rainfall and temperature in the area. The clearing of the Maragoli Hills forest for wood, fuel and to create room for settlement due to rising population is one of the causes of climate change in the region. Because of these, temperatures are increasing while the amount of rainfall is declining (Sewe *et al.*, 2016). The two have a significant impact on the mosquito breeding and survival. There is limited documented evidence that associates climate change to widespread malaria prevalence in the region. Most of the available research that has been carried out concentrate on climate change and its impact on agriculture and socio-economic activities in the area but gives little attention to the spread of malaria (Kuya, 2015).

Malaria prevalence in the county is on the rise according to the current malaria indicators, and the children under the age of five are the most vulnerable unlike other members of the population cohort as per registers from various health centers in the region across the years (Amboko *et al.,* 2016).

Therefore, mapping of malaria-prone areas will be essential for proper planning on the allocation of the scarce resources to target the most vulnerable people. This is a new phenomenon in this study that will offer mitigation approach to malaria prevalence.

Previous studies by Zhou *et al.,* (2012), focused on the contribution of non-climate factors in the spread of malaria; the use of ITN nets, domestic sprays and socio-economic level members among other measures for malaria prevention. A lot of efforts have been put in place by both the county and national government in financing the malaria prevention and treatment to minimize the prevalence (Afrane *et al.*, 2016). Despite all these actions, the prevalence is high.

Economically, there has been the misappropriation of resources in the fight against malaria. Also, a lot of time has been wasted in the treatment of malaria by mothers leading to low economic output. The donors are withdrawing their support leaving the heavy burden on the national government, county government and individual patients to fund the treatment. With changes in climate and increased malaria prevalence, there is a need to find the correlation between the two for future predictions and better preparations by the local community.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the available literature on climate change globally, in Africa and Kenya and Vihiga County the study site. It then discusses research on how climate change affects the spread of diseases especially malaria at the global level, Africa, and Kenya as a country. The section highlights the history of malaria mapping from a worldwide scale, Africa and Kenya with a narrow focus on Vihiga County. It then evaluates a conceptual framework that will be adopted in this study and finally identifies gaps in literature in the study area.

2.2 Climate Change

Climate, in its broadest sense, is the statistical properties of the climate system that persists for several decades or longer time usually at least 30 years. These statistical properties include averages, variability, and extremes (Kerry, 2017). Climate change may be due to natural processes such as changes in the sun's radiation, volcanoes or internal variability in the climate system, or due to human influences such as variations in the atmosphere or land use (IPCC, 2013). It is an alteration in the pattern of climate for example precipitation, winds, temperature, humidity, over an extended period and may be due to a combination of natural and human-induced causes (Kerry, 2017).

Global climate varies naturally over a time scale from decades to thousands of years and longer. These natural variations can originate in two ways: from internal fluctuations that exchange energy, water and carbon between the atmosphere, oceans, land and ice, and from external influence on the climate system, including variations in the energy received from the sun and the effects of volcanic eruptions. Human activities can also influence climate change by changing concentrations of carbon dioxide and other greenhouse gases in the atmosphere, altering the concentrations of aerosols and altering the reflectivity of Earth's surface by changing land cover (Estrada & Botzen, 2017).

Global climate change remains one of the most significant environmental threats over the coming century. The impacts on human population herewith are uncertain but are an essential focus of policy debate in regarding mitigation and adaptation of the diseases (Herrero *et al.*, 2016). The average global surface temperature has warmed up to 0.8°C in the past century and 0.6°C in the past three decades. This is attributed mainly to human activity (Mazults & Eckardt, 2017). A recent report produced by the U.S National Academy of Sciences confirms that the last few decades of the 20th century were, in fact, the warmest over the past 400 years (Reinhardt *et al.*, 2016).

The Intergovernmental Panel on Climate Change (IPCC, 2013), projected that if greenhouse gas emissions, the leading course of climate change, continue to rise, the mean global temperatures will increase between 1.3°C to 5.8°C by the end of 21st Century (Dolesh 2017). The report continues to highlight the evidence of climate change globally. The rising temperature and changes in precipitation are undeniable. The effect is apparent with impacts already affecting ecosystems, biodiversity, and people. In both developed and developing countries, climate impacts are reverberating through the economy, from threatening water availability to sea-level rise and extreme weather impacts to coastal regions and tourism. (IPCC, 2007). In some countries, climate impacts affect the ecosystem services that communities are largely dependent upon, threatening development and economic stability. Future results are projected to worsen as the temperature continues to rise and as precipitation becomes more unpredictable (Kerry, 2017).

Climatologists suggest that there is an upward trend in the global temperature and with a current estimate of 2°C by the year 2100 (Estrada & Botzen 2017). The annual temperatures are expected to rise between 3°C and 4°C as compared to 1980-1999 periods. Warming in the equatorial regions will be minimal and of the coastal areas (Mazutls & Eckardt, 2017). According to the IPCC report (IPCC, 2013), they predict there will be a decrease in the total amount of rainfall, but there will be an increase in the intensity of rain in the subtropics (Onyango *et al.*, 2016).

Africa as a continent has warmed up over the 20th century, and general circulation models project warming across Africa ranging from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario) (Mulinya, 2017). For comparison purpose, warming through the 20th century was at the rate of about 0.5°C per decade, precipitation patterns in East African are more variable that there has been an increase in rainfall over the last century (Henderson *et al.*, 2017). However, others researchers suggest a moderate warming scenario. To them, parts of equatorial East Africa is likely to experience 5 – 20% increased rainfall from December – February and 5 – 10% decreased rainfall from June – August by 2050 (Hulme *et al.*, 2001). Climate change of this magnitude will have far-reaching negative impacts on the availability of water resources, food and agricultural security, tourism, coastal development, biodiversity and human health (Sultan & Gaetani, 2016).

According to the National Climate Change Response Strategy (NCCRS) report released in 2010, there are several highlighted pieces of evidence of climate change in Kenya since 1960 to current. The NCCRS also referred to as the "Strategy" is the culmination of a long-term process to develop a comprehensive and concerted suite of strategies to respond to challenges posed by climate change in the country. According to the NCCRS report, the evidence of climate change in Kenya is unmistakable (Bryan *et al.,* 2013).

Temperature has become irregular and unpredictable in the country, and when it rains, the downpour is more intense as compared to previous years (Eriksen & Lind, 2015). Extreme and harsh weather is a health hazard. To be more precise, the report reveals that since the early 1960s both minimum and maximum temperatures have been on an increasing (warming) trend (Egondi *et al.,* 2012). The minimum temperature has risen by 0.7 – 2.0°C and the maximum by 02 - 1.3°C depending on the season and the region. In areas near large water bodies, the maximum temperatures have risen more than in other areas, but the minimum temperatures have either not changed or become slightly lower. Mean annual temperatures have increased by 1.0°C since 1960 and an average of 0.21°C per decade. The Lewis Glacier on Mount Kenya has lost 40 percent of its mass since 1963 (Ajuang *et al.,* 2016).

On the other hand, there has been increased variability of rainfall year after year, and within the year. There is a general decline in rainfall in the primary rainy season of March to May "the Long-Rains" (Bryan *et al.,* 2013). In other words, drought in the "Long Rains" season is more frequent and prolonged. There is a positive trend (more rains) from September to February. This suggests that the "Short Rains" (October – December) season is expanding into what is usually a hot and dry period of January and February. In contrast, local observations suggest that the 'long rains' of March to April have become increasingly unreliable in the location such as Eastern province (Ajuang *et al.,* 2016).

Kenya has only 25 official meteorological stations and where they exist, whether recordings may be too short to fill gaps or only collect information regarding a few parameters. These have led to inadequate data on changing climate trends of some regions within the country (Tompkins *&* Caporaso 2016). This restricts the capacity to validate climate models and therefore reduce confidence in the scenarios they generate (Leedale *et al.,*2016).

Vihiga County is located within the Modified Equatorial Climate of Lake Victoria basin. This type of climate covers counties in Western and Nyanza regions of Kenya (Wanja *et al.,* 2016). Because of its location along the equator, the area experiences the double maxima rainfall per year. The first rainfall is received in March and May, the long rains of a mean monthly rainfall of about 270mm and the short rains fall in the months August to November of a mean monthly of 180mm (Mulinya, 2017).

The study carried out in the region by Wanja *et al.,* (2016) in Vihiga County, Shows the rising temperatures and declining rainfall in the area. The study reveals a declining rain with a mean annual rainfall of 150mm and increasing temperature of up to 31°C. The research associates climate change to agricultural output in the Vihiga County.

Another study in Vihiga region by Zhou *et al.,* (2012), dwelt on malaria prevalence and how non-climatic factors have impacted the spread of malaria in the area. There is a need to associate the changing rainfall trends and temperature in the region with malaria prevalence.

2.3 Data on climate trends in Vihiga County

Vihiga County does have meteorological stations in Kaimosi at Kaimosi forest station and some rainfall station in schools like Chavakali and another at Mahanga near Margolis Hills Forest. However, some of these stations didn't have adequate rainfall and temperature parameters for the past forty years. This is because some have been recently established while others especially those in school did have sufficient information on temperature. Because of the inadequacy in meteorological data, the county relies on data from the stations in Kakamega for weather monitoring. In this study, the preferred metrological data that was used was from Kakamega meteorological department owing to is closeness to Vihiga County and the availability of data across the years both in temperature and rainfall.

To validate the changes in climate, this studies collected statistical data on rainfall and temperature for the past forty-seven years (1960- 2013). The climatic characteristics of temperature and rainfall were considered in this study because they have a significant impact on the life cycle of the mosquito, a vector that is known to spread malaria that is claiming millions of lives globally annually. Minimal variations in temperature and rainfall will have a significant impact on mosquito survival.

2.4 The Impact of Climate Change on the Spread of Malaria

Globally, climate change is expected to escalate the occurrence and intensity of future diseases outbreaks, and perhaps increase the spread of diseases in some areas (Waldock *et al.,* 2013). In Africa, climate variability and extreme weather events have been cited as fundamental factors in initiating malaria epidemics especially in highlands of western Kenya, Uganda, Ethiopia, Tanzania, Rwanda and Madagascar (Hasegawa *et al.,* 2016). While other factors, such as topography and health preparedness can influence the spread of malaria, scientists have found a correlation between rainfall and high maximum temperatures to have the upper hand in the increased number of malaria cases (Kim *et al.,* 2017).

From 1920 to 1950, the highlands of Eastern Africa experienced occasional malaria outbreaks. Nonetheless, since then, the current pattern is characterized by increased outbreak frequencies, expanded the geographical range and increased case-fatality rates (Stern *et al., 2011*). The survival of mosquito vector *Anopheles spp* and the mosquito parasite that causes malaria *Plasmodium falciparum* is also affected by climate. Temperatures affect the development rates by vector and parasites while rainfall affects the availability of mosquito breeding sites (Zhiyong *et al.,* 2016).

The role of climate change in the increase in malaria incidence in African highlands has been controversial (Martens *et al.,* 1999). However, it is difficult to deny the fact that climate plays an important role in malaria incidence. Others suggest no net change (Rongers *et al.*, 2002) or even a decline in malaria prevalence irrespective of changes in environmental conditions (Gething *et al.,* 2010). These contrasting results reflect in part the complexity of the disease and the fact that parasite frustration by mosquito vector is influenced by a range of intrinsic and extrinsic factors (Lafferty, 2009).

On the other hand, according to research that integrates weather and diseases, it is projected that changes in temperature and rainfall caused by climate change will lead to the spread of malaria in the tropical region up to 2050 after which it will start to decline (McMichael *et al.,* 2006). This is because greenhouse gas emission is increasing due to industrialization. These gases will have a significant impact on temperature and rainfall trends and vegetation that are linked to the spread of malaria. This will lead to a considerable increase in temperature and drastic fall in rainfall in the Sahel regions leading to a reduced spread of malaria disease (Beay *et al.,* 2017).

The report continues to state that, the regions within and around the equator will experience an increased spread of the disease due to increased rainfall and temperatures. Climate variables such as temperature, humidity, and rain will affect the level of distribution of malaria when the vector changes; and the life cycle of the parasite and behaviour also is altered. With the increase of temperature, malaria disease is projected to move to the high land regions or higher altitude regions (Alout *&* Foy, 2017).

Impacts on malaria transmission are considered critical consequences of future climate change although it should be recognized that changes in malaria are unlikely to be a significant contributor to modification in the total burden of disease owing to global climate change (McMichael *et al.,* 2006). Malaria parasite and its vector may adapt to evolving environmental conditions over time, questioning the present approach of applying the current temperature –

dependents life cycle rates (dynamical models) or climate disease bounds (statistical models) to future climate condition (Hoffmann *&* Sirgo, 2011).

Kenya faces a heavy burden of disease of which about 30 percent of this disease burden is due to malaria. Malaria occupies the first position as the leading disease-causing mortality in both adults and children (Kipruto *et al.,* 2017). In 2006, an estimated 11.3 million malaria cases occurred in Kenya, making it one of the five countries contributing over half of the malaria cases reported in the WHO African region (Wanja *et al.,* 2017). About 70% of Kenya's population dwells in areas where malaria is transmitted. Malaria is responsible for 30% outpatient visits and 19% of all admission. At least 14,000 children are hospitalized annually for malaria, and there are an estimated 34,000 deaths among under-five annually according to the Ministry Of Public Health and Sanitation (MOPHS) (Egondi *et al.,* 2012). Economically, about 180 million working days are lost each year because of malaria illness leading to low economic output (Wanja *et al.,* 2017).

Mosquitoes carrying the malaria parasite transmits malaria. Malaria distribution depends on the availability and productivity of mosquitoes breeding habitat. The availability of the habitat of reproduction is related to stagnant water that remains after rainfall, while the productivity of the habitat of reproduction is a function of the ambient temperature (Fatmawati *&* Tasman, 2015). Rainfall increases the abundance of the breeding habitats while higher temperature increases the malaria parasite development cycle (Hay *et al.,* 2000).

In the regions where temperatures are low, the longevity of the mosquito may not be extended enough to complete the Sporogenic cycle (Garske *et al.,* 2013).

During summer isotherms, malaria is restricted in specific areas. Still, there are exceptional circumstances in regions of high altitudes in Africa where mosquitoes find shelter in warm huts and parasites and can complete their sporogony in the artificial conditions (Spencer *et al.,* 1987).

2.5 Rainfall as a Determinant of Malaria

Different studies have associated malaria abundance with high rainfall (Komen, 2017). However, there is insufficient data that links the relationship between the abundance of mosquitoes and high rain directly. This is because some mosquitoes strain like *Anopheles gambiae,* can breed prolifically in temporary and turbid water bodies such as animal hoof prints, and rain paddles which do not require high rainfall (Kipruto *et al.,* 2017).

Conversely, some species prefer permanent water bodies. But the most important factor to note is that both breeds of mosquito require adequate rainfall amount to be able to breed. Therefore, rainfall sufficiency and saturation deficiency affect the mosquito survival (Parham *& Michael,* 2010). Because of this, there is a good reason for using rainfall to evaluate the probable presence of vectors and the survival for malaria transmission. Even though the flooding often causes the destruction of breeding sites (Komen, 2017) and a temporary reduction of vectors, it never eliminates the vector. High rainfall, therefore, can still be considered the potential for transmission of malaria.

Water pools after it has rained creates the breeding ground for mosquitoes breeding sites according to African Monsoon Multidisciplinary Analysis (AMMA) (Kipruto *et al.,* 2017). Heavy rainfall can flush the riverbeds washing away the hatched eggs of the mosquitoes reducing the longevity of the mosquitoes. In addition to longer rainy seasons that are suitable for malaria spread, temperatures have also been warming in formerly cooler higher-elevation of East African highlands, subsequently; these areas are experiencing spread of malaria in populations that had not previously been frequently exposed to the disease (Lafferty, 2009).

Vihiga County receives mean monthly rainfall of 1900mm per year with two maxima rainfall season. Between the months of March-May, the region gets long rains (Zhou *et al.,* 2012). It is during this period when the region experience high malaria prevalence as indicated by malaria prevalence data collected from various health centers. The rains provide mosquito with breeding sites. These sites are pools of stagnant water in the farms, homes, alongside the roads and footpaths and any other surface that receives and store water for a period to facilitating breeding (Wanja *et al.,* 2016).

2.6 Temperature as a Determinant of Malaria

It should be noted that environmental temperature varies inversely with the duration of the sporogenic cycle of the mosquito. When the temperature is high, they tend to speed up the mosquito development while at the same time reduce the interval between blood meals of the *Anopheles* mosquito which leads to frequent host-vector contact (Weiss *et al.,* 2014).

However, as the temperature rises above 32°C, the mosquito survival rate of the mosquitoes becomes progressively lower (Martens *et al.,* 1999). As the temperatures drop below 18°C, the transmission becomes few because the temperature becomes the limiting factor. At 22 °C, sporogony is completed in less than three weeks, and mosquito survival is frequently high (15 %) for the transmission cycle to be completed (Kipruto *et al.*, 2017)

Therefore, the potential number of ineffective mosquitoes reaches a peak at 30.8 °C, after which it drops off rapidly. Temperatures higher than 32°C, have been reported to cause high vector population turnover but also weak individual and high mortality survival (Weiss *et al.*, 2014). Thermal death for mosquitoes occurs around 41-42°C.

The Table 1.1, page 2; shows the impact of temperature on the duration of sporogony, on the survival of the vector cohort survival after the required period for sporogony at different temperatures and on larval duration (Okuneye *&* Gumel, 2017).

The spread of malaria is seasonal and limited to the warm and rainy months in Vihiga County. However, the changing climate conditions such as the persistence of warm and rainy days for most of the year can increase the incidence of malaria events in the area (Zhou *et al.*, 2012).

2.7 The Mosquito Life-Cycle

Malaria is a disease that is spread by a parasite of species *Plasmodium* that is transmitted from one person to another through the bites of infected *Anopheles* mosquitoes. There are four life cycle stages of the mosquito; these are an egg, larva, pupa, and adult. These steps can be divided into two; the aquatic and terrestrial according to the inhabitant of the mosquito. The first three stages; egg, larva, and pupa takes place in the water hence marine environment while the adult stage is a terrestrial stage (Westenberger *et al.*, 2010).

After pupal exclusion, the mosquito needs to mate, and after mating, the Anopheles mosquito requires the blood meal to obtain the necessary nutrients for ovarian development. After blood digestion, gonotrophic stages of the mated female adult changes from blood feed to half gravid then to gravid. The gravid female, oviposit their eggs in stagnant water to hatch the eggs. This is made possible because stagnant pools have oxygen tension, a condition that develops in stagnant water once micro-organisms begin to flourish in it (Zhou *et al.*, 2012).

The eggs hatch into larva within 2-3 days within the tropics. Once they hatch their eggs, the mosquitoes are in their larval stage for 4-7 days. The mosquitoes will stay in the pupae phase for about two days until they exit their pupae skin and fly off to find their first blood meal. At normal temperature and nutrients conditions, this entire process takes about 10-14 days. As an adult mosquito, a majority of them, their lifespan lasts about two weeks. Most of them end their life-cycle when they are eaten by the dragon, birds, and spider. However, they can be killed by the effect of nature like wind, rain or drought (Sandeu *et al.*, 2016)

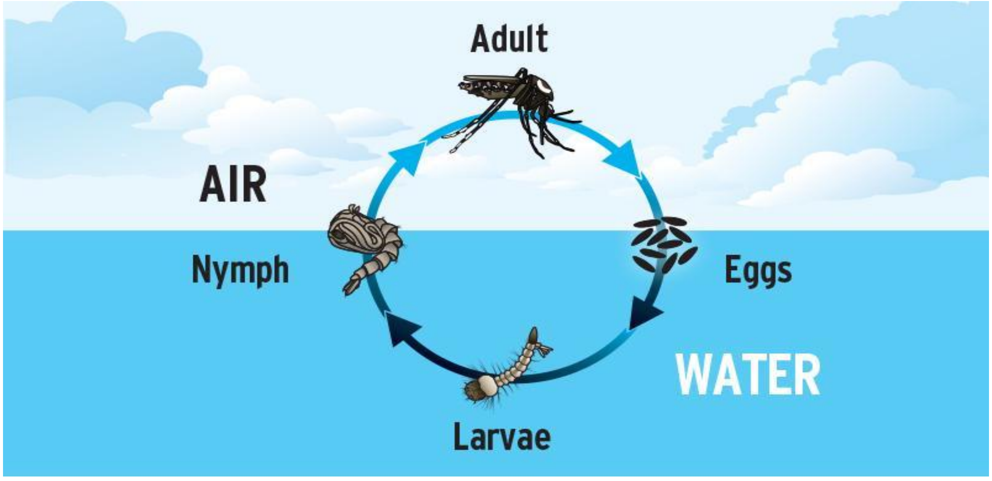

Figure 2.1.Mosquito Life Cycle

Source. Earthalivect.com (2017)

Therefore, to complete the life cycle of the mosquito so as for it to spread the parasite among human hosts, the mosquito in which the parasite dwells must live long enough for the parasite to develop (Zhou *et al.*, 2012). When the temperatures are higher, it shortens the incubation period, and the virus spread faster (Confalonieri *et al.*, 2007).

According to Haque *et al.*, (2010) climate change has the following spatial-temporal effects on malaria. First, an increase in distribution where low temperature – epidemic, malaria currently limit it may become present in a few areas. Secondly, it will decrease its distribution where temperatures become too high for mosquitoes to be sufficiently abundant for transmission of malaria. Thirdly it will increase or reduce the mode of transmission in areas with ‘stable' malaria, and some areas may change from unstable to stable malaria. Then lastly, it increases the risks of localized outbreaks in areas where the disease is eradicated, but vectors are still present, such as in Europe and the United States (Haque *et al.*, 2010).

2.8 Mosquito as a Malaria Vector

The mosquito becomes a vector when it carries infection from one person to another. The female Anopheles mosquitoes inject the sporozoites parasite in the bloodstream during its blood meal. When the climate is warmer, the adult Anopheles mosquitoes digest the blood meal faster and tend to feed more frequently. When the parasite reaches the liver cell, it reproduces and eventually ruptures releasing merozoites which then invades the red blood cells (Westernberger *et al.,* 2010).

When temperatures are high, they then reproduce and rupture the cells. At this stage, the infected person starts to feel chill and fever; the clinical symptoms of malaria. The person requires antimalarial drugs. At this juncture, if a mosquito bites the person, it will ingest gametocytes that fertilize in its slavery glands to form zygotes and become ookites. These will then develop into sporozoites in the salivary glands of the mosquitoes that will be injected into the human being during the next blood meal, and the cycle starts again (Zhou *et al.*, 2012). At the sporozoites stage, the development is affected by the temperature level within the surrounding (Sandeu *et al.*, 2016).

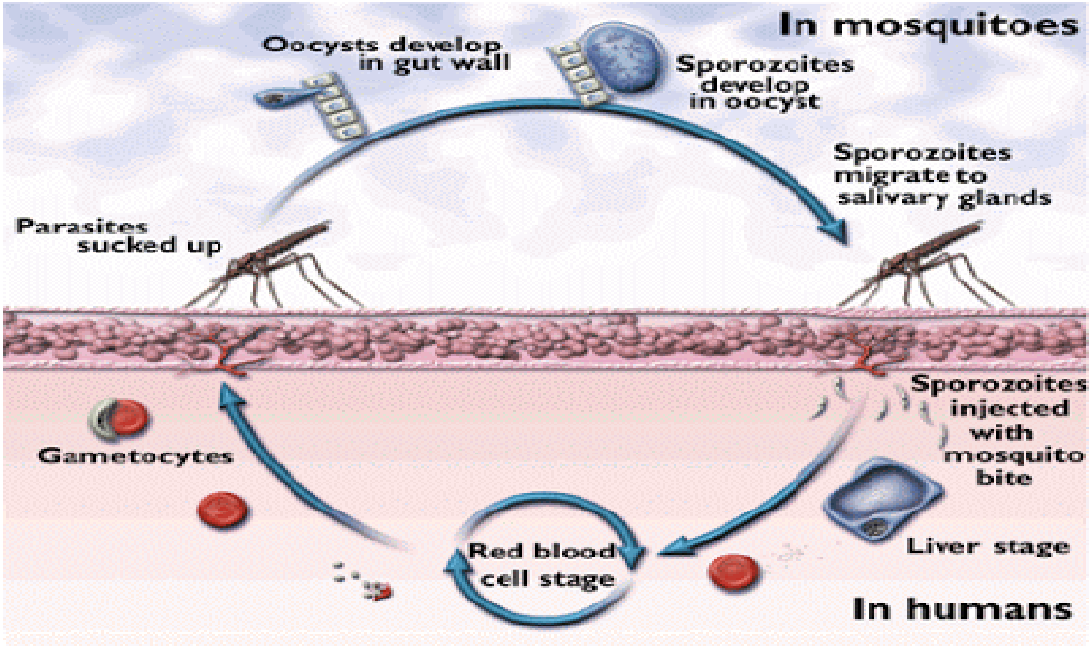

Figure 2.2: Mosquito Sporogenic cycle

Source: *Medilinks.blogspot.com (2017)*

From the Figure 2.2, it is imperative to note that when temperatures are high, the adult Anopheles mosquito will digest its blood meal faster and tend to feed more frequently. High temperatures make it possible to complete its extrinsic incubation within a short time. This, therefore, raises the number of vectors that can transmit the malaria parasite hence translating to high malaria prevalence.

2.9 The History of Malaria Mapping

The global maps produced between the 1900s and 2000s on the spread of malaria show varied the distribution of malaria. Before intervention, malaria was highly epidemic in North-Central Europe, over Northern Russia, Northern Australia and in the Northern United States, stable malaria transmission occurred in Mississippi Valley (United States), Central and North America, Southern Africa, India, Malaysia – Indonesia, China, and over a large area covering the Middle East and south-Central Russia (Dalrymple *et al.*, 2015). After the human intervention, the contemporary maps show that the distribution of malaria is now mainly restricted to the tropics, and a substantial decrease in malaria endemicity has been observed worldwide. Malaria has been eliminated in Europe the United States, Russia, most of China and Australia and has significantly reduced in Central and South America and India and to a more considerable extent over Africa (Yun *et al.,* 2017).

According to the current global mapping, the *Anopheles gambiae* is the principal vector species know vector that transmits malaria in Africa. On the contrary, the massive Pacific Ocean has always been free from Anopheles and hence free from malaria. Vectors are still present in Europe and North America (Martens *et al.,* 1999). Climate-induced effects are more consistent with the observed changes in a few regions of Africa and South America. Climate change may have significant impacts in the East African highland area in the future, where the population at risk is substantial. (Mlacha *et al.,* 2017).

In Africa, some malaria distribution maps are available based on climatic and other environmental prediction of malaria transmission (Korum *et al.,* 1995). However, they make little or no use of the data from the field survey of malaria prevalence which forms the most extensive body of relevant information. Reliable empirical maps of the geographical distribution of malaria are urgently needed for accurate estimation of the disease burden, to identify geographic areas which should be prioritized regarding resource allocation and for assessing the progress of the intervention programs (Mlacha *et al.* 2007).

The Mapping Malaria Risks in Africa (MARA) projects is a collaborative network of the leading African scientists and other institutions with the aim of providing empirical maps of malaria in Africa (Omumbo *et al.,* 2002). Initially, this involved the development of continental vast climate based theoretical models of climate collection of parasite prevalence data to validate and improve on these models. However, the availability of Remote Sensory (RS) data sources, computerized Geographical Information Systems (GIS) and geo-statistical Methods have provided unprecedented information and capacity for development of malaria risk maps (Rongers *et al.,* 2002).

Subsequently, several empirical maps have been produced citing a combination of the environmental and malaria data collected as part of the MARA project at both country and regional levels in Kenya and West Africa. In each case, mapping exercise has been used to further develop the methodology for empirical mapping of malaria (Omumbo *et al.,* 1998).

Kenya had a first malaria risk cartography map in 1959. The map was produced as an atlas in partnership with the Kenyan government. Even though the map was developed based on the expert's opinion and climatology knowledge, there is insufficient evidence that this map was used. It was used twenty years later in describing the national malaria risk in 1970 when the map was put to use. The map was then used to classify the country into endemicity zones based on an approximation of children years ranging between 2-9 years and later on in 1992; it was used in the formulation of Kenya's malaria plan (Spitzen *et al.,* 2017).

In the mid-1990s, after the launch of the MARA initiative, the empirical malariometric data was used to map revised cartography of malaria risk in Kenya

(Spitzen *et al.*, 2017). During this period, the country developed an epidemic strategy for an early warning system. In 2009, a malaria risk map was designed for Kenya as a country. This was based on the parasite survey that was carried out from 1975-2009 (Hume *et al.,* 2001).

Currently, Kenya Medical Research Institute-KEMRI in relation with other interested bodies continues to work to update information on malaria prevalence nationwide through school survey, providing technical support during the KMIS 2015. They are also involved in assembling evidence from various research groups across the country. This helps in updating and reviewing the levels of malaria risk nationwide and by the county. This aims at improving on the 2012 profile with the presentation of disease risk and intervention coverage by sub-county to support within the county decision making on malaria prevention and treatment. This is to identify more accurately those populations that are in danger, based on regional environmental and climatic patterns of those areas (Omumbo *et al.,* 1998).

The map was based on the most extensive single survey data from every country in the sub-Saharan Africa and data from Kenya Malaria Indicator Survey (KMIS) of 2007-2010 was used. This made Kenya be the first country in sub-Saharan Africa to develop a formal sub-national framework using empirical data on malaria transmission. This publication served as a platform for identifying the most endemic districts in the Lake Victoria region to reduce the prevalence. This map was later updated in 2012. This gave way to the first comprehensive malaria epidemiological and control profile to be developed. The map was used to stratify the present counties into a varying level of average malaria endemicity to the planning of devolved governance in Kenya in 2013(Bryan *et al.,* 2013).

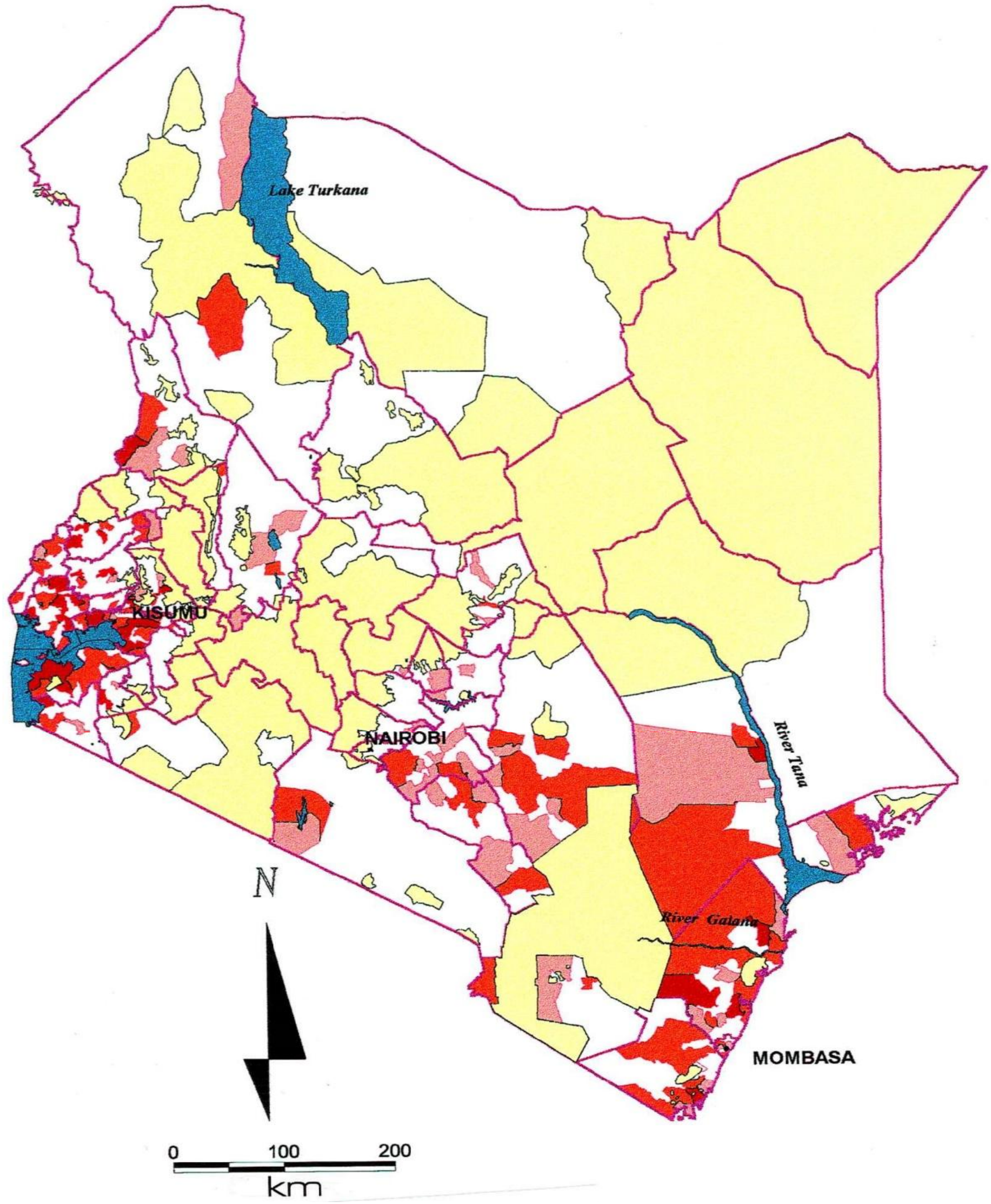

Figure 2.3: Kenya's Malaria map
S*ource: Medilinks.blogspot.com (2017)*

Map showing fourth-level administrative boundaries (or locations), estimates of high (dark red), moderate (medium red) and low (light red) *Plasmodium falciparum* endemicity, the entire mask layer for low probability of malaria (yellow), and locations for which no relevant data were available (white).

However, the map focused on counties only. This left out the critical regions within the counties that were malaria hotspots. This is study is to try and fill the gap that was left. The research will focus on Vihiga County, by mapping the region based on the difference in altitude. The study aims at generating a malaria spread map for the county. There is a need for a detailed map on current malaria transmission targeting areas and regions where malaria transmission among children under five years are high. Such maps should make use of both the prevalence data obtained from health centers on patients' medical reports and relevant climatic information data received from Meteorological Departments. Remote Sensing (RS) and Geographical Information System (GIS) database in the location of those areas to enable mapping them (Ndenga *et al.,* 2006).

Malaria mapping is critical in the current study due to the changes in climate trends globally where accurate models are used in data analysis. Vihiga County is within an endemic region where malaria transmission is perennial but high from June and August and again in late November. This is because of the current rainfall seasons both of long rains and short rains (Wanja *et al.,* 2016).

2.10 Conceptual Framework

Most of the human health diseases are not directly linked to climate change per see. However, the changes in climate enhance their occurrence. Rising temperatures will affect pathogens and vectors life cycle in this study mosquitoes hence affecting the rate of infections. Reduction in precipitation may likely reduce the prevalence in specific areas by creating a un-conducive environment for the thriving of vectors while sometimes flashing them out during flooding. (Rogers and Randolph, 2000). However, the level of impact will vary because of geographical differences in temperature and precipitation due to altitudinal differences, quality of health infrastructure and community capacity to mitigate and adapt to climate change. The study comes up with a malaria spread map as a mitigation and adaptation measure to malaria control in Vihiga County. This will help in locating malaria hotspots during the long rainy season. If rainfall and temperatures changes can be monitored and recorded, it can be used to predict either low or high malaria outbreak.

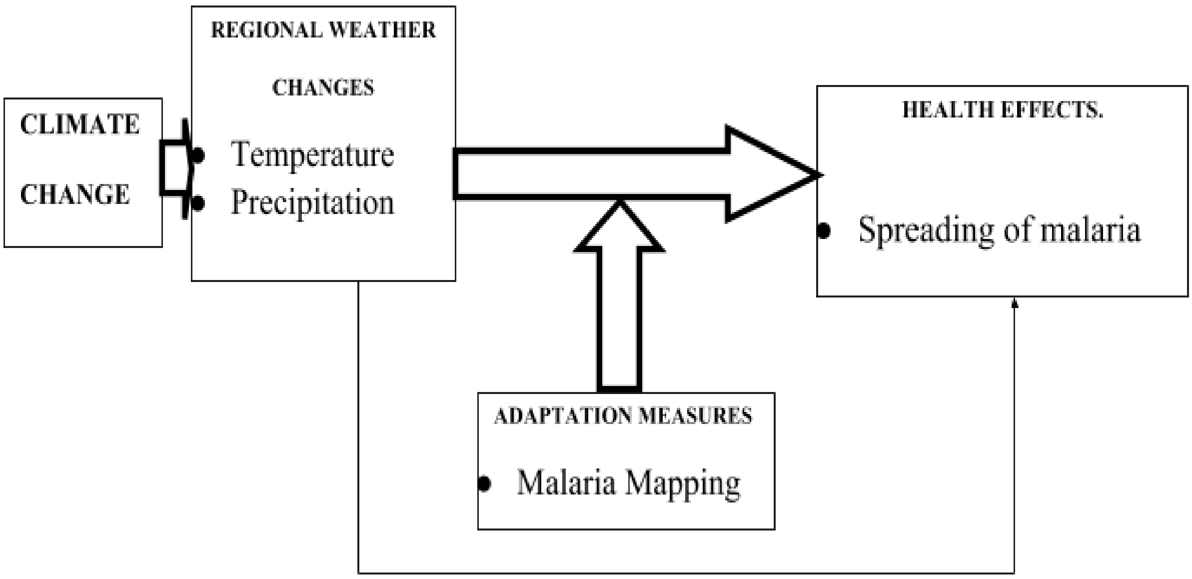

Figure 2.4: Conceptual framework

***Source*: Adapted from Patz *et al.* (2005)**

2.11 Gaps in Literature

This study identified various gaps in the literature that forms the centre of this research. First, climate and health research has received little attention and therefore it is still at its early stage both locally and globally. The relationship between climate changes on disease either directly or indirectly has not been fully understood. Even though there is a lot of literature on climate change, there remain uncertainties about its potential impact on health (IPCC, 2007). These uncertainties are due mainly to three main areas which are the objective of this study: First, climate change trends, secondly, the link between climate change and health in this case malaria and lastly, human mitigation and adaptation capabilities in this case malaria mapping. Some studies have been carried in the Vihiga County by Kuya, (2015) on climate change. However, this study does not link these changes to the spread of malaria. This study, therefore, is to try to relate the changes in temperature and rainfall to malaria prevalence in the area.

Secondly, the study on malaria in the area by Zhou *et al.*, (2012), focused on the malaria prevalence across the population cohort from infant to adulthood. The impact of malaria on the children under five years and its effect on the social-economic status of the community has received little attention in the recent years. Therefore this study tends to focus on the impact of climate change on malaria amongst children under five years for the past five years.

Thirdly, most studies on the impact of climate change on health have been done in the developed countries where tools, technology and the capacity to carry out such research is available. However, the developing countries like Kenya are the most at risk, yet they cannot carry out such research (McMichael, 2009). Insufficient tools and technology have led to the inadequate investigation of the relationship between climate change and diseases. For example, climate data used in malaria studies has not been of sufficient quantity or quality to establish clear links between malaria and climate (Hay *et al.,* 2002). Therefore, this studies narrows down to Vihiga County, even though the county does not have its meteorological station, climate data from the neighboring Kakamega were used to try to establish the changes in climate and how they impact malaria prevalence in the region.

Finally, the study will generate a sentinel map to show areas of high malaria prevalence in the county by locating malaria hotspot areas. This aimed at mitigating the impact of the disease in the area by identifying health centers that will be used as sentinel units. The changes in climate especially rainfall and temperatures will be used as early warning signals when they exceed a given threshold. This information will be relayed from sentinel health centers to malaria monitoring units at a local and national level for malaria epidemic detection and emergency action.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The chapter focuses on the study site, data sources and data collection methods employed. It includes the research design used, the target population, data validity and reliability, data analysis and data acquisition on map drawing.

3.2.1 Population of Vihiga County

The county is densely populated with a population growth rate of 2.98% per annum with an average population density of 900 persons per square kilometre (GoK, 2009). The county is the most populous rural setting in Kenya with a total population of 615,734 according to 2009 census with population projection of 653,529 by 2017(Table 3.1)

Table 3.1: Population Statistics of Vihiga County

Sub County	2009			2015			Anticipated Pop 2017
	Male	Female	Total	Male	Female	Total	
Sabatia	61,439	68,239	129,678	68,590	75,314	143,869	152,804
Vihiga	43,672	47,944	91,616	48,749	52,903	101,647	107,954
Emuhaya	35,762	40,632	76,394	39,065	45,233	84,298	105,044
Luanda	51,374	57,301	108,675	57,569	63,737	121,306	113,029
Hamisi	70,469	77,790	148,259	78,757	85,887	164,614	174,698
County	**262,716**	**291,906**	**554,622**	**293,529**	**322,205**	**615,734**	**653529**
Under Five Years					**2012**		**2017**
Pop					106,554		113,394

Source: 2009 Kenya Population and Housing Vol.1A

3.2.2. The Study Area.

Vihiga County consists of five sub-counties namely; Sabatia, Hamisi, Emuhaya, Luanda, and Vihiga. The region receives annual total rainfall ranging between 1800mm and 2000mm with distinct long and short rainy seasons. The temperature reaches between 14 and 32°C with a mean temperature of 23°C. The altitude varies from 1300m to 1500m above the sea level. The County covers an area of 531.0 km^2 and about 30 km^2 forest cover in Hamisi Sub-county. The county borders Nandi County to the East, Kakamega County to the North, Siaya County to the West and Kisumu County to the South.

The county has the right amount of forest covers such as Kibiri forest and Maragoli forest which is the extension of Kakamega forest. The critical economic commonly practiced in Vihiga County is crop farming such as tea, maize, sweet potatoes, beans, millet, bananas, papaya, cassava, mushrooms, and avocado. Animal husbandry especially dairy and zebu cattle and poultry is also practiced. The residence is also engaged in small retail shopping within the significant town of Mbale, Majengo, Luanda, Serem, among others.

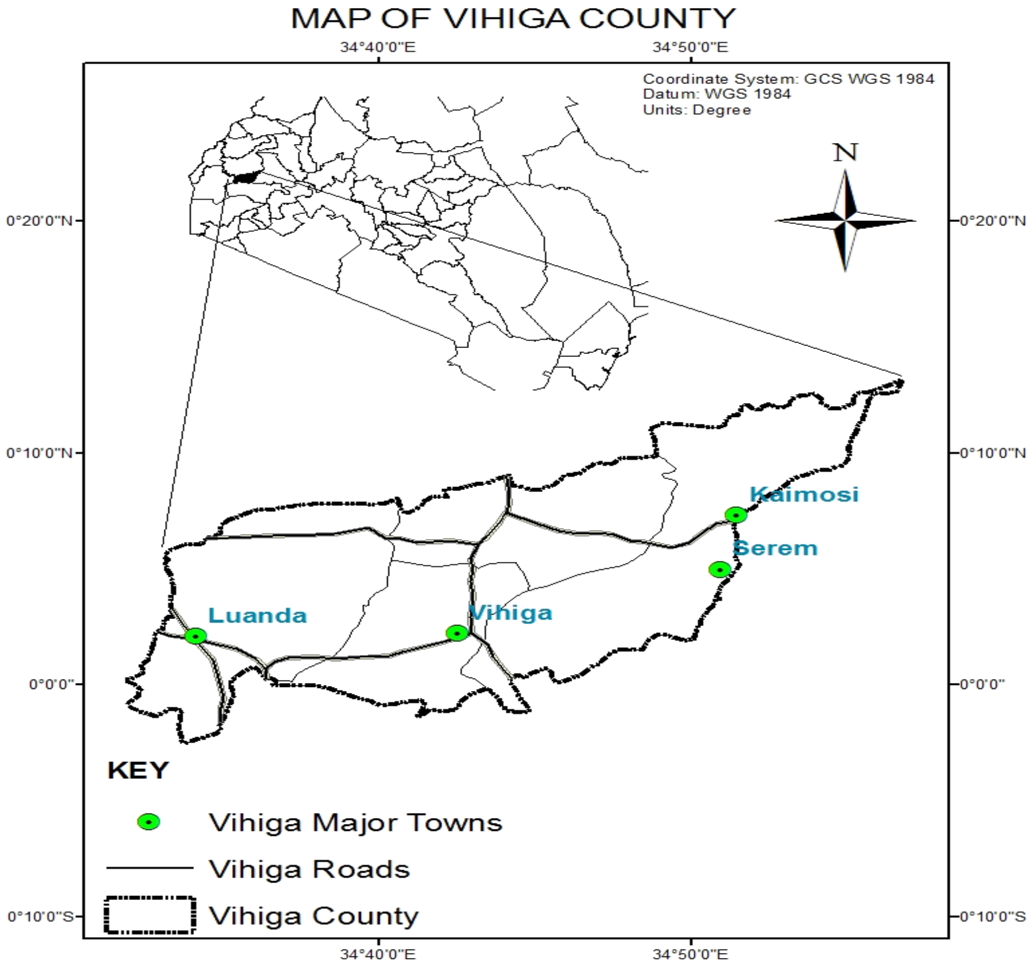

Figure 3.1: Map of Vihiga County

Source; Kenya Data 2017

3.3 Research Design

The study employed a qualitative research method. The method tries to locate the observer in their real world. The technique uses a naturalistic approach that seeks to understand any happening in specific context without controlling the occurrence of the truth (Kothari, 2004). The study used descriptive research design and diagnostic research design. This is because the research is concerned with describing the trends of malaria prevalence among the children under five years for the last five years. Diagnostic as the study had to determine the frequency of malaria prevalence concerning climate change (rainfall and temperature). Probability sampling design was used where purposive sampling strategy was employed. The method was valid as it allowed the researcher to focus on the households of children under the age of five years and critical health centres at different altitudinal level. Questionnaires, interviews schedules FGD were tools used to collect data from the respondents.

3.4 Data Sources and Data Collection

Both primary and secondary data sources were used. Primary data included the responses and views of patients and health personnel on their perceptions on climate change issues. The information was gathered using the questionnaires that were administered to the children caretakers in every household chosen and health workers in various health centres. The open and closed-ended questionnaires were used to find out the views of the parents (households) and health personnel on issues of climate change and spread of malaria and mitigation measures that have been put in place by both national and county government. Interviews schedules were held from the key informants to gain information on malaria prevalence and the effectiveness of the control measures being used. They comprised of the Director of health in Vihiga County, malaria co-ordinator of the county, officers-in-charge in every health centres, the nurses, the parents and caregivers to the patients of children under five years who are the target group of the study.

Secondary data collected from secondary data sources that were not analysed. These include the statistical data on rainfall and temperature retrieved from meteorological stations within the area of the study like Kaimosi, Kakamega. Statistical data for malaria prevalence for the past five years were obtained from the District Hospital Information System (DHIS). Beyond five years, data wasn't available in some health centres.

3.5.1. Sampling Procedure

Vihiga County has five sub-counties that have various ecological zones with changes in rainfall and temperature that have a significant influence on mosquito life cycle. All these five sub-counties formed the basis of this study targeted for sampling. The study made use of the Morgan table, and out of a population of 290,325 households 14,516 were the ideal sample size to be used that represented 5% to represents the entire county. However, because the study was interested in households with children under the age of five years, 2.1% which represents approximately 300 families was used. Table 3.2 shows the summary.

3.5.2. The Sample Size

The health centres that had malaria prevalence in the DHIS were over 65 in total from the entire county. However, twenty-five health centres were chosen purposively for this study. Five health centres were picked from each sub-county to generate as sentinel map. This was based on their altitudinal location either in high, medium and lower level ground. Both public and private hospitals were sampled. However, public health canters were preferred over private as public health offer free malaria treatment hence the likelihood of registering a higher number of patients, unlike the private health centers that charge for the treatment. (Bruce, 1978).

Table 3.2: The Sample Size

Sub-County	Total Households(2015)	5% of the households	2.1% Sample size
Vihiga	62,124	3106	64
Hamisi	64,475	3223	66
Emuhaya	49,871	2494	52
Luanda	54,732	27366	57
Sabatia	59,123	2956	61
Total	**290,325**	**14,516**	**300**

Source: Central Bureau of Statistics 2009 for households per Sub County.

3.5.3. Target population

This study targeted children under the age of five years who are vulnerable to malaria prevalence for the last five years in Vihiga County. A total of twenty-five health centres, five from each sub-county were selected for the study. These are health facilities that had malaria in children five years continuously for the five years period. Their choice was also based on the altitudinal location either, low, middle or upper ground. The target population was derived from these twenty-five health facilities. The target population was 300 respondents. These comprised of 5 sub-county Directors of Health; 25 officers-in-charge of the health facilities; 20 nurses, four from each health facility; and finally 50 members of the local community to be used in FGD, ten from each Sub-county. The remaining 200 respondents comprised of household heads and those responsible for taking care of children under the age of five years. 40 households were selected purposively from each sub-county based on their altitudinal house location and the accessibility of the families to the health facility.

3.5.4. Sampling Technique.

Purposive sampling technique was used in the selection of the area of study of Vihiga County, the health facilities and the respondents to be included in the study. Vihiga County was selected because the county has varied topography which differs in the altitude. The altitudinal difference has a great significance on the climate variability of the region especially the rainfall and temperature which in return influence the mosquito breeding level. Twenty-five health facilities were chosen purposively based on their location and registered malaria prevalence as recorded in the county DHIS. This was ideal to provide data for comparison for five years as influenced by the changes in temperature and rainfall.

The households were also chosen purposively. Only houses that had at least two children under the age of five years were selected to be part of the sample population. This is because majorly focused on the children under five years who are susceptible to malaria outbreak across the year.

3.5.5. The Administration of the Research Instruments.

The researcher administered the research tools of data collection with the assistance of four field assistants to cover the five sub-counties. The researcher sought the permission from the Department of Geography and obtained the letter of authority from the school of Graduate studies at Masinde Muliro University of Science and Technology. The copy is in Appendix 4. The later was submitted to Ministry of Education Vihiga. The letter introduced the researcher to the County Director of Health (Appendix 5). The letter was sent to the County Director of Health of Vihiga who farther granted the researcher with relevant copies of letters of permission to each sub-county Director of Health and officer-in-charge in the five sub-counties. A copy such a letter granted to the researcher each five sub-county if found in Appendix 6. This allowed the researcher to have access to the required information from various health facilities. This includes DHIS information that is restricted only to the officer-in-charge who have the passwords. The researcher was able to organise the scheduled interviews with county malaria coordinator, doctors, nurses, and disseminate the questionnaires to the nurses and patients and coordinate for Focus Group Discussion with the locals. Copies of the interview schedule questions, FGD, and the questionnaires are as provided in the appendices 1, 2 and 3.

3.6.1. Study Limitation.

The study was limited to the selected areas within four sub-counties in Vihiga County. The survey targeted only 200 households who had at least children under five years as portrayed from the medical records from the selected health facilities. This discarded valuable information on the adult population.

Climate change does not work in isolation on malaria influence. It is intertwined with non-climatic factors such land use, economic activities of the residence, educational level and other social events. With all other non-climatic factors held constant, the study focused on the role of rainfall and temperature variation in the region against reported cases of malaria prevalence.

The study only focused on mean monthly temperatures and meant monthly rainfall variations and how this changes impacted on mosquito breeding level. This was to compare the changes of these elements with similar records on the malaria prevalence.

3.6.2. Study Delimitation.

The research did not focus on the climatic factors and how they influence the spread of malaria. This is because of limited time and funds to in-cooperate them. Also, there are available literature on the same topic different authors in the region (Zhou *et al.*, 2012). Therefore there was a need to dwell on a different issue that has not been covered.

The research didn't involve the entire households in the region. Only a few areas and households and health facilities were chosen as a sample for the study. Twenty-five health facilities and two hundred households were selected for the study.

However, this delimitation led to the loss of vital information about malaria prevalence in the adults that could have been vital for projection of the future trends. Also, without focusing on non-climatic factors and how they the spread of malaria, may lead to confusion on how extent climate change alone can have on malaria prevalence.

3.7 Data Validity and Reliability

Data validity is the ability of the study to arrive to reach a correct conclusion and measures what it aimed at measuring while data reliability is the extent to which repetition of the study will produce the same results at the same condition (Pose & Lampard, 2002).

The questionnaire was first pre-tested at Kilingili Hospital to evaluate its clarity, style, meaningfulness, and ease or difficulty in answering the questions before it was administered to the households and health personnel. The questionnaire was found to be lengthy as noted by the Health Officer In-charge at the hospital. However, he acknowledged that the items were relevant and he suggested other things for inclusion. Based on this feedback, the questionnaire was revised to ensure consistency and quality before distribution for data collection.

3.8 Data Analysis

The collected data were subjected to both qualitative and quantitative analysis with the help of standardized statistical packages to extract needed information on household characteristics, malaria prevalence and climate changes from the questionnaires and interviews. Data analysis involves assigning an order, structure and the ultimate meaning of the gathered information. It helps the researcher to draw meaning, interpretation, and understanding from the info (Kothari, 2004).

Quantitative analysis. Data from the health centers on malaria prevalence in the region, temperature and rainfall trends from the meteorological department were analysed quantitatively. Data from the DHIS from the hospital were analysed quantitatively. Microsoft Excel was used in computing statistical data. The software was used because it could generate accurate graphics on malaria prevalence, rainfall and temperature trends in the county.

Qualitative analyses using PAS was used to compute the results from the data that was collected using the questionnaires and interviews on the parents/ caregivers on malaria prevalence in children. Medical practitioners' perception of climate changes, malaria prevalence, impacts of both climate change and malaria prevalence on the society and the success of prevention and treatment measures were analysed using the same method (Kothari, 2004).

3.9 Data Acquisition for Mapping

Data on mapping was acquired from the Global and cover facility 2017 May on the web www.global and cover. The data path; 170 and Row 060.

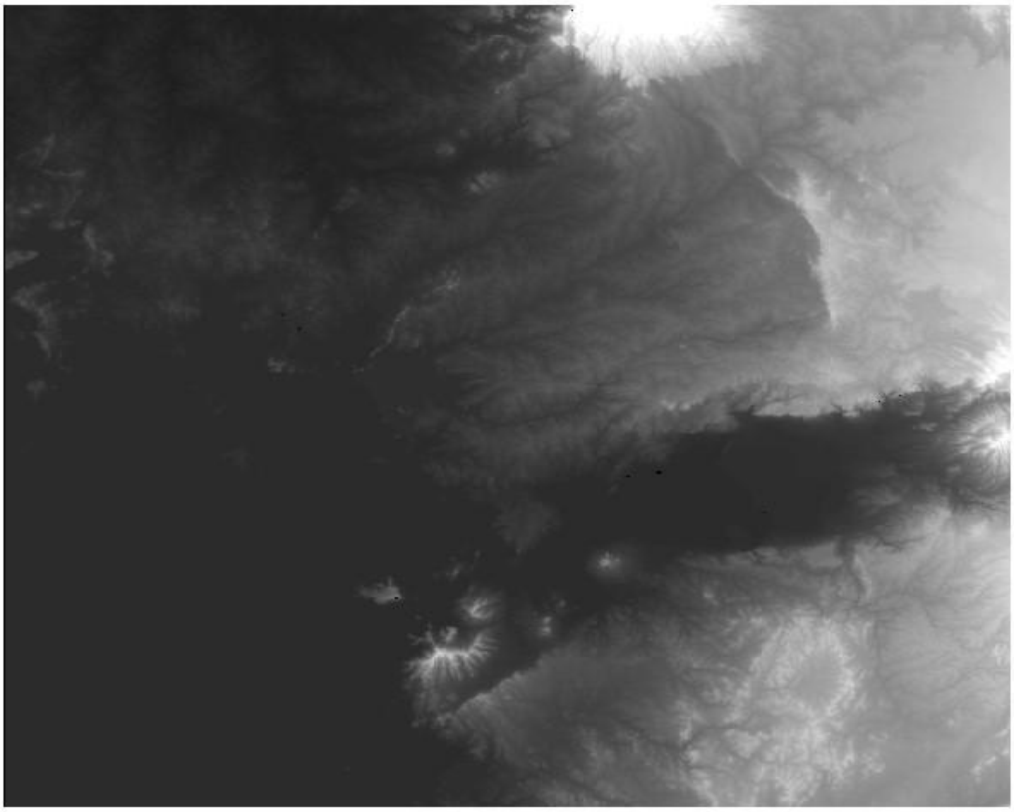

Figure 3.2: The Dem of the Lake Victoria Basin Region.

The Map was drawn later and analysed using the ArcGIS. The processing started by clipping the Digital Earth Map (DEM) using Kenya shapefile for Vihiga County. This is because the DEM was more extensive than the area required. The DEM was in a different projected coordinate UTM zone 36N in the Northern

Hemisphere. The shape was in geographic coordinate Arc 1960. It was then overlaid during the clipping with shapefile of Vihiga county map. Then the spatial data analysis was then done to generate a slope map that was used to identify households and health centres with spatial elevation in the region.

3.10 Health Centres from each Sub-County

Vihiga county has the following health facilities; five (5) referral hospitals in each sub-county, thirty (30) dispensaries, twenty-two (22) health centres, nineteen (19) medical clinics, two (2)Nursing homes and four (4) others. The doctor to population ratio is 1:50,000, the infant mortality rates are 100/1000 while the under-five mortality rates stand at 120/1000.

The prevalent diseases are malaria, respiratory tract infections, pneumonia. Major hospitals in the county are Vihiga Referral Hospital, Emuhaya Referral hospital, and Hamisi Referral hospital. For mapping health centres to come up with sentinel map, the following health centres were selected from each sub-county.

Table 3.3: Health Centres from Each Sub-County

NO	Vihiga	Emuhaya	Luanda	Hamisi	Sabatia
1	Vihiga R.H.	Emuhaya R.H	Luanda Town	Banja H.C.	Sabatia H.C
2.	Mbale Side C.	Ekwanda	Ipali H.C	Serem H.C.	Kegondi H.C.
3.	Mbale Rural	Luanda Town	Esiarambatsi H.C.	Tigoi H.C.	Bugina H.C.
4.	Lyanagiga H.	Ebusyubi Dis	Green Valley C.	Hamisi R.H.	Givundimbuli H.
5.	Mulele Disp	Kima Mission	Rotary Doctor.	Kaimosi Mission	Itando Disp

Five health units in every five sub-counties were chosen for mapping. This was to reduce congestion on the map and only to show fundamental health units for malaria early warning and detection in case of an epidemic outbreak for emergency attention. These sentinel sites most of which were health centers and dispensaries were located using the global position system (GPS) for accurate map drawing. A sentinel map was then drawn.

In this study, three factors were used to select a specific health centre in a given region to be used as a sentinel health centre in a malaria hot spot area. First, the number of children under the age of five years who were diagnosed with malaria for both outpatient and severe admission per week. A mean of 10-14 patients in a health facility in the lower region and middle ground, was considered falling within ‘normal range.' In the upper region, the ‘normal' range was between 7-11 treatments (DHIS, 2017). The health centres in the urban and major town, the normal range were evaluated to be between 12-16 children treatment per week. Patients beyond the set normal range as highlighted above were considered as an early warning of malaria outbreak in the region. The information on weekly and monthly malaria outpatients' treatment and severe admission was acquired from the summarised graphical chart as posted on the wall in the health centres.

Secondly, their choice was based on the altitudinal difference, lower, medium or above ground. The lower ground 1300-1365, the middle ground 1366-1430m and higher ground between 1431-1500m. This was to assess the differences in temperature and rainfall amounts that are likely to create an ambient environment for malaria breeding.

Thirdly, it was based on whether the centre was a public or a private health facility. Private facilities tend to record low malaria patients unlike public ones within the same region. It's because malaria treatment in public hospitals is free unlike in the private patients pay for treatment. The following health centres were picked from each sub-county as sentinel health centres as shown in Table 3.3.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter shows the results and discussions of the study whose general objective was to determine the impacts of climate change on the spread of malaria amongst children under the age of five in Vihiga County, Western Kenya. The specific objectives were: To analyse the changes in the rainfall and temperature trends for the past forty years in Vihiga County. To assess the impact of rainfall and temperature changes on the spread of malaria amongst the children under-five years in Vihiga County and finally to map spatial variation of malaria spread in Vihiga County.

4.2 The Temperature Trends in Vihiga County

The study sought to establish from the respondents in the questionnaires whether there had been any change in temperature for the past thirty-five years. From the findings, the majority 70.0% of the respondents reported that there had been a change in temperature while 30.0% of them indicated that there had been no change in temperature. (Figure 4.1) shows the results.

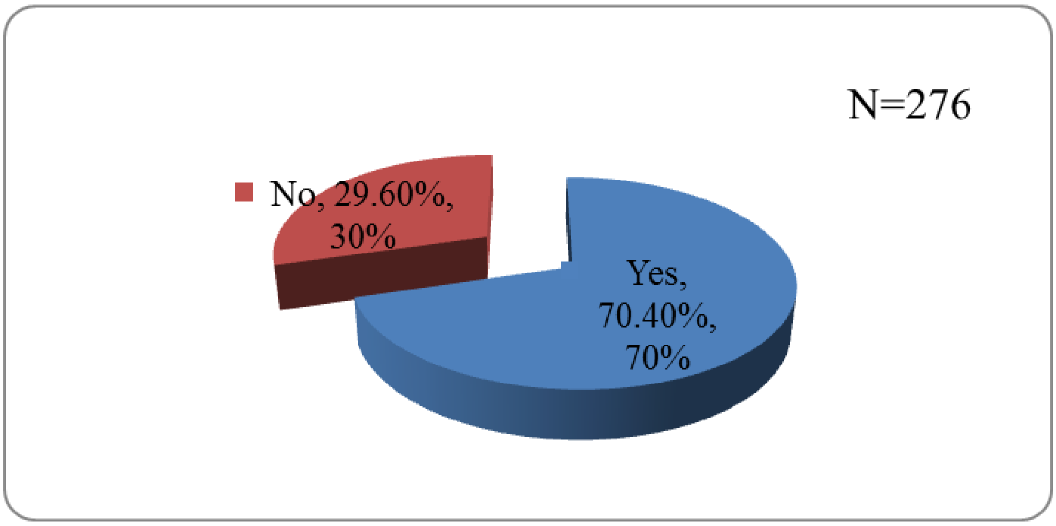

Figure 4.1: People's Perception of changing Temperature

From the finding, the majority of the respondents who agreed on rising temperature sighted increased hot days and nights in months that previously were known to be cool and warm. Most of the respondents who were able to detect this rise in temperature were doctors, nurses, and clinical who could access the temperature measuring instruments. This is in line with a previous study that revealed increasing of temperature in Vihiga County by Kuya (2015). Those who decline, they sighted inability to detect any changes as they didn't know how to recognize the changes in temperature as it requires sophisticated equipment and knowledge.

4.3 Respondents Rating of Temperature

The study sought to find out if there is any change in temperature in the region. The information was gathered according to the altitudinal difference, the lower ground 1300-1365, the middle ground 1366-1430m and higher ground between 1431-1500m. From results, 74.1% of the respondents reported that they received medium temperature ranging between 21°C - 27°C. While another 11.1% (28°C-

30°C) of them reported that they received a high temperature (31°C-39°C). However, 14.8% (20°C-15°C) of the respondents indicated that they received low temperature. Results are shown in Figure 4.2.

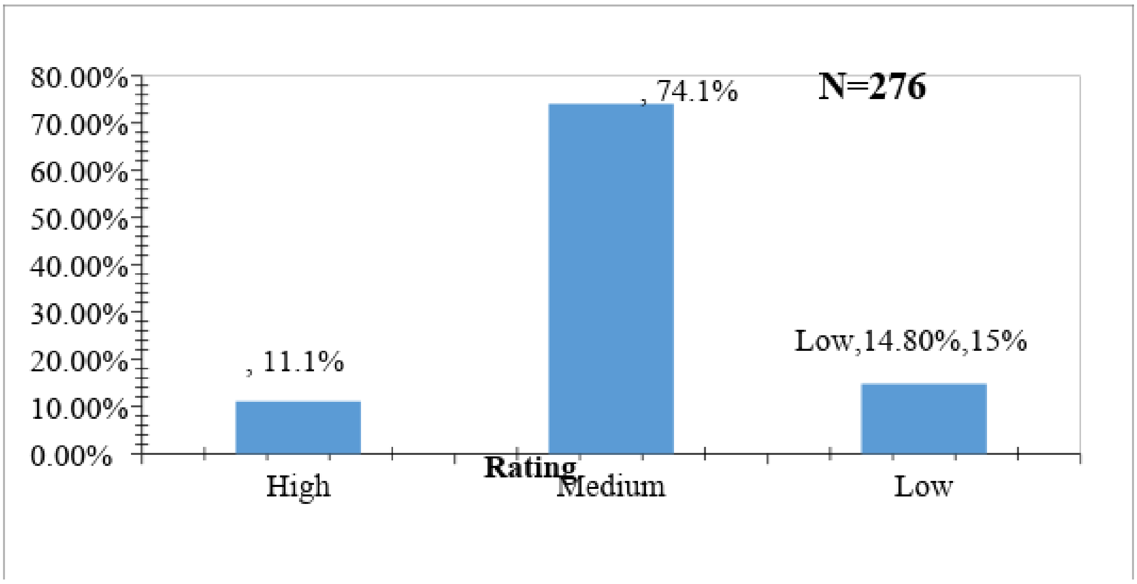

Figure 4.2: Temperature of Rating

From the results, most of the respondents agreed that the temperature is above the average (18°C-27°C) across the year. Even though responses are based on the respondent views on temperature, and guidelines as given the questionnaires. Those respondents who work in health gave formative answers. The respondents from the lower region pointed out the temperatures have increased as nights were hotter compared to the previous years. Medium to high temperature provides an ideal environment for mosquitoes breeding as indicated in Table 2.1. In the table, temperatures above 21°C favour breeding of mosquitoes within a short period. This will in turn favour breeding of mosquitoes leading to the increased number of mosquito vector in the area hence increased malaria prevalence (Kipruto *et al.*, 2017).

4.4 Mean Annual Temperature of Vihiga from Meteorological Station.

The mean yearly temperature of Vihiga as obtained from Kakamega Meteorological department for the last thirty-three years is as in figure 4.3. The mean annual temperatures were computed using Microsoft Excel software. The year 2009 recorded the highest temperature (28.4°C). The lowest mean annual temperature was recorded in 2002 (25.5°C).

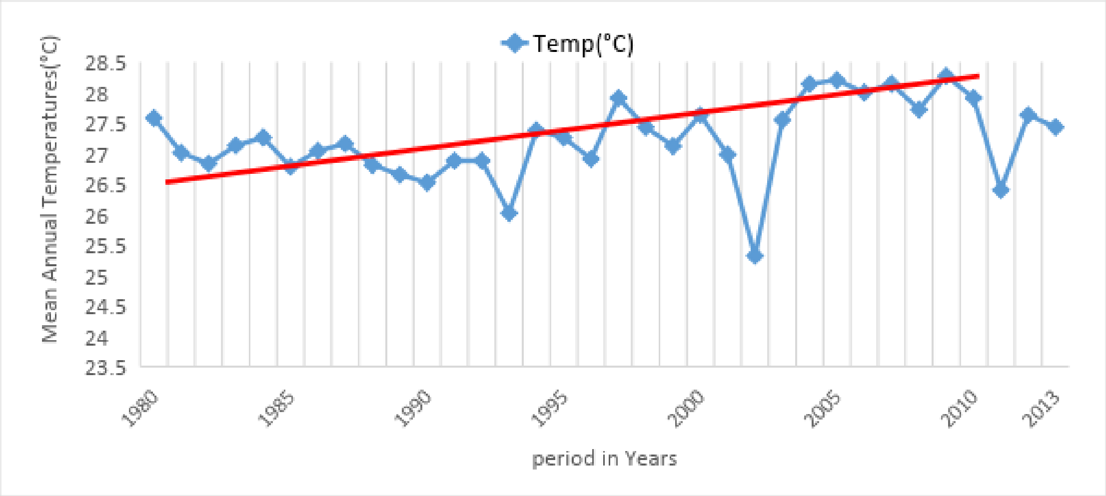

Figure 4.3: Mean Annual Temperature of Vihiga County (1980-2013)

This increase in temperature is very significant to both plant and animal life in the region. Mulinya (2017), in her study on climate change in Kakamega County and how it affects the small-scale farmers' output, realised that there is a definite trend in temperature change of 0.04°Cper annum. Vihiga too should be experiencing the same. This change when accumulated over the years, preferably thirty-three years, can have a massive impact on both the survival of flora and fauna and microorganisms that cause diseases and infections to both plants and animals in the area. The increase of 2°C is of significant impact to the breeding of vectors especially the mosquitoes in the region (Kipruto *et al.*, 2017).

4.5 Mean Monthly Temperature of Vihiga in 2013.

The study also sought to establish the temperature changes across the year. The mean monthly temperature for the year 2013 was analysed. The year was picked for analysis because it provided the latest parameters temperature as supplied from Kakamega metrological station. The results are indicated in the graph in figure 4.4.

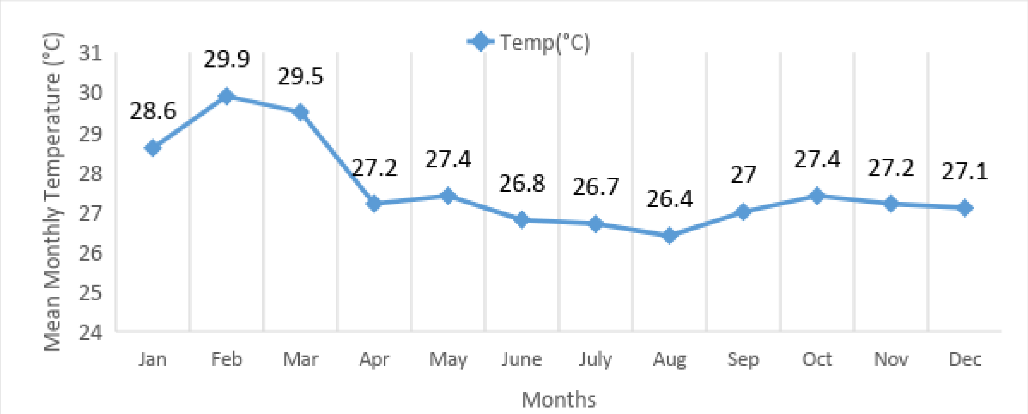

Figure 4.4: Mean Monthly Temperature of 2013

There was an increase in temperatures in January (27°C), reaching the maximum of 29.9°C in February. The temperatures remain above 26.4°C across the years. Temperature above 22°C is ideal for mosquitoes breeding as indicated in table 2.1. The lowest temperature was in August (26.4°C) while the highest temperature was in February (29.9°C). This high temperature, quicken the rate of vector productivity in the region. Temperature above 22°C vectors sporogony is completed in less than three weeks, and the mosquito survival is high for malaria transmission cycle to be completed (Kipruto *et al.*, 2017). This increment in temperature from the year 2011-2013 is confirmed with increased malaria prevalence in Vihiga County for children under five years.

4.6 The Perception of Medical Practitioners on Temperature Change

Most of the respondents from the questionnaires and FGD agreed temperatures have increased in the county for the past recent years (79.32%). They acknowledged that hot days have increased while 9.20% declined that hot days have not improved. 14.48% did not have any knowledge of weather temperature have increased. To them, temperatures remain the same throughout the years as indicated in Table 4.1.

Table 4.1: Perception of Medical Practitioner and households on the temperature trends

Temperature	Percentage (%)
Hot Days Increased	76.32
Hot Days Declined	9.20
Hot Days Remain the same	14.48

The results are congruent with the view of the households on the increased temperature in the area. The results also agree with previous research by Wanja *et al.,* (2016) that revealed a rise in temperature in Vihiga County. According to him, the temperatures in the region have increased by 2°C for the past thirty-five years. To him, such an increase could have a massive impact on crop production leading to low crop production.

4.7 Causes of Temperature Change in Vihiga

There was a need to analyse the responses from the questionnaires to find out what would have been the probable causes of climate change in the region. Table 4.2 shows the responses of the household heads on the major causes of temperature change in the area. It was necessary as most of them are resident from the area who have knowledge of socio-economic activities that could contribute to this change.

Table 4.2: The Causes of Temperature Change in the region

Cause	Percentage (%)
Deforestation	23.3
Global warming	36.7
Don't Know	40.0

It was evident that 23.3% of the respondents suggested that deforestation could have been the cause of the changes in the mean temperature in the county. They cited the example of deforestation of the Maragoli hills forests by the locals for the provision of wood fuel and timber. They also mentioned the encroachment of residents for settlement in Kaimosi forest and the general cutting down of trees in homes for domestic use and creation of room for settlement and agriculture. About 36.7% of the respondents indicated that the changes in temperature were due to general global warming. However, a majority of the interviewee (40.0%) were not aware of the causes of the temperature changes in the region. This is because, deforestation in the region was minimal to them to cause climate in the area and if it was because global warming, it is a worldwide problem which is likely to have minimal impact on them.

However, it was noted that global warming and deforestation had had an impact on climate change. This is attributed to an upward trend in temperature each year that can be associated with increased releases of chlorofluorocarbons. Global warming leads to increased rainfall that enhances vector abundance and distribution. It also leads to high temperatures allowing mosquitoes to survive cold areas where they would otherwise have died. This, in turn, allows more mosquitoes to live, breed and transmit malaria across the year.

Deforestation was sighted to be a possible cause of global warming as it reduces vegetation that uses carbon dioxide reducing its concentration, the main component of greenhouse gases (GHG) that causes global warming. Deforestation also increases the rate of mosquitoes' multiplication and survival of the vector. Forest and vegetation, provide humid and cold conditions that are unfavourable for mosquitoes survival. Deforestation of Maragoli Hills Forests, riverine vegetation and planted trees at homes, creates high temperature for vectors survival. It also exposes individuals in the highland areas who have a low immune system to malaria due to increased temperatures.

According to Kuya (2015), climate change in Vihiga is associated with the human settlement in forest reserves and frequent deforestation for firewood and timber. The cutting down of Maragoli Hill forest is the principal example. General global warming was sited to be the primary cause of climate change in the region.

4.8 Respondents View on Rainfall Trends in Vihiga County

From the questionnaires, a majority (66.7%) reported that they received a medium amount of rainfall (700-1400 mm p.a.) while 29.60% admitted that they received a high amount of rain (above 1500 mm p.a.). However, 3.7% of the respondents reported that they received a low amount of rainfall (below 500mm p.a.). The responses were based on the location of the individual household either in high grounds, middle grounds, and lower grounds. Figure 4.5 has the results for the same.

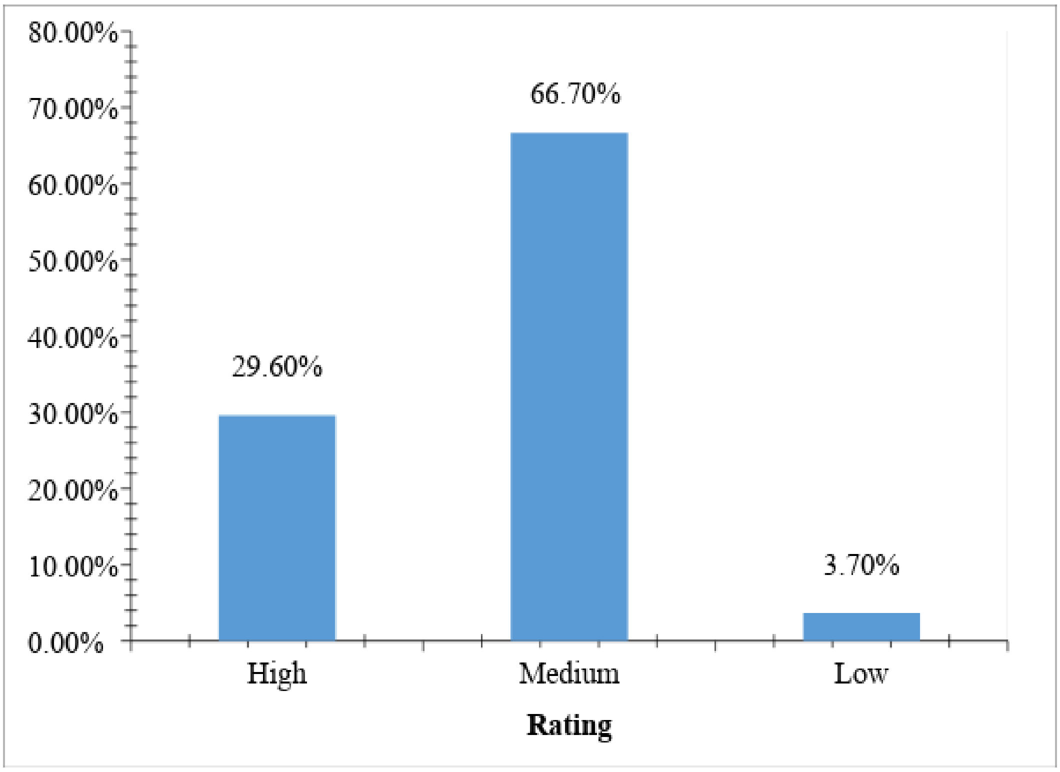

Figure 4.5: Rainfall Rating

From the study, the area receives average rainfall throughout the year. This is an indication of declining rainfall amount as the region is known for high rain from the previous climate records. The locals admitted that rainfall has changed during the rainy season. Whenever it rains, it is heavy causing flooding in the area.

Flooding is frequent in the lower altitude creating habitat suitable for mosquito breeding leading to increased malaria prevalence cases. The study is in line with Ndegwa *et al.*, (2006), who suggest that the region receives long rains in March to May with mean monthly of about 200 mm and short rains in August to November of mean monthly 180 mm.

The study further sought to establish from the respondents from the questionnaires whether there had been any change in rainfall. The majority (78.0%) reported that there had been a change in the amount of rain received in the region while 22.0% admitted that there had been no change in the amount of rainfall received in the area. The findings are shown in Figure 4.6.

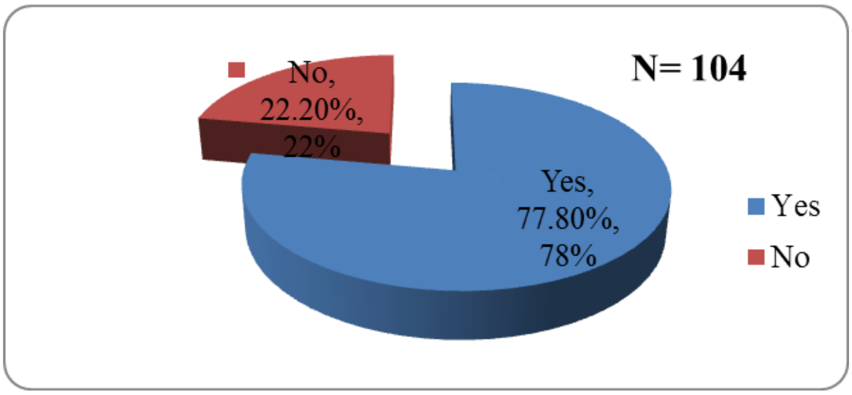

Figure 4.6: Change in Rainfall received in Vihiga County

Those who reported of the changes in rainfall attributed these changes to poor land use activities in the region that have led to massive deforestation citing the Maragoli Hills Forest and the riverine trees. This is to create room for settlement and agriculture to cater for the food security to the increasing population. This is in harmony with studies carried out by Kuya (2015) in the region. In his, he cited deforestation as the leading cause of climate in Vihiga, especially the Maragoli

Hills Forest. Those who disagreed of there being no changes in rainfall cited lack of knowledge about climate change in the area hence they didn't have any experience on what could be the cause of the shift in rainfall amount in the region.

Figure 4.7: A section of deforested Maragoli Hills Forest.

(Source: KNBS, Vihiga, 2013)

4.9 Mean Annual Rainfall of Vihiga

The study analysed the mean annual rainfall for the past fifty-three (1960-2013) for Vihiga as obtained from the Kakamega Meteorological station. To get the mean annual rainfall for each year, the mean monthly rainfall was added and then divided by twelve months in a year. Figure 4.8 shows the results.

The figure indicates the months of March-May recording high rainfall patterns as compared from August- December which receives short rains. However, the trends have changed with long rains delaying up to the mid of April and ending with the onset of June. Short expected rains used to start from the late June to the onset of August. Currently, they have been pushed forward to early September (Kuya, 2015)

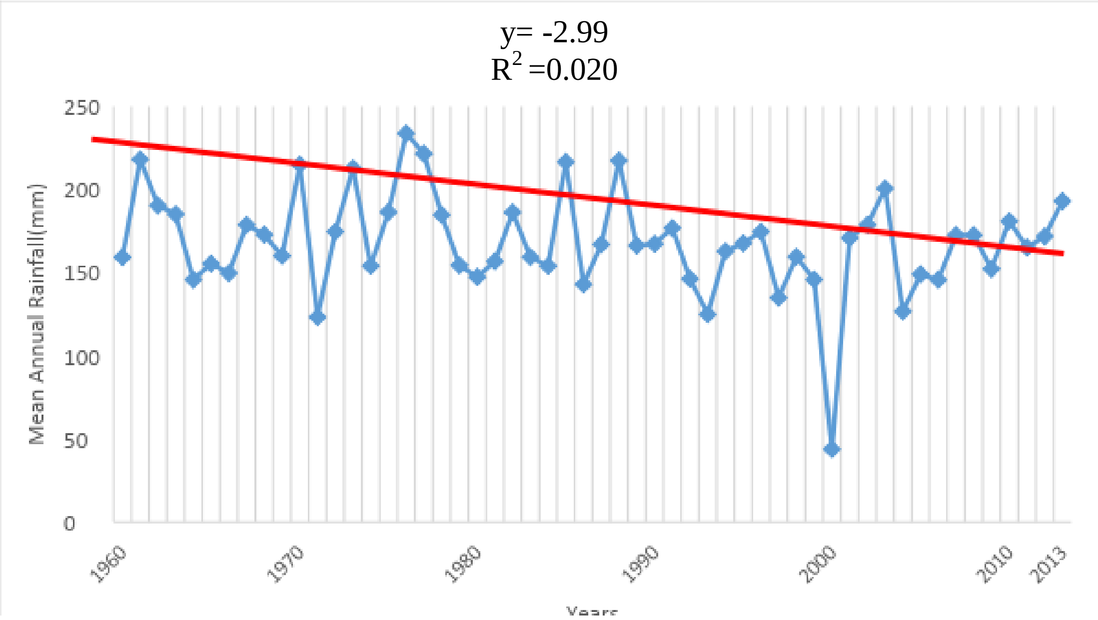

Figure 4.8: Mean Annual Rainfall of Vihiga County since 1960-2013

From figure 4.7, y= -2.99 signifies that there has been a drop of 2.99mm while R^2 =0.020, indicate a decline of 2% in rainfall for this period. From the above figure, rainfall trends in the region are dropping. In the year 1975, the area recorded a highest mean annual rainfall (200mm) while in the year 2000 recorded (<50m). This seems to have been the year when the area began facing the reality of climate impact. This is a downward trend in the mean rainfall for a drop of about 150mm.

This finding agrees with Mulinya (2017), who revealed that there are constraints faced by small-scale farmers in adapting to climate change in Kakamega County. From the study, it was established that there had been a change in rainfall in the county for the past forty-six years. The study revealed that rainfall amount had had a negative trend of 3 mm per annum. A similar survey of climate change in Vihiga County by Kuya (2015), Vihiga County has experienced a decline in rainfall of about 150 mm for the recent past thirteen years.

4.10 Total Monthly Rainfall of Vihiga County for 2012

The monthly total precipitation for the year 2012 were analysed, and the finding was as shown in the bar graph in Figure 4.9. The year 2012 was picked for analysis because it was the first year on which the researchers had data on malaria prevalence from the hospitals (DHIS-2017) as shown Figure 4.13 for correlation with rainfall in the region as provided by the meteorological department of Kakamega.

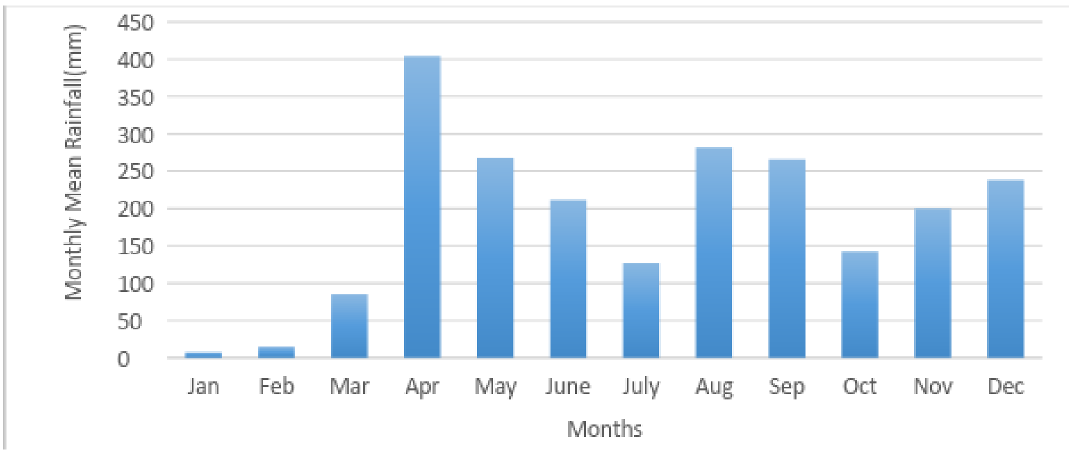

Figure 4.9: Monthly Total Rainfall Distribution of Vihiga County for the year 2012

The month of April had the highest rainfall total (400mm) while January had the lowest rainfall amount (<50mm). There is a large rainfall range (>350mm). This means that from January to March, the area is dry. The region receives rainfall throughout the year with double maxima rainfall with long rains in April to June and short rains from August to December. These seasons are clearly outlined from others years as shown from the meteorological data.

This finding agrees with studies in the region by Kuya (2015). There are a decline and change in pattern, a trend that has been evident in the recent past years. The area receives long rains in March to May with short rains from August to December. Long rains are delaying up to mid-April and ending as early as June. Short rains are expected to start as from late July, are delayed to early September and ends in November leading to an extended dry period from December- March

Malaria transmission in the country varies significantly based on the location. These are areas where malaria transmission is throughout the years (endemic regions) while one region where malaria transmission is seasonal (epidemic). Also, the adult population has become immune to malaria infections whereby a bite from the mosquitos does not necessarily translate into a malaria outbreak.

However, finding from the Vihiga DHIS shows that malaria outbreak in the region is seasonal. The primary malaria transmission season is between March-September. There is low malaria transmission from October to January. This is because, during this periods, the region receives low rainfall with some months being dry. This leads to the drying up of the breeding sites of the mosquitoes leading to the massive death of the parasite (Zhou *et al.,* 2012).

4.11 Impacts of Temperature and Rainfall Changes on Malaria Vector productivity

From the questionnaires, the research found out that malaria transmission was high between March-May (45.1%). December- January recorded less prevalence (1.1%). On the other hand, 14.3% of the respondents reported that malaria transmission was at its peak in June – August.

Table 4.3: Month with Peak Malaria Transmission

Months	Percentage (%)
December – February	1.1
March-May	45
June – August	14.3
September – November	1.1
Not aware	38.5

The majority who reported high malaria prevalence in the months of March-May attributed this to high rainfall during this period that creates an ambient environment for mosquitoes breeding. High temperatures and rain were cited as the major contributors to malaria transmission from June –August

Malaria transmission in the country is based on the location of the region. There are areas in the country where malaria transmission is throughout the years (endemic areas) while others malaria transmission is seasonal (epidemic). Also, the adult population have become immune to malaria infections hence regardless of the mosquito bites, and they are likely not to suffer from the disease (Zhou *et al.,* 2012)

However, finding from the Vihiga DHIS shows that malaria outbreak in the region is seasonal. The primary malaria transmission season is between the months of March-September. There is low malaria transmission from October to January. This is because, during this period, the region receives low rainfall with some months being dry. This leads to the drying up of the mosquitoes breeding grounds leading to the mosquitos' massive death hence low malaria prevalence (Charwood *et al.*, 1995)

The above data was validated using the data from the hospitals on the trend of malaria prevalence amongst children under five years in Vihiga County for the past five years. The information from the DHIS was used to compute results are as shown in figure 4.10 shows the results.

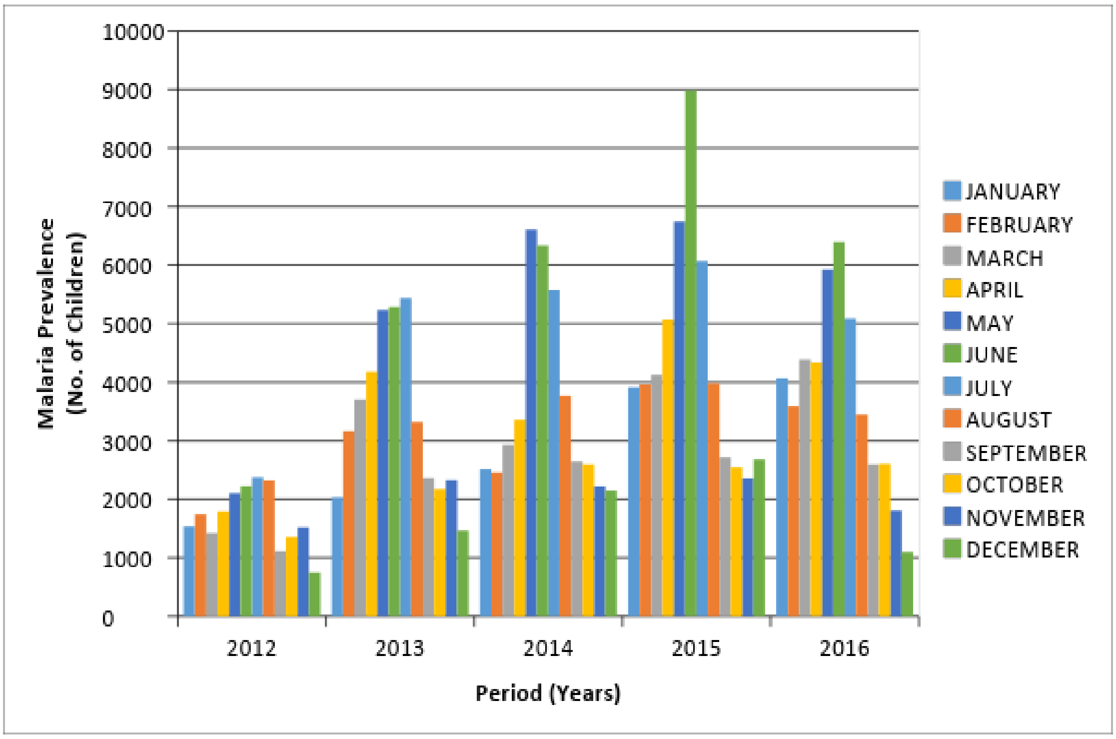

Figure 4.10: Trends of Malaria Prevalence under five years in Vihiga County

Source. DHIS-2017

Figure 4.10 reveals that the region records high (above 2000 patients) malaria prevalence across the year. The prevalence rise (above 2000 patients) from March reaching its climax (above 6000 patients) in June then drops to below 2000 patients in August. These periods correlate with the season of high rainfall and temperature in the region as shown in Figures 4.4 and 4.9. This is because, during this time, the mosquitoes are breeding as high temperature and waters pools provided by the rainwater that provide the ambient environment. This may last for a period of two to three weeks (Sandeu *et al.,* 2016). After the completion of mosquito life-cycle in water, the sporogenic cycle that requires feeding on blood meal starts. It is during this stage that the vector begins to transmit the malaria-causing virus. This led to the rise of malaria for three consecutive months (May, June, and July).

This is similar to a previous study by McMicheal *et al.,* (2006) that revealed high malaria in April- June during the long rains. Those who were not aware of any changes in malaria prevalence across the year were unable to distinguish between variations as malaria is an endemic disease in the region.

The An. Gambia has been found to survive even in the dry season. This as noted earlier, the species require little amount of stagnant water to breed and hatch its eggs. This could be as little as marks left on the roads by animal foot, plastic containers and plant leaves. With the availability of tea plantations, this makes it possible for the mosquito to have enough water for breeding throughout the year.

Further studies on *An.gambia* can survive in the dry season. This is because the species can breed in minimal water spots as small as animal hoofs, plant leaves, small containers in and water drainage facilities (Figure 4.11). Such water availability makes it possible for the mosquitos to breed and develop throughout the year. In such area, the influence of climate change may low impact as water is available throughout the year.

Figure 4.11. A Photo of Water Drainage Channel in Mbale Town.

Source: The Researcher, 2018.

The built-up environment such as the one in Figure 4.11, forms an artificial habitat for mosquitoes to breed and reproduce at a fast rate. This is one way through which human activities contribute to the spread of malaria especially in the region that initially showed little or no prevalence. This with the addition to poorly constructed houses contributes to high malaria prevalence among the poor people of Vihiga County. Homes that have cracks, the house that host animal, have poor ventilation, licking roofs during the rainy season and serving both as kitchen, and creates a conducive environment for breeding causing high malaria risks. These kind of houses are widespread among the villages of Vihiga especially in the sub-tribe of Maragoli where every family keeps the animals in their house due to insecurity. The same houses serve as kitchen and bedrooms for children.

4.12 Respondents view on Rainfall and Temperature changes contribution to Malaria Outbreak

From the study, 83.0% of the respondents' admitted that changes in rainfall and temperature contributed to malaria outbreak with only 17.0% of them reporting that changes in rainfall and temperature did not add to the malaria outbreak.

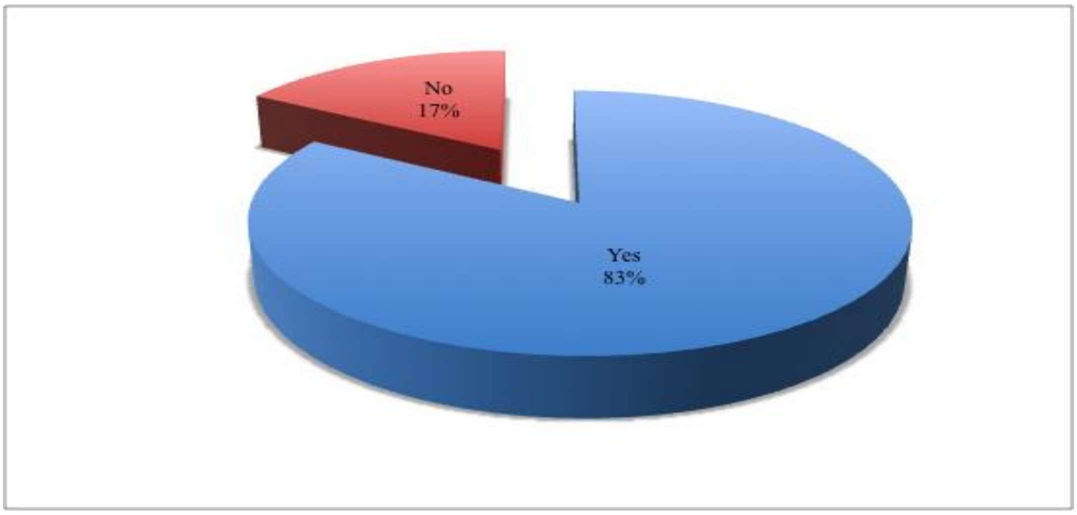

Figure 4.12: Contribution of Changes in Rainfall and Temperature to Malaria Outbreak

The majority who agreed of high malaria was because of high cases of malaria patient witnessed during the rainy periods as compared to similar periods in the previous years. Those who had declined, was because they didn't know how climate changes could influence malaria prevalence. This is because malaria prevalence in the region remains high across the years.

However, it should be noted that mosquitoes are susceptible to the water temperature, especially during the larval stage. When the water temperature rises, the larva takes a short period to mature (Ernest *et al.,* 2012). This in returns will relate to high reproduction rate of the mosquitoes. During this time, they feed on organic debris and microorganisms in the water while moulting their exoskeleton several times until they become pupae (Westenberger *et al.,* 2010). Therefore, any slight change in temperature could lead to a high number of vector resulting in a high rate of malaria prevalence.

Doctors' in-charge of various health centres acknowledged that climate change has contributed to the influx of malaria patients in the region. Regional malaria co-ordinator cited malnutrition as an indirect cause of high malaria prevalence. Children especially those under five years are fed are fed on the same type of meal especially maize flour porridge. This is because of changes in rainfall patterns, which have affected the farmers' calendar in the region. There used to be two maize planting seasons with high yields at the end of each season. Currently, with the changes in rainfall patterns, farmers only plant relay on the first season crops planted in March. September crops give little output leading to a low-profit-margin. The crops are fed to animals thus increasing the level of poverty. This, in turn, makes it difficult for residents to seek proper medical treatment whenever their children are sick

4.13 The Cause of Rapid Increase in Malaria Prevalence

From the research, 23.3% of the respondents believed that reduced use of mosquito nets was the leading cause of rapid malaria prevalence leading to increased malaria outbreak while another 31.1% agreed to poor treatment as the cause. However, a vast majority (45.6%) of the respondents believed that rapid malaria prevalence occurred due to other reasons as shown (Table 4.4)

Table 4.4: Causes of Rapid Malaria Prevalence leading to an increased Malaria outbreak

Cause	Percentage (%)
Poor use of Mosquito nets	23.3
Poor treatment.	31.1
Others Causes.	45.6

Those who indicated that a rapid increase in malaria prevalence in the region was due to other factors besides the use of bednet highlighted both climatic factors and non-climatic factors as the cause. Their high percentage of patients, especially children under five, sleep under a net but still suffer from malaria. This means mosquitoes bite people during other hours of the day when they are awake and not bedtime. This could be during the daytime when children are playing or during evening time just before they tire to bed.

Availability of ambient environment outdoor was also cited to be the cause has led to an increase in mosquito population that can bite all day long without waiting for night hours. This ambient environment can be linked to changes in temperature and rainfall in the recent past years. Respondents cited increased rainfall in some areas as the cause of this high prevalence.

However, other respondents cited the mobility of people from the lower regions to the upper region as a contributing factor in malaria transmission in the area both in the lower ground and middle-level ground. This occurs during market days in Mbale, Chavakali, Luanda, Mudete, and Gambogi. Mosquitoes bite the individuals from lower regions, then transmitting the parasite to those from the upper area. Especially children under age five years are carried to markets as their mothers don't have a caregiver to leave them at home.

Other respondents cited poor housing and hygiene at homes. Most population interviewed live in poverty. This hinders them from constructing decent houses. Most of their houses have cracks providing hiding places for mosquitoes. Others cook from the same house where children sleep. These, in turn, raises the temperatures for mosquitoes breeding and quicken the development of the parasite.

Poor hygiene was cited as a contributing factor. Most households tend to house their livestock in the houses where they cook and sleep. Animals' hooves form holes creating breeding grounds especially if the house licks during the rainy season. There is a lot of unlashed grasses, untrimmed banana leaves, plastic containers littered within the backyards of the houses. These hold water during the rainy season providing mosquitoes with breeding grounds.

Poorly maintained roads in the regions have led to numerous potholes on the roads especially the marram roads in the rural areas. The same is in the urban centres of Mbale, Chavakali, Majengo, Luanda, Serem among others. This creates pools of water in the area providing the breeding grounds for the mosquitoes.

The relationship between malaria and climate change has been broadly studied than any other disease in Africa (Omondi *et al.,* 2006). This is because climate information can be used to generate malaria risk maps in the process of the absence of high-quality epidemiological information (Omondi *et al.,* 2006).

Changing climate has led to warmer temperatures in the highlands of East Africa leading to increased malaria cases. Additional cases occur when increased temperatures arise simultaneously with an increase in precipitation (Confalonieri *et al.,* 2007). Kenya experienced a six-fold increase in the number of malaria cases compared to previous years (Omondi *et al.,* 2003). A significant body of researchers projects that the overall global warming is expected to increase the seasonality and range of malaria both across Africa and on the worldwide scale (Omondi *et al.,* 2003). Malaria infection rate is expected to increase by 16-28 percent in person month in Africa by the year 2100 (Patz *et al.,* 2005).

4.14 Household with Children Under Five Years.

From the questionnaires, the research found out that 67.0% of the respondents agreed they had children under the age of 5 years while 33.0% of them reported that they did not have children of that age. The study further inquired if any of the children were suffering from malaria either then or in the recent past. It was established that all respondents (100%) who had children under the age of 5 years, agreed that at least one of their children was suffering from malaria or have suffered from malaria recently.

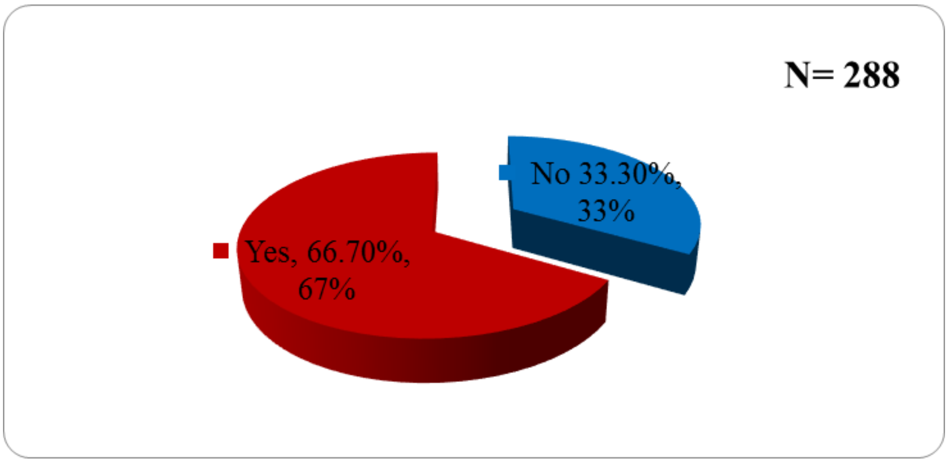

Figure 4.13: Have Children under the Age of 5 Years

From the study, it's evident that children under the age of five years are profoundly affected by malaria, unlike the adults. This is because of the lower body immunity to cope with the disease. The study also revealed that most women take along their children when they are working in the farm. Women do most of the farm activities like tea picking, weeding, and fetching water. These expose these women and their children to mosquito bites for more extended hours as compared to their male counterparts. Besides, whenever they are on the field, they don't wear their children protective cloths leaving most of their bodies exposed to mosquito bites. Also, during family gatherings like funerals, circumcisions, weddings, mothers carry their children to these parties. The festivity can extend until late hours of the night and for several days. They expose their children to more extended time for mosquito bites leading to high malaria prevalence. The study is in harmony with (WHO, 2017) that revealed high mortality rate (10%) among children under five years in Sub-Saharan Africa due to malaria.

4.15 Seasonality of Malaria Prevalence in Vihiga

From the study, a majority (61.5%) admitted that malaria was seasonal in the area while (38.5%) of the respondents reported that malaria was not seasonal. Table 4.5 has the results.

Table 4.5: Malaria Prevalence in Vihiga County

Prevalence	Percentage (%)
Seasonal	61.5
Not Seasonal	38.5

For those who admitted to malaria being seasonal, pegged the argument on high rainfall and temperature from March-June. This provides an ambient environment for multiplication of mosquitoes, malaria vectors leading to high malaria during this period. This is consistent with the study by Parham & Michael (2010) that attributes high malaria during the heavy rainfall of March-May.

4.16 Medical Practitioners views on Malaria trends in Health Centres

Medical practitioners were asked to indicate the direction of the number of patients in health centres treated of malaria daily. A high percentage (49.3%) of the respondents admitted that the pattern was increasing while 3.3% of them reported that the trend remained the same. Table 4.6 has the findings.

Table 4.6: Trend of the Number of Patients in Health Centres

Trend	Percentage (%)
Declining	47.4
Increasing	49.3
Remain the same	3.3

Those who responded on declining malaria trends sighted improved Methods of malaria prevention. These include the use of treated mosquitoes nets, and malaria drugs and testing. However, the majority of respondents who agreed to increase malaria prevalence were mothers who attest that prevalence amongst children is still high. Most women come from poor backgrounds that cannot afford full malaria treatment for their children. They opt for cheap painkillers from the chemistry or even sharing the drugs amongst them and the children.

4.17 Children under Age 5 years treated of Malaria Daily

The study collected data on the daily malaria treatment in Vihiga County from the daily malaria treatment records in the hospitals. There was a need to establish the number of children under the age of five who are treated with malaria each day. The total was added in a week and divided by the number of days.

Table 4.7: Number of children treated of malaria daily

Parameter	Frequency (F) N=60
Mean	13.
Maximum	32
Minimum	0
Standard deviation	7.

From the above data, the number of children under the age of five years in Vihiga County treated malaria daily had a mean of 13. This clearly shows that on average, 14 children were treated for malaria daily in each of the health centres that were located in the lower region. The findings also show that in some health centres, the maximum number of children treated for malaria had risen to 32 children daily while the minimum amount was 0 meaning that some days pass without any child being treated. This difference may be due to either confidence that parents had in the health centres or the difference in the prevalence per region or locality. The standard deviation of 7 recorded in finding. This is the variation or dispersion of values from the mean.

The above results indicate that malaria prevalence is still high amongst children in the region. If the trend continues, there is a likelihood of malaria prevalence increasing in the future. This could lead to a massive financial burden on the families seeking treatment for children.

To validate the above data, the study sought to establish the trend amongst the commonly treated diseases in Vihiga County for the last five years. The data from the DHIS from the hospital were used. The figure 4.11 drawn shows the computed data.

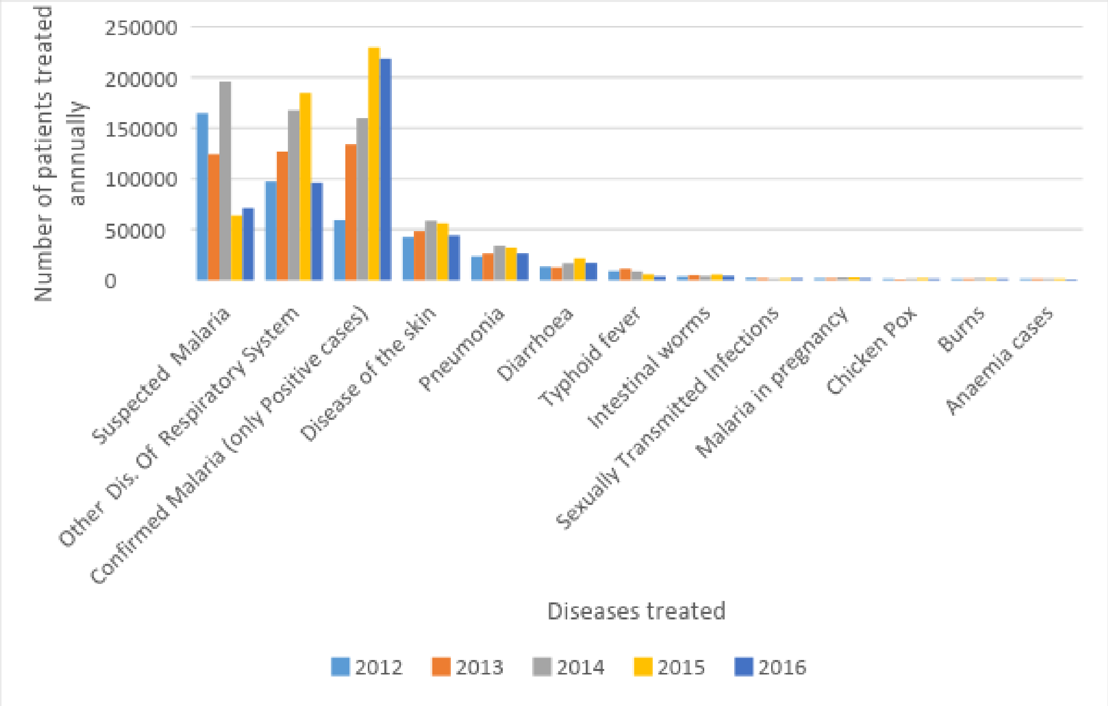

Figure 4.14: The diseases treated annually in the past five years in Vihiga County

Source. DHIS-2017

From the figure 4.14, the cases of suspected malaria are the leading in the prevalence in the region. The respiratory diseases follow this and at the third level confirmed malaria cases. If the suspected malaria cases and confirmed malaria cases are summed up, they will account for a high percentage of overall diseases treated in the county. This proves that malaria is the leading in prevalence in the county. The data also reveals that there has been a steady increase in confirmed malaria prevalence in the region in recent past years. The years 2015 and 2016, have recorded high malaria prevalence above two hundred thousands of confirmed malaria per year.

To identify which population cohorts are affected with malaria prevalence, the study evaluated the hospital attendance based on the age. Two groups were identified, those below five years and those above five. The groups were later divided based on the gender. The figure 4.15, shows the results.

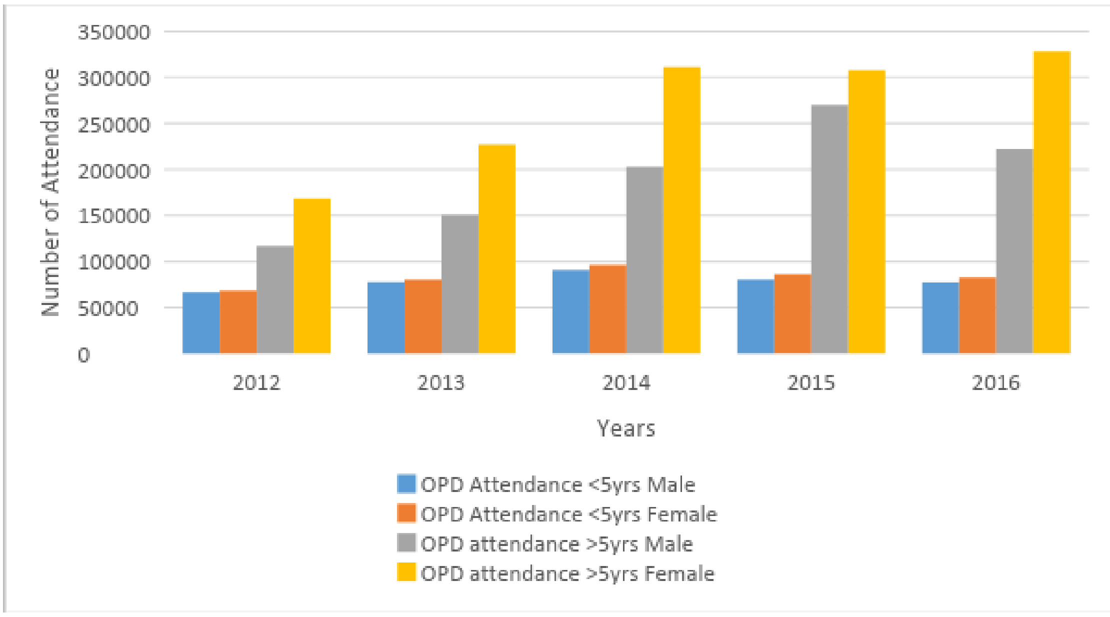

Figure 4.15: Treatment attendance for the past five years in Vihiga County

Source. DHIS-2017

From the Figure 4.15, children under five years both male and female, have high attendance per year for the past five years. Though there was a slight increase in the year 2014 up to 2016. Females under five years have slightly high attendance level as compared to males each year. If these figures are interpreted alongside the data collected on kind of diseases treated as shown in Figure 4.14, suspected malaria cases and confirmed malaria case, are likely to be the common disease treated. The hospital attendance amongst children under five years is still high. However, the participation of patients above five years have increased drastically over the years in almost all health centres in the county with female registering high attendance then followed with a male.

4.18 Malaria and prevention and treatment measures

The study further sought to establish from the respondents whether they believed preventive measures had been effective in preventing malaria.

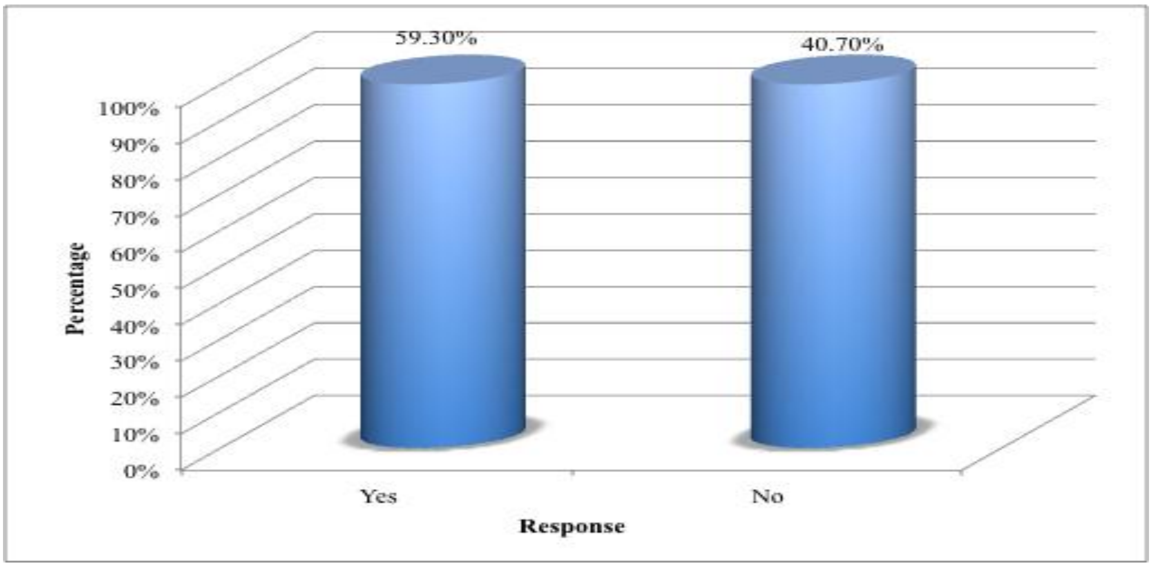

Figure 4.16: Preventive Measures had been Effective in preventing Malaria

Majority of the respondents (59.3%) admitted that preventive measures have been useful in preventing malaria while 40.7% of them reported that preventive measures did not adequately prevent malaria.

The above results reveal that even though the majority of the people believe that preventive measures have been sufficient, a high percentage still disagrees. This could be because of high malaria prevalence that has been recorded in the past five years.

4.19 The Impacts of Malaria on the Local Community in Vihiga

Just like any other problem in the society, the study also sought to establish the impact of malaria prevalence on the community especially amongst the children under five in the region and the follow-up the responses during the interviews and focus group discussion (FGD).

High infant mortality- There has been a high mortality rate of infants in Vihiga County for the last five years. As the statistics from the hospital registers revealed mortality rates in the county of about 202,521 children over the previous five years (DHIS, 2017). This has brought a lot of loss to the families within the county.

High financial burden- Malaria prevention and treatment requires high budgetary allocation. Each year, the Kenyan government spends over 15 billion on malaria which accounts for 26%. County government support currently stands at 22% of expenses each year for malaria prevention and treatment. External donors like the World Bank, World Health Organization, and other organizations accounted for 40% of the costs. This leaves the patient with 12% of the expenses. However, the current withdrawal of foreign aid in malaria treatment, in the future the patients are likely to pay heavily for the treatment.

High population- The current statistics from the department of statistics Vihiga County has revealed an increase in population within the county for the last five years. During 2009, the community was about 546,929 people, but this increased to 676,456 in2015. This could be attributed to because of the high infant mortality rate. The parents tend to give birth to more children with the hope that some of them will survive the malaria epidemic. This has led to a high fertility rate. However, in most cases, all these children live beyond five years which translates to a high population that leads to the high dependency ratio hence high poverty level in the county.

Lost working hours-The study also revealed that most women waste their working hours to attend to their sick children suffering from malaria infections. The long queues witnessed in all health centres are made up of women waiting to be attended to. This has led to a high economic loss to the county as a lot of working hours are lost. This has also led to imbalanced gender employment in the county. Many firms tend to prefer male candidates to women. This has rendered many women unemployed making them unable to compete with their male counterpart favourably economically. Women, who opt to carry their children on the farms during working hours, expose them to mosquito bites leading to high malaria prevalence.

Health Complication-From the study, it was revealed that children, who suffer from severe malaria unusually cerebral malaria, become vulnerable to other diseases in the future. These include mental disability in the adult life. Vihiga County has many mentally challenged people especially in major towns of Luanda, Mbale, Majengo, and Chavakali among others. This could be caused by other factors like stress due to hard economic life, drug abuse among others. However, the impact of malaria cannot be neglected even though it requires a broader perspective.

Table 4.8: The Summary of the Impacts of Malaria in the Local Community in Vihiga

Problem	Impacts to the community
1. High mortality	High infant mortality The leading killer in the county with 634,000 death for the five years. The high financial burden to the families.
2. Financial burden	High budgetary allocation for treatment by stakeholders External donors are showing signs of withdrawal of their support in the future This is likely to leave the patient with heavy financial burden in future.
3. High Population	High death rates have led to a high fertility rate of 5.3%.In case of the survival of all children, leads to high population in the county. High population leads to the high dependence ratio hence high poverty level.
4. Lost working Hours.	Most women spend their working hours attending to their children medical needs. Imbalanced gender employments as men are preferred over women.
5. Health Complication	Those who suffer from severe cerebral malaria are vulnerable to other diseases especially mental diseases in the future.

4.20 Malaria Spread Map of Vihiga County

The study generated a malaria slope map of Vihiga County. This was to divide the region into three main areas of lower, middle and upper grounds. In this study, the lower ground ranges from 1300-1365, the middle ground 1366-1430m and higher ground between 1431-1500m. The Figure 4.17 Shows the slope map generated.

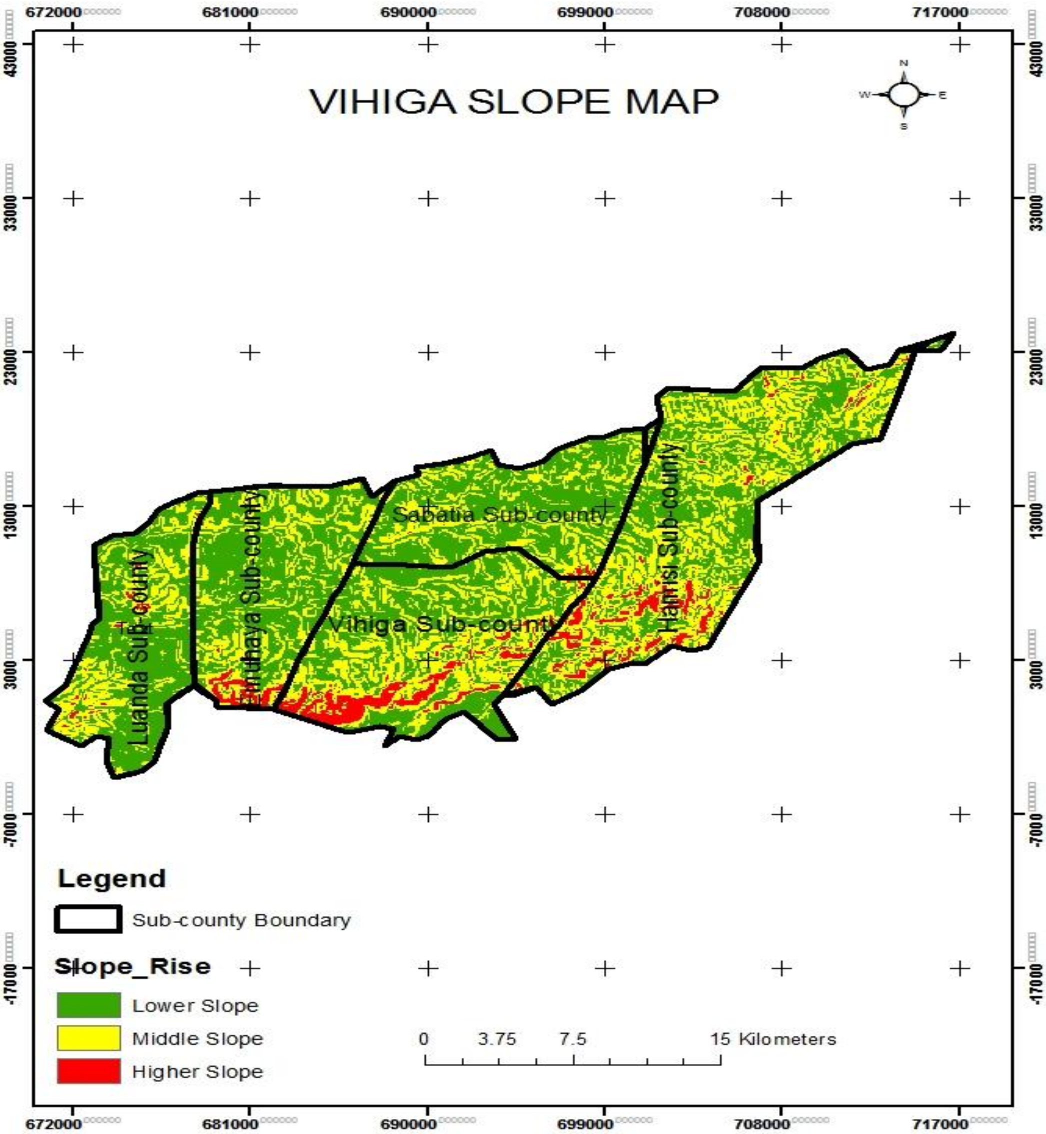

Figure 4.17: Vihiga County Slope Map.

From the slope map in Figure 4.17, three significant regions can be seen. The higher ground, middle ground and finally the lower grounds. The lower map has been added to help in identifying the region alongside the slope map. From the slope map, most of the higher grounds are found on the southern part of the map extending from Emuhaya, Vihiga, and Hamisi. On the other hand, most of Sabatia and Luanda occupy the middle and lower grounds.

The study sought to classify the region based on altitude and climate to generate a map showing specific areas that are likely to be malaria hot spots. This is to help in the future prediction of which area and when they are likely to experience malaria epidemic. The study yielded the results as indicated in Figure 4.18.The results showed that most of the households were located in the middle ground, reported by 67.0% of the respondents. On the other hand, 26.0% of the respondents said that their families were found in the higher grounds, while another 7.0% of them indicated that their households were located in lower grounds. Figure 4.18 shows the results.

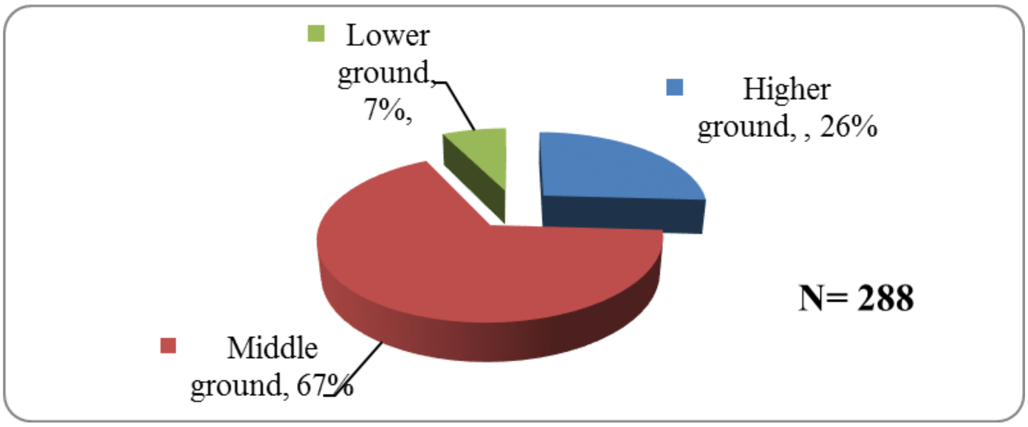

Figure 4.18: Location of Households

From the results in Figure 4.18, most households settled in the middle ground as the land is gentle enough to allow settlement and farming. The region also is far away from the vectors that cause diseases like malaria. There were a few settlements in the lower. This is because the area experiences frequent flooding. Also some area like Majengo, Iduku have swamps that allow breeding of mosquitoes leading to high malaria prevalence. These conditions have been facilitated by heavy rainfall, high temperatures, and high humidity during the daytime. At the higher grounds, these low settlement. The land is hilly with steep slope hindering the construction of infrastructure like houses. For example locations of Mahanga, Gilwatsi, Givole are located in high and mountainous areas. The regions low malaria epidemic as low temperatures became a limiting factor to mosquitoes breeding.

(Zhou *et al.,* 2012), in the study revealed that the altitudinal difference lower and upper grounds had an impact on the mosquito habitat among the residents in Mudete and Mbale. The research showed that there was high malaria prevalence in U-shaped valleys in the lower regions, unlike V-shaped valleys in both lower grounds and upper areas. The study too revealed high malaria prevalence during the rainy seasons than during the dry season. This is because high rainfall leads to swamps especially in U shaped valleys leading to high habitat for mosquitoes.

The study also sought to find out the level of malaria prevalence in every sub-county for the last five years (2012-2016. The figure 4.16 shows the results.

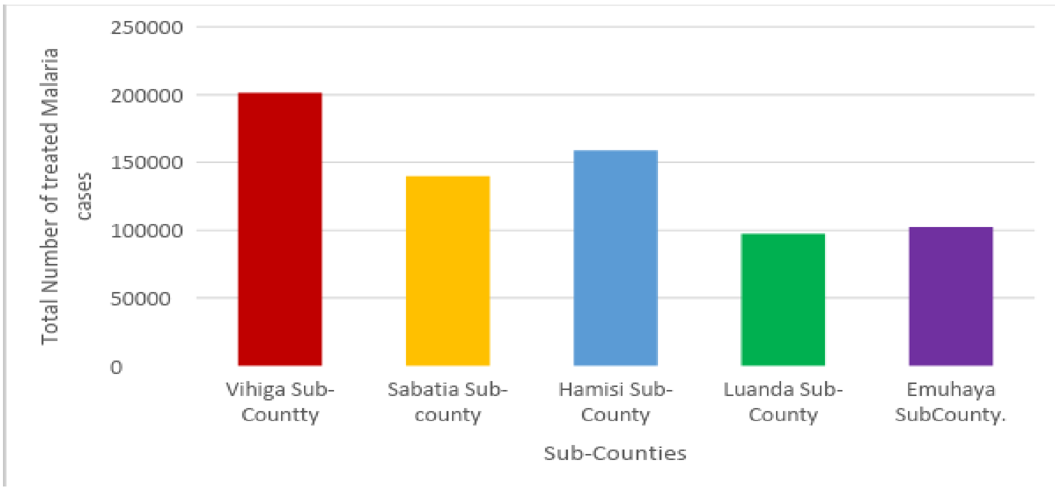

Figure 4.19: Total Malaria Prevalence in Vihiga County from 2012-2016

From the Figure 4.19, the analysis shows that Vihiga sub-county is leading in malaria prevalence, followed by Hamisi, then Sabatia Sub-county. Luanda and Emuhaya registered the least number of patients treated for malaria in the region. Even though Vihiga and Luanda sub-counties are found in the higher ground, they recorded high malaria prevalence. This because they have more urban centres like Mbale and Majengo in Vihiga while Luanda town in Luanda sub-county. These urban centres have better health facilities. Therefore, people moved from other lower and middle-level regions neighbouring these counties to seek medical treatment in the urban areas. Rural-urban migration was cited as other contributing factors. Because of many urban centres in the two counties, the urban centres have high population than the rural areas hence high malaria prevalence.

4.21 Malaria Epidemic Forecasting, Early Warning, and Early detection

Malaria forecasting and the early warning was both intended to warn of environmental conditions that are suitable for the occurrence of a malaria epidemic. In this study, the changes in temperature and rainfall mean monthly were used as indicators for malaria early warning in the region. A temperature exceeding mean monthly of 26°C in months preceding rainfall exceeding mean monthly of 150 mm in the February-May, should be a warning of high malaria prevalence in three months period times(Zhou *et al.,* 2012).

Early warning, therefore, will entail monitoring rainfall and temperatures in the medium ranges with the help of local meteorological stations. In this study, mean monthly temperatures and rain from Kakamega meteorological department were analysed to detect how changes in rainfall and temperatures contribute to the malaria outbreak. To identify an early outbreak, the study based on the weekly and monthly malaria outpatient treatment and severe malaria admission in health centres in the sentinel sites.

4.22 The Location of Sentinel Sites

The need for specific maps that focus on crucial risk area and information on when and where the malaria epidemic is likely to occur in future requires locating of sentinel sites. These are the area where malaria cases and the possible risk factors could be monitored simultaneously and where various approaches to early warning and control could be evaluated.

4.23 Malaria Trends for Five Years in the Sentinel Health Centres

The study chooses five sentinel health centers in each sub-counties. For this study, the sub-county of Vihiga and Emuhaya were selected from for slope analyses. The information acquired was to help to choose another sentinel enters in the other three sub-counties of Luanda, Hamisi, and Sabatia for mapping. The two sub-counties were selected as a sample for analysis based on the following factors. First, both have an approximately equal size in the area. However, they differ regarding population patients treated of malaria each year. Vihiga County register's high malaria prevalence while Emuhaya registers low malaria prevalence as shown in figure 4.19. Vihiga County also has more hilly areas while Emuhaya County has few hilly regions with most of the area being in the lower regions as shown in figure 4.17. Their total malaria prevalence for the past five years was computed for each sub-county. This was to explain the differences in malaria trends in the two selected sub-counties. Both Figure 4.17 and Figure 4.21 present data from Vihiga and Emuhaya Sub-County respectively.

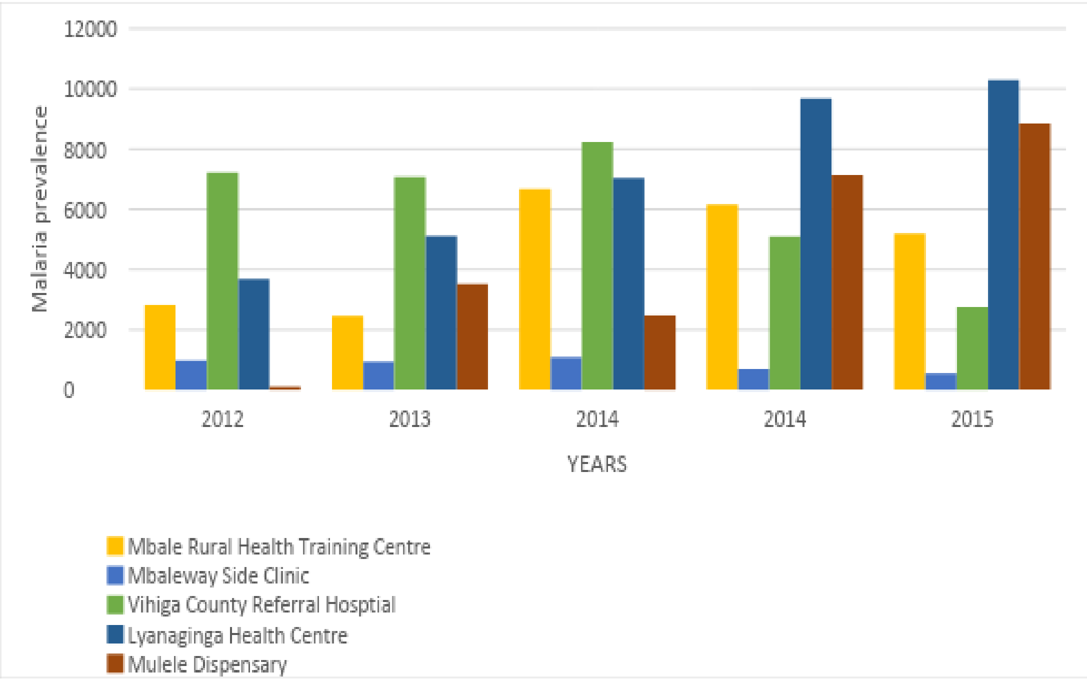

Figure 4.20: Total Malaria Prevalence in Vihiga Sub-County from 2012-2016

The Figure 4.20 shows the total malaria prevalence in Vihiga sub-county from five health centres for the past five years. Some health centres revealed high malaria prevalence across the years. These include Mbale rural Health Training Centre and Mbale Rural Health Training Centre. However, the two health centres are experiencing a drop in malaria prevalence. This was attributed to improved health standards in the health centres. While on the other hand, Lyanaginga Health Centre and Mulele Dispensary have a positive trend in malaria prevalence. Others had a downward trend in incidence. These included Mulele and Egago Dispensaries. However, most health centres show an increase in malaria prevalence for the past five years.

For mapping, other factors were held constant that could have contributed to this changes in the malaria prevalence. And therefore the study sought to identify if the location of the health centres at different altitude had an impact on malaria prevalence amongst the individuals seeking treatment from the hospitals and health centres located in those areas concerning rainfall and temperatures in the regions. This leads to the Table 4.9; that establishes each health centre based on the altitudinal heights in meters.

Table 4.9: The Health Centres from Vihiga Sub-County

NO	Health Centre	Malaria Prevalence	Low Ground	Middle Ground	High Ground
1.	Lyanaginga Health Centre	High Across the Years	√		
2.	Mulele Dispensary	Low - High	√		
3.	Mbale Rural H.T. Centre	Low - High			√
4.	Vihiga Referral	Low - High			√
5.	Mbaleway Side Clinic	Low Across the Years		√	

From the table 4.9, there has been high malaria prevalence all the year round in Lyanaginga Health Centre. The health centre is located at a lower region in a

Vihiga County. The high malaria prevalence could be attributed to high temperature in the valley region and breeding ground along the rivers. Mulele dispensary is located in the lower area. Malaria prevalence is rising as from hospital registers. This could be due to rising temperatures that have created an ambient environment for malaria breeding. Both Mbale Rural health and training centre and Vihiga Referral hospitals are located at the higher level ground. Mbaleway Side Clinic records low malaria across the year even though it is found in the middle ground. This is because the health centre is private; therefore the treatment is likely to be expensive for low-income individuals who live within and around the area. Therefore, even though Vihiga Sub-county has many high land areas, the health centres recording high malaria prevalence due to high population in the urban centres of high society.

There was a need to analysis the malaria prevalence in Emuhaya Sub-county to correlate the level grounds to malaria prevalence in the region.

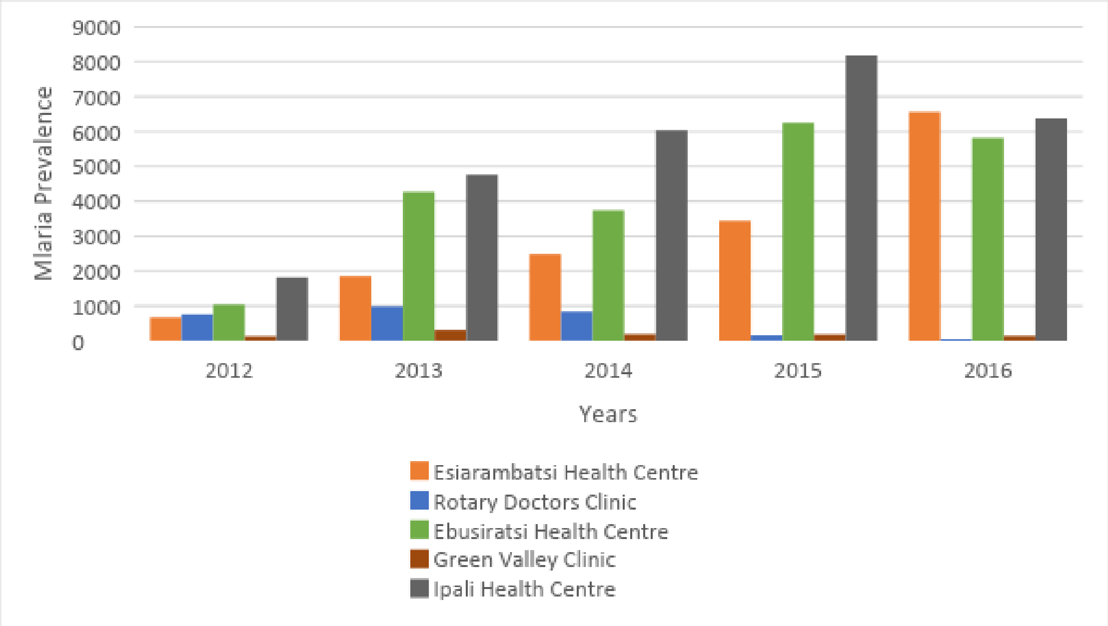

Figure 4.21: Total Malaria Prevalence in Emuhaya Sub-County from 2012-2016

From the Figure 4.21, the malaria prevalence has been on the rise in the region in most of the health centres. The climax is in the year 2015, with a decline in the year 2016. Some stations recorded a decrease in malaria prevalence while others reveal constant prevalence. To establish the relationship between the slope and malaria prevalence in the county, five health centres were chosen based on their malaria prevalence trends and their location. Table 4.10 shows the findings.

Table 4.10: The Health Centres from Luanda Sub-County.

NO	Health Centre	Malaria Prevalence	Low Ground	Middle Ground	High Ground
1.	Ipali Health Centre.	High Across the Years	√		
2.	Ebusiratsi Health Centre	Low - High		√	
3.	Esiarambatsi Health Centre	Low - High		√	
4.	Green Valley Clinic	Low Across the Years	√		
5.	Rotary Doctor Clinic	Low - High			√

From the findings, Ipali and Green Valley Clinic are found in the lower region in Luanda Sub- County. However, Ipali Health Centre records high malaria prevalence across the years while Green Valley Clinic has recorded low malaria prevalence for the last five years. This could be for various reasons. First, Ipali could be recording high prevalence because it is a public health centre that attracts the majority of low-income earners for treatment while Green Valley Health Centre is a private institution that could be expensive.

In both areas, the environmental conditions could be conducive for malaria prevalence. The residents around Ipali health centre have migrated to the upper ground. This is to escape the vectors like mosquitoes that cause malaria disease leading in the area. Ebusiratsi and Esiariambatsi recorded a rising in malaria prevalence over the five years. This attributed to ambient conditions in the field for the mosquito breeding as evidenced by the rise in the temperature in the middle grounds that leads to high mosquitoes breeding. Also, the increasing annual population leads to high malaria prevalence because of fertile ground that allows farming. Rotary Doctors Clinic being a private clinic is recording decline in malaria treatment. This was attributed to the fact that the patients sought treatment in the public health centre where treatment is offered freely unlike in a private health centre that is likely to be expensive.

The information in Table 4.10 and Table 4.11 should be interpreted alongside with Vihiga slope map in Figure 4.17 showing counties to help in locating all the five sub-counties in Vihiga County.

4.24 Sentinel unit in Emuhaya, Sabatia and Hamisi Sub- Counties

To map the entire Vihiga County, five sentinel centers were selected in the remaining three sub-counties of Emuhaya, Sabatia, and Hamisi using the criteria used in Luanda and Vihiga sub-counties. This was based on their location, prevalence level, and preferably public facilities for comfortable of communication and dissemination of personnel, drugs, and equipment during an emergency. The following health centres were chosen.

Table 4.11: Sentinel unit in Emuhaya, Sabatia and Hamisi Sub- Counties.

NO	Luanda Sub- County	Sabatia Sub-County	Hamisi Sub-County
1.	Emuhaya Referral	Sabatia H.C	Banja H.C
2.	Ekwanda H. C.	Kegondi H.C	Serem H .C
3.	Luanda Town Disp	Bugina H.C	Tigoi H.C
4.	Ebusyubi Disp.	Givudimbuli H.C	Hamisi Referral
5.	Kima Mission Hosp.	Itando Disp	Kaimosi Mission

The above health centres were picked across three sub-counties. Some of them are known to be malaria hotspots in their respective sub-counties. Others are known to have had low malaria prevalence for the past years, but currently showing malaria resurgence. Mapping their location is ideal for early malaria detection, prevention, and treatment. Their position, malaria prevalence rate, can be used to provide early warning for malaria epidemic in their respective sub-counties.

4.25 Sentinel Sites and Health Centres in Vihiga County

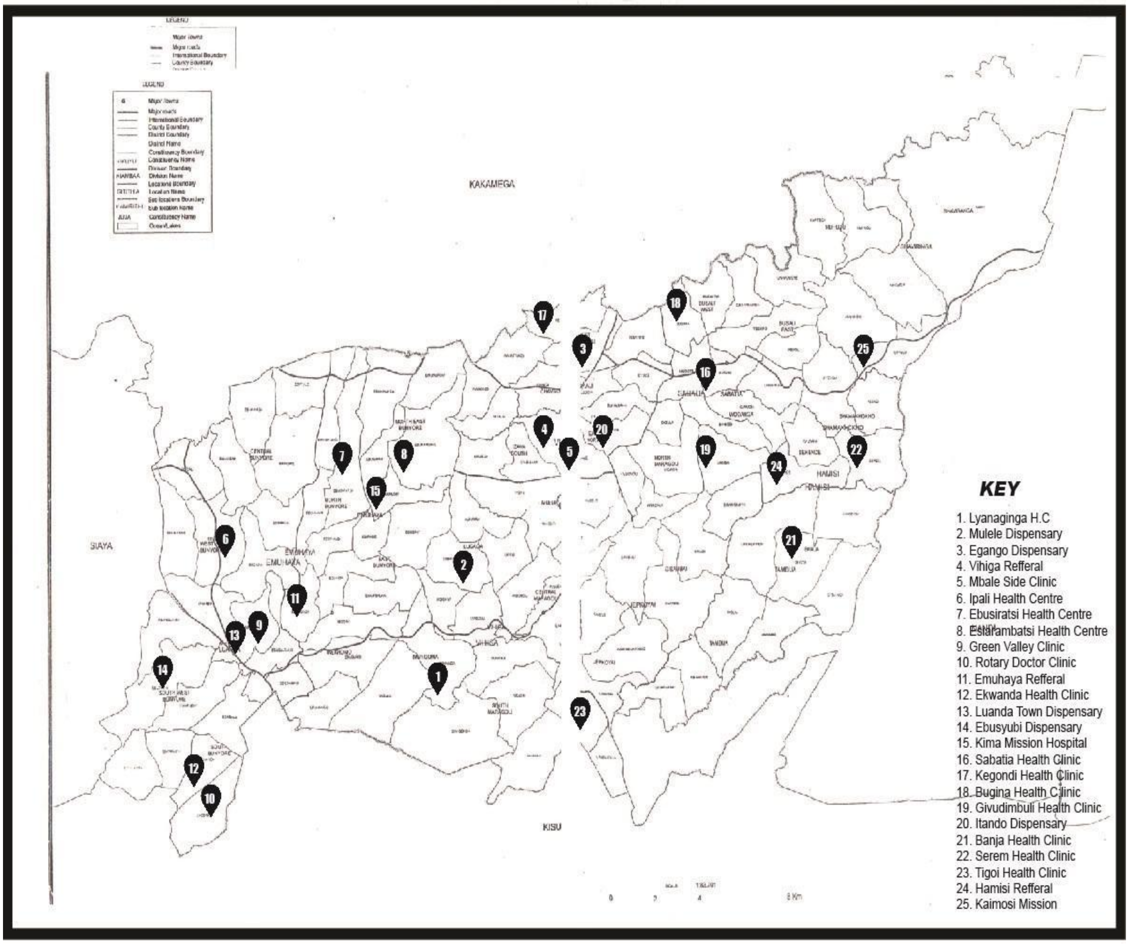

Figure 4.22: Sentinel Sites of Vihiga County

For the location of every health centres in its location area, the map of Vihiga county was acquired from the office of statistics. The map was then scanned, and the health centres were located in their precise location using GPS. The health centres were chosen as sentinel centres in the region. Their choice across the county was based on difference altitude and malaria prevalence as recorded in the DHIS from the hospitals. The malaria prevalence above the normal range in an area will send an early warning for impending malaria outbreak. This is based on the changing climate trends in rainfall and temperature that determine mosquito vector breeding level and biting habit leading to malaria prevalence.

4.26 Significance of a Malaria Spread Map

To establish the significance of a malaria spread map, respondents were asked whether the mapping of malaria hotspots could help reduce malaria prevalence amongst children under five years in the county. Findings are shown in Table 4.13s that follows.

Table 4.12: Mapping of Malaria Hotspots

Responses	Percentage (%)
Yes	17.6
No	2.2
Not Aware	80.2

From the finding, 17.6% of the respondents believed that mapping of risky malaria areas or hot spots could reduce prevalence while another sample of 2.2% the respondents' thought that mapping could not cut the prevalence. However, a considerable majority (80.2%) of the respondents were not aware whether mapping could reduce malaria prevalence.

From the above findings, it was evident that the majority of the residents did not know how mapping could assist in malaria reduction. This is because it is a new field that requires more research. For those who admitted that it could be of help to reduce malaria prevalence comprised of those who have had prior information on how mapping has been used in other areas of human life to solve a human problem.

Malaria mapping is a new phenomenon in the war against malaria. Few maps have been generated in the country with a first national malaria map created in 1970 (Kipruto *et al.,* 2017). The map was used to classify the country into endemicity based on an approximation of children of ages ranging between 2-9 years. It was until 2009 when a malaria risk map was developed for Kenya as a country (Kipruto *et al.,* 2017). The map was then used to classify the counties into a varying level of average malaria endemicity to the planning in the devolved governance in Kenya in 2013 (Kipruto *et al.,* 2017).

In conclusion malaria maps showing the critical sentinel health will aid in the prediction of malaria epidemic outbreak in Vihiga. The local authority in conjunction with national government will take a quick initiative in sending medical personnel, drugs, equipment in the affected areas. It will assist to estimate the total cost in treatment and prepare for future outbreaks.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

This chapter gives the summary of the findings and conclusions based on the objectives. Each objective's findings and conclusions have been explained. Finally, the section offers recommendations for policymakers based on the gaps realized during the study for further studies.

5.2 Summary

The research has revealed that there is evidence of climate change in Vihiga County. The temperature is rising, and rainfall is declining over the past years. These changes in temperature and rainfall have facilitated the breeding of mosquitoes leading to high malaria prevalence amongst children due to their low body immunity.

Malaria is a disease transmitted by a mosquito vector that entirely relies on changes in rainfall and temperature. With such changes in high rain and temperatures, the vector has an ambient environment for breeding and survival hence high malaria prevalence. The government efforts to provide sensitization on malaria through mass media, provision of ITN nets, households' use of domestic sprays, have had a significant impact on malaria prevalence reduction, but still, the prevalence is on the rise in the region. Malaria spread map provides definite and precision location of areas of high malaria prevalence within the region.

5.3 Conclusions

The study arrived at the following conclusions based on each objective. The investigation revealed a rise in temperature change. The views from the respondents confirmed the increase in temperatures as compared to the previous years. Analysed climate data from Kakamega Meteorological Station revealed a rise of 2°C in temperature for the last forty-five years with 0.04°C annual rise. Similar studies on climate change in the region and neighbouring counties by different researchers reveal a positive trend in temperatures. However, the study showed a decline in the rainfall. The rainfall has declined by almost 150 mm in the last forty-five years after analysis. The investigation also revealed a change in rainfall trends with the long rainy season being shortened. From the findings, there will be a reduction in rainfall in the future years

High temperatures above 22°C have provided a momentarily suitable condition for uncontrollable multiplication of mosquito the primary vector in malaria transmission leading to high malaria prevalence especially in children of five years old and below. Such high temperatures recorded in the area favours the breeding and quicken the maturity of mosquito larvae to adult mosquitoes within a week as the conditions, creates a warmer environment hence increased mosquitoes geographically especially in the lower grounds altitude areas.

From the slope map generated, it was observed that there was a high malaria prevalence in the lower and medium level, unlike the upper grounds. The high temperatures recorded in the lower regions and the presence of a water pool provides an ambient environment for the mosquito breeding. The sentinel health units were located in the malaria hotspots for early warning of a malaria outbreak

5.4 Recommendations

From the study, the following recommendations were revealed.

5.4.1 Policy Recommendations

The research has shown the presence of climate change in the region. Therefore, there is a need for the locals to collaborate with international bodies like the World Bank, to mitigate the present climate change impact in various sectors of human life. The national government of Kenya and county government of Vihiga should work hand in hand with such bodies to foster better land use, forest management and advocate for knowledge and use of technology like mass media with the aim of mitigation, sustainability, and adaptability in climate change.

It is also essential for future adaption and mitigation programs on malaria prevalence, to focus on the prediction of rainfall and temperatures changes based on a set threshold of mean daily temperatures. The daily temperature changes have a significant impact on mosquitos' activities. There is need of setting up more meteorological station in schools and colleges to help monitor climate change to give inaccurate readings based on ecological differences of the regions involved.

The significance of mapping of malaria hotspots and generation of sentinel map is viewed to be essential in the allocation of resources to combat malaria outbreak. There is a need for viable communication during malaria outbreak after the first early warning from the sentinel health unit, to the county government and ministry of health at the national level. This will help to avoid delay of information whenever there is an outbreak especially in the remote areas where roads are impassable during the rainy season.

5.4.2 Recommendations for further research

There is also a need to investigate the impact of current immunization against malaria. The Kenyan government has been chosen as a trial country for vaccination against disease in Africa which is supposed to kick off in the year 2017. However, the health impact of the drug on the children under five years about climate changes remains to be an area of research. The mosquitoes are known to mutate against the changing climate and medicines making it difficult for a single drug to cure the malaria disease.

REFERENCES

Afrane, Y. A., Mweresa, N. G., Wanjala, C. L., Gilbreath III, T. M., Guofa, Z., Ming-Chieh, L., & ... Guiyun, Y. (2016). Evaluation of long-lasting microbial larvicide for malaria vector control in Kenya. *Malaria Journal*, *15*1-9

Atieli Harrysone, (2012). *Effect of Bednet use, topography and targeted vector control on Malaria transmission in the Highlands of Vihiga and Kakamega counties, Western Kenya*. Kenyatta University.

Ajuang, C. O., Abuom, P. O., Bosire, E. K., Dida, G. O., & Anyona, D. N. (2016). *Determinants of climate change awareness level in upper Nyakach Division, Kisumu County, Kenya*. Springerplus, *5*(1), 1015

Alout, H., & Foy, B. D. (2017). Ivermectin: a complimentary weapon against the spread of malaria. *Expert Review Of Anti-Infective Therapy*, *15*(3), 231-240.

Amboko, B. I., Ayieko, P., Ogero, M., Julius, T., Irimu, G., & English, M. (2016). Malaria investigation and treatment of children admitted to county hospitals in western Kenya. *Malaria Journal*, *15*1-9

Amegah, A. K., Rezza, G., & Jaakkola, J. J. (2016*). Temperature-related morbidity and mortality in Sub-Saharan Africa: A systematic review of the empirical evidence*. Environment International, *91*133-149

Antao, T., & Hastings, I. M. (2011). *Environmental, pharmacological and genetic influences on the spread of drug-resistant malaria*. Proceedings. Biological Sciences, *278*(1712), 1705-1712.

Baldé, M. C., Camara, M., Barry, A. O., Sow, S., Sidibé, C. T., Lamah, O., & ... Bah, H. (2011). [Malaria prevalence survey in 24 Guinean villages in the Kindia area]. *Bulletin De La Societe De Pathologie Exotique (1990), 94*(2 Pt 2), 192-194

Beay, L. K., Kasbawati, & Toaha, S. (2017). Effects of Human and Mosquito Migrations on the Dynamical Behavior of the Spread of Malaria. *AIP Conference Proceedings*, *1825*(1), 1-8

Beeson, J. G., Rogerson, S. J., Mueller, I., Richards, J. S., & Fowkes, F. I. (2011). *Intermittent Preventive Treatment to Reduce the Burden of Malaria in Children: New Evidence on Integration and Delivery*. Plos Medicine, *8*(2).

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., & Herrero, M. (2013). Adapting agriculture to climate change in Kenya: household strategies and determinants. *Journal Of Environmental Management*, *114*26-35

Bruce, T. W. (1978). *Conducting Educational Research.* New York: Harcourt Brace Jovanovich, Inc.

Bureau of Statistics (2009). *Population Census*. Government of Kenya.

Cairns, M. E., Walker, P. T., Okell, L. C., Griffin, J. T., Garske, T., Asante, K. P., & ... Milligan, P. J. (2015). Seasonality in malaria transmission: implications for case-management with long-acting artemisinin combination therapy in sub-Saharan Africa. *Malaria Journal*, *14*(1), 1-13

Confalonieri U., B. Menne, R. Akhtari, K. Ebi, M. Hauengue, and R. Kovats. (2007). *Human health.* In M. Parry, O. Canziani, J. Palutikof, P.v. Linden, and C. Hanson

Crawley, J., Chu, C., Mtove, G., & Nosten, F. (2010). *Malaria in children.* Lancet (London, England), *375*(9724), 1468-1481.

Dalrymple, U., Mappin, B., & Gething, P. W. (2015). *Malaria mapping: understanding the global endemicity of falciparum and vivax malaria*. BMC Medicine, *13*140.

District Hospital Information System (2017). *Malaria Prevalence Data*. Vihiga County.

Dolesh, R. J. (2017). *Climate Change, Parks and Health*. Parks & Recreation, *52*(6), 30.

Ebi, K. L., Kovats, R. S., & Menne, B. (2006). An Approach for Assessing Human Health Vulnerability and Public Health Interventions to Adapt to Climate Change. *Environmental Health Perspectives*, *114*(12), 1930-1934

Egondi, T., Kyobutungi, C., Kovats, S., Muindi, K., ettarh, R., & Rocklöv, J. (2012). Time-series analysis of weather and mortality patterns in Nairobi's informal settlements. *Global Health Action*, *5*23-32

Eriksen, S., & Lind, J. (2015). Adaptation as a political process: adjusting to drought and conflict in Kenya's drylands. *Environmental Management*, *43*(5), 817-835

Ernest, V., Fink, A. H., Morse, A. P., & Paeth, H. (2012). The Impact of Regional Climate Change on Malaria Risk due to Greenhouse Forcing and Land-Use Changes in Tropical Africa. *Environmental Health Perspectives*, *120*(1), 77-84

Ernst, K. C., Adoka, S. O., Kowuor, D. O., Wilson, M. L., & John, C. C. (2006). Malaria hotspot areas in a highland Kenya site are consistent in epidemic and non-epidemic years and are associated with ecological factors. *Malaria Journal*, *5*78-10

Estrada, F., Tol, R. J., & Botzen, W. W. (2017). Global economic impacts of climate variability and change during the 20th century. *Plos ONE*, *12*(2), 1-16.

Fatmawati, & Tasman, H. (2015). An optimal control strategy to reduce the spread of malaria resistance. *Mathematical Biosciences*, *262*73-79

Garske, T., Ferguson, N. M., & Ghani, A. C. (2013). Estimating Air Temperature and Its Influence on Malaria Transmission across Africa. *Plos ONE*, *8*(2), 1-13.

Gay, L. R. (1987). *Educational Research: Competencies for analysis and application*. London: Merrill Publishing Company.

Gething P., Smith L., Patic A., Tatem A., Snow R. & Hay I. (2010). *Climate Change and the global malaria recession Nature* 465 (7296): 342-346.

Githinji, S., Noor, A. M., Malinga, J., Macharia, P. M., Kiptui, R., Omar, A., & ... Snow, R. W. (2016). A national health facility survey of malaria infection among febrile patients in Kenya, 2014. *Malaria Journal*, *15*1-9

Haque, U., Hashizume, M., Glass, G. E., Dewan, A. M., Overgaard, H. J., & Yamamoto, T. (2010). The Role of Climate Variability in the Spread of Malaria in Bangladeshi Highlands. *Plos ONE*, *5*(12), 1-9.

Hasegawa, T., Fujimori, S., Takahashi, K., Yokohata, T., & Masui, T. (2016). Economic implications of climate change impacts on human health through undernourishment. *Climatic Change*, *136*(2), 189-202

Hay, S.I., Cox, J., Ronger, D.J., Randolph, S.E., Stern, D.I., Shanks, G.D., Myers, M.F. & Snow, R.W. (2000). *Climate change and the resurgence of malaria in the East Africa highlands*. Nature, 905-9

Henderson, J. V., Storeygard, A., & Deichmann, U. (2017). Has climate change driven urbanization in Africa? *Journal Of Development Economics*, *124*60-82.

Herrero, M., Addison, J., Bedelian, C., Carabine, E., Havlík, P., Henderson, B., & ... Thornton, P. K. (2016). Climate change and pastoralism: impacts, consequences and adaptation. *Revue Scientifiqueet Technique (International Office Of Epizootics)*, *35*(2), 417-433.

Hoffmann A. & Sigro C. (2011). *Climate Change and evolutionary adaptation*. Nature 470 (7335): 479-485.

Homan, T., Maire, N., Hiscox, A., Di Pasquale, A., Kiche, I., Onoka, K., & ... Takken, W. (2016). Spatially variable risk factors for malaria in a geographically heterogeneous landscape, western Kenya: an explorative study. *Malaria Journal*, *15*1-15.

Hume M. R., Doherty T., Ngara M., New, D. & Lister. (2001). *African Climate Change*: 1900-2100. Climate Research 17: 145-168.

Idris, Z. M., Chan, C. W., Kongere, J., Gitaka, J., Logedi, J., Omar, A., & ... Kaneko, A. (2016). High and Heterogeneous Prevalence of Asymptomatic and Sub-microscopic Malaria Infections on Islands in Lake Victoria, Kenya. *Scientific Reports*, *6*36958

Intergovernmental Panel on Climate Change (IPCC) (2007). *Climate Change*. Synthesis report. Cambridge University Press: Cambridge, United Kingdom and New York.

Intergovernmental Panel on Climate Change (IPCC) (2013). *The Physical Science Basis Contribution of Working Group I to the Fourth Assessment Report of Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, United Kingdom and New York.

Kathuri, N. J., *&* Pals, A. D. (1993). *Introduction to Educational Research.* Egerton: Egerton University Education Book Series.

Kepha, S., Nikolay, B., Nuwaha, F., Mwandawiro, C. S., Nankabirwa, J., Ndibazza, J., *&* Brooker, S. J. (2016). Plasmodium falciparum parasitaemia and clinical malaria among school children living in a high transmission setting in western Kenya. *Malaria Journal*, *15*1-13

Kerry, J. (2017). Climate change shouldn't be a partisan issue in the first place. *Vital Speeches Of The Day*, *83*(1), 8-14.

Kim, S., Masud, M. A., Cho, G., *&* Jung, I. H. (2017). Analysis of a vector-bias effect in the spread of malaria between two different incidence areas. *Journal Of Theoretical Biology*, *419*66-76

Kipruto, E. K., Ochieng, A. O., Anyona, D. N., Mbalanya, M., Mutua, E. N., Onguru, D., *&*. Estambale, B. A. (2017). Effect of climatic variability on malaria trends in Baringo County, Kenya. *Malaria Journal*, *16*51-11

Kjellstrom, T., Briggs, D., Freyberg, C., Lemke, B., Otto, M., *&* Hyatt, O. (2016). Heat, Human Performance, and Occupational Health: A Key Issue for the Assessment of Global Climate Change Impacts. *Annual Review Of Public Health*, *37*97-112

Komen, K. (2017). Could Malaria Control Programmes be timed to Coincide with Onset of Rainfall? *Ecohealth*, *14*(2), 259-271.

Koram, K. A., Bennett, S., Adiamah, J. H., & Greenwood, B. M. (1995). Socio-economic risk factors for malaria in a peri-urban area of The Gambia. *Transactions Of The Royal Soci ety Of Tropical Medicine And Hygiene*, *89*(2), 146-150.

Kothari, C. R. (2004). *Research Methodology*. New Age International Publishers (P) limited, New Delhi.

Krejce, R. V., & Morgan, D. W. (1970). Determinig Sample Size for Research Activities: *Educational And Psychological Measurement*. 30. pp.607-610. State Publisher.

Kuya,C. B. (2015). *Climate change and Kenya's Socio-economic Development: A case study of Vihiga County*. University of Nairobi.

Laffety K.D. (2009). *The ecology of climate change and infectious diseases*. Ecology 90(4): 888-900.

Martens P., Kovarts R. S., Nijohf S., De Veries M., Livermore J., Brandley D.J., Cox J. & McMichael A.J. (1999) Climate Change and future population at risk of malaria. Global Environ Change 9:S89-S107.

Mazutis, D., & Eckardt, A. (2017). Sleepwalking into Catastrophe: cognitive biases and corporate climate change inertia. *California Management Review*, *59*(3), 74-108.

Mbodj, F. G. (2000). [Malaria and diarrhea, principal causes of infant deaths]. *Pop Sahel: Bulletin D'information Sur La Population et Le Development*, (10), 10-11

McMichael A.J., Woodruff R.E. & Hales S. (2006) *Climate Change and human health*: present and future risks. Lancet 367 (9513): 859-869.

Mlacha, Y. P., Chaki, P. P., Malishee, A. D., Mwakalinga, V. M., Govella, N. J., Limwagu, A. J., & Dongus, S. (2017). Fine scale mapping of malaria infection clusters by using routinely collected health facility data in urban Dar es Salaam, Tanzania. *Geospatial Health*, *12*(1), 494

Mulinya Caroline., (2017) Factors Affecting Small Scale Farmers Coping Strategies To Climate Change In Kakamega County In Kenya. *IOSR Journal of Humanities And Social Sciences (IOSR-JHSS),* 22

Ndegwa, B., Githeko, A., Omukunda, E., Munyekenye, G., Atieli, H., Wamai, P., & Yan, G. (2006). Population dynamics of malaria vectors in western Kenya highlands. *Journal Of Medical Entomology*, *43*(2), 200-206.

Okuneye, K., & Gumel, A. B. (2017). Analysis of a temperature- and rainfall-dependent model for malaria transmission dynamics. *Mathematical Biosciences*, *287*72-92

Oliver, S. V., & Brooke, B. D. (2017). The effect of elevated temperatures on the life history and insecticide resistance phenotype of the major malaria vector Anopheles arabiensis (Diptera: Culicidae). *Malaria Journal*, *16*11-23

Omondi, C. J., Onguru, D., Kamau, L., Nanyingi, M., Ong'amo, G., & Estambale, B. (2017). Perennial transmission of malaria in the low altitude areas of Baringo County, Kenya. *Malaria Journal*, *16*1-8

Omumbo, J., Ouma, J., Rapuoda, B., Craig, M. H., le Sueur, D., & Snow, R. W. (1998). Mapping malaria transmission intensity using geographical information systems (GIS): an example from Kenya. *Annals Of Tropical Medicine And Parasitology*, *92*(1), 7-21.

Onyango, E. A., Sahin, O., Awiti, A., Chu, C., & Mackey, B. (2016). An integrated risk and vulnerability assessment framework for climate change and malaria transmission in East Africa. *Malaria Journal*, *15*(1), 551.

Otieno, G., Koske, J. K., & Mutiso, J. M. (2016). Transmission Dynamics and Optimal Control of Malaria in Kenya. *Discrete Dynamics In Nature & Society*, 1-27

Parham, P. E., & Michael, E. (2010). Modeling the Effects of Weather and Climate Change on Malaria Transmission. *Environmental Health Perspectives*, *118*(5), 620-626.

Patz, J., D. Campbell-Lendrum, T. Holloway, and J. Foley. (2005). *Impact of regional Climate Change on Human Health*. Nature. 438:310-317

Reinhardt, F. L., & Toffel, M. W. (2016). Managing Climate Change: Lessons From The U.S. Navy. *Harvard Business Review*, *95*(4), 102-111.

Rongers D.J., Randolph S.E. & Snow R.W. (2002).satellite imagery in the study and forecast of malaria. Nature 415, 710-715

Sandeu, M. M., Abate, L., Tchioffo, M. T., Bayibéki, A. N., Awono-Ambéné, P. H., Nsango, S. E., & ... Morlais, I. (2016). Impact of exposure to mosquito transmission-blocking antibodies on Plasmodium falciparum population genetic structure. *Infection, Genetics and Evolution: Journal Of Molecular Epidemiology And Evolutionary Genetics In Infectious Diseases*, *45*138-14

Sewe, M. O., Ahlm, C., & Rocklöv, J. (2016). Remotely Sensed Environmental Conditions and Malaria Mortality in Three Malaria Endemic Regions in Western Kenya. *Plos ONE*, *11*(4), 1-16

Shuford, K., Were, F., Awino, N., Samuels, A., Ouma, P., Kariuki, S., & ... Roth Allen, D. (2016). Community perceptions of mass screening and treatment for malaria in Siaya County, western Kenya. *Malaria Journal*, *15*1-13

Singh, B. K. (2010). Climate change and human health: an environmental perspective. *Climate Research*, *41*(1), 41-44

Singh, P., Yadav, Y., Saraswat, S., & Dhiman, R. C. (2016). Intricacies of using temperature of different niches for assessing impact on malaria transmission. *Indian Journal Of Medical Research*, *144*(1), 67-75.

Spencer, H. C., Kaseje, D. C., Collins, W. E., Shehata, M. G., Turner, A., Stanfill, P. S., & ... Koech, D. K. (1987). Community-based malaria control in Saradidi, Kenya: description of the programme and impact on parasitaemia rates and antimalarial antibodies. *Annals Of Tropical Medicine And Parasitology*,13-23.

Spitzen, J., Koelewijn, T., Mukabana, W. R., & Takken, W. (2017). Effect of insecticide-treated bed nets on house-entry by malaria mosquitoes: The flight response recorded in a semi-field study in Kenya. *ActaTropica*, *172*180-185.

Stern, D. I., G ething, P. W., Kabaria, C. W., Temperley, W. H., Noor, A. M., Okiro, E. A., & ... Hay, S. I. (2011). Temperature and Malaria Trends in Highland East Africa. *Plos ONE*, *6*(9), 1-9

Sultan, B., & Gaetani, M. (2016). Agriculture in West Africa in the Twenty-First Century: Climate Change and Impacts Scenarios, and Potential for Adaptation. *Frontiers In Plant Science*,

Tompkins, A. M., & Caporaso, L. (2016). Assessment of malaria transmission changes in Africa, due to the climate impact of land use change using Coupled Model Intercomparison Project Phase 5 earth system models. *Geospatial Health*, *11*(1 Suppl), 380.

Velema, J. P., Alihonou, E. M., Chippaux, J. P., van Boxel, Y.,Gbedji, E., & Adegbini, R. (2014). Malaria morbidity and mortality in children under three years of age on the coast of Benin, West Africa. *Transactions Of The Royal Society Of Tropical Medicine And Hygiene*, *85*(4), 430-435.

Waldock, J., Parham, P. E., Lelieveld, J., & Christophides, G. K. (2013). Climate and human health: the impact of climate change on vector-borne diseases, Paphos, Cyprus (17-19 October 2012). *Pathogens And Global Health*, *107*(8), 387-392.

Wang, X., & Zhao, X. (2017). A Malaria Transmission Model with Temperature-Dependent Incubation Period. *Bulletin Of Mathematical Biology*, *79*(5), 1155-1182.

Wanja, E. W., Kuya, N., Moranga, C., Hickman, M., Johnson, J. D., Moseti, C., & Ohrt, C. (2016). Field evaluation of diagnostic performance of malaria rapid diagnostic tests in western Kenya. *Malaria Journal*, *15*1-10

Wanja, E., Achilla, R., Obare, P., Adeny, R., Moseti, C., Otieno, V., & ... Buff, A. M. (2017). Evaluation of a laboratory quality assurance pilot programme for malaria diagnostics in low-transmission areas of Kenya, 2013. *Malaria Journal*, *165*1-13.

Weiss, D. J., Bhatt, S., Mappin, B., Van Boeckel, T. P., Smith, D. L., Hay, S. I., & Gething, P. W. (2014). Air temperature suitability for Plasmodium falciparum malaria transmission in Africa 2000- 2012: a high-resolution spatiotemporal prediction. *Malaria Journal*, 13(1), 1-23

Westenberger, S. J., McClean, C. M., Chattopadhyay, R., Dharia, N. V., Carlton, J. M., Barnwell, J. W., & ... Winzeler, E. A. (2010). A systems-based analysis of Plasmodium vivax lifecycle transcription from human to mosquito. *Plos Neglected Tropical Diseases*, *4*(4), e653

World Malaria Report, World Health Organization (2017): *Malaria Report.* Geneva, Switzerland.

Yun, W., Biao, C., Guoding, Z., Danyu, S., Jiangtao, L., Cong, W., &. Ai, X. (2017). Comparative physical genome mapping of malaria vectors Anopheles sinensis and Anopheles gambiae. *Malaria Journal*, *16*1-10.

Zhiyong, Z., Mitchell, R. M., Kariuki, S., Odero, C., Otieno, P., Otieno, K., & ... Ya Ping, S. (2016). Assessment of submicroscopic infections and gametocyte carriage of Plasmodium falciparum during peak malaria transmission season in a community-based cross-sectional survey in western Kenya, 2012. *Malaria Journal*, *15*1-13.

Zhou, G., Lee, M., Githeko, A. K., Atieli, H. E., & Yan, G. (2012). Insecticide-Treated Net Campaign and Malaria Transmission in Western Kenya: 2003-2015. *Frontiers In Public Health*, *4*15

APPENDICES

Appendix 1: Questionnaire

Dear Respondent,

<u>RE: QUESTIONNAIRE ON THE IMPACTS OF CLIMATE CHANGE ON THE SPREAD OF MALARIA AMONGST CHILDDREN UNDER FIVE YEARS IN VIHIGA COUNTY</u>

My name is Hillary Wafula, a student of Masinde Muliro University of Science and Technology undertaking a Master's Degree in Geography. As part of my Master Degree thesis, I am carrying out a study on the above topic and your views and contributions will be highly appreciated.

The questionnaires will be treated confidential and the data collected will be used for academic and scholarly purposes only. For more information and clarification and how to hand in fully complete d questionnaire, you write to wafulahil@gmail.com or call 0710176533.

<u>PART ONE.</u>

<u>THE QUESTINNAIRE ON MALARIA TRAETMENT FOR THE HEALTH CARE PERSONNEL</u>

Name of the Health Centre_________________ Date______________________

Level of the Health Centre________________________ Sub County__________

Guiding Questions.

1. How many children under the age of five do you treat of malaria every day?

   ____

2. From your observation, what can you say of the number of the patients recorded each year in your health centre?
   a) DECLINING [ ]
   b) INCREASING [ ]
   c) REMAIN THE SAME [ ]
3. Do you think malaria prevalence is seasonal in your area? YES [ ] NO [ ].
4. Which months do you experience peak of malaria transmission in the area?

a) DECEMBER-FEBRUARY [ ]

b) MARCH-MAY [ ]

c) JUNE-AUGUST [ ]

d) SEPTEMBER- NOVEMBER [   ]

5. What do you think are the causes of this seasonal malaria transmission in the area?

____

____

____

____

6. What do you think has contributed to the continued malaria transmission throughout the year in your area?

____

____

____

____

7. From your experience as medical practitioner, do you think the changes in rainfall and temperatures in the area have contributed to the increased malaria outbreak in your area? YES [ ] NO [   ]
8. Can you be able to give notable evidence to your answer?

____

____

____

____

9. What remedy could you give to the above problem?

____

____

____

____

____

10. What could be the cause of rapid malaria prevalence if not attached to rainfall and temperature changes?

____

____

____

____

11. What can you say about malaria prevalence for the past 20 years

a) DECLINING [ ]b) INCREASING [ ]

12. What can you attribute to your answer above

____

____

____

____

13. What has the country government done in fight of malaria and how effective has been the method?

____

____

____

____

14. With your experience, what would be the best malaria control approach for your area?

____

____

____

____

15. Identify any treatment and prevention method of malaria that you use against.

____

____

16. Do you think it has been effective? NO [ ] YES [ ].Give your reason____

____

____

THANK YOU FOR YOUR CONTRIBUTION

PART TWO.

CLIMATE CHANGE AND MALARIA SPREAD QUESTIONNAIRE

Study site________________ Date____________________ House No.__________

G.P.S. Altitude____________ Latitude_________ Longitude______________

Location of the House

I. Hill top [ ]

II. Mid hill [ ]

III. Valley Bottom [ ]

A). THEME 1: ECOLOGICAL CHANGES.

1. What is your rating of the following climatic elements in your area?

RAINFALL. High [ ]

Medium [ ]

Low [ ]

TEMPERATURE. High [ ]

Average [ ]

Low [ ]

2. From the above information, do you think there has been a change in?

RAINFALL. YES [ ]

NO [ ]

TEMPERATURE. YES [ ]

NO [ ]

3. If your answer is YES, can you site evidence from your area?

____

____

____

____

4. What do you think could have been the course of the changes in rainfall and temperature in the area?

____

____

____

5. What has been the effect of these changes in rainfall and temperatures to the environment?

6. Do you have children under the five years old? YES [ ] NO [ ]

7. If YES, do you have any of the children who are sick of malaria currently or lately? YES [ ] NO [ ]

8. What kind of treatment approach are you using to treat the patient?

9. Do you believe the preventive measures have been effective in reducing the malaria prevalence in your household? If YES, mention any of the preventive measures and state its effectiveness.

10. What other alternative measures would you recommend for malaria treatment in your area?

THANK YOU FOR YOUR CONTRIBUTION.

Appendix 2: Community Focus Group Discussion Questions

Impact of climate Change on Malaria Prevalence amongst children in Vihiga County.

Interview questions for Focus Group Discussion

1. As a residents of Vihiga County, how do you rate climate trends in the county?
2. What is your comment on temperature and rainfall trends?
3. Do you believe temperature and rainfall changes have an impact on malaria prevalence in the county?
4. Who are most affected by malaria prevalence in your region?
5. Would you associate malaria outbreak with seasonal changes in rainfall and temperature?
6. Who are mostly affected in the family when there is malaria outbreak?
7. Do you think the intervention measures by the national and county government have been effective in controlling malaria prevalence in your region?
8. Do you think malaria hot spot mapping would be the best way to reduce Malaria prevalence?

Appendix 3: Key Informant Interview Questions

THEMESFOR KEY

INFORMANTINTERVIEWS Theme1:

Situation of climate trends in the Vihiga

Leading question

• How would you rate climate trends in this area?

Theme2: Impact of climate trends on Malaria Prevalence.

Leading question

• Do you believe that the changes in rainfall and temperature have an impact on malaria prevalence in the region?

Theme3: Malaria Prevalence amongst Children under five years.

Leading question

• What do you think on malaria prevalence under five years in the

region?

Theme4: Malaria diagnosis and treatment (For healthcare personnel)

Leading questions

• How is malaria diagnosed and treated at the health facility where you work?

• How effective is the method treatment employed in your facilities?

Theme5: Malaria mapping in the region.

Leading questions

• What kind of malaria treatment method you recommend in your area?

• Do you think malaria mapping could help to reduce malaria prevalence?

Appendix 4: Letter of Authorisation from the Chairman of FESS

Tel: 30817
Fax: 056-30873
E-mail cse@mmust.ac.ke
Website www.mmust.ac.ke

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY
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P.O. BOX 190
Kakamega – 50100
Kenya

Masinde Muliro University of Science and Technology (MMUST)

Department of Social Science and Education

Our Ref: MMU/COR:522016 (22)

Date: 20th March, 2017

To Whom It May Concern

RE: HILLARY WAFULA MUSINZI – GEO/G/0014/15

The above named is a bonafide Masters student of Masinde Muliro University of Science and Technology (MMUST) in the Department of Geography. He has completed his course work and defended his proposal. The student is to collect data on Malaria prevalence among children under age of 5 years for the last 20 years in Vihiga County.

Any assistance accorded to him will be highly appreciated.

Yours faithfully,

MASINDE MULIRO UNIVERSITY DEPT. OF SOCIAL SCIENCE EDUCATION CHAIRMAN P.O. Box 190 KAKAMEGA DATE...... MMUST

Dr. Ochieng L. Ahaya
CoD, Social Science and Education

Appendix 5: Letter of Authorisation from the Ministry of Education

MINISTRY OF EDUCATION
STATE DEPARTMENT OF EDUCATION

Telegrams: ....
Telephone: (056) 51450
When replying please quote

COUNTY EDUCATION OFFICE,
VIHIGA COUNTY,
P.O. BOX 640,
MARAGOLI.

REF: CDE/VC/ADM/VOL.2/39/90

10th April, 2017

TO WHOM IT MAY CONCERN

RE: AUTHORITY TO CONDUCT RESEARCH
HILLARY M.WAFULA-GEO/G/0014/15

Reference is made to letter no. MMU/COR: 522016 (22) dated 20th March 2017.

Permission is hereby granted to the above named Master student of Masinde Muliro University of Science and Technology (MMUST) in the Department of Geography to collect data on **"Malaria Prevalence among children under age of 5 years for the last year's research in Vihiga County"**, Kenya to enable him write a Thesis as required of him, by the University.

For

Victoria W. Mulili
County Director of Education
VIHIGA COUNTY

Copy to:

County Commissioner
VIHIGA

Appendix 6: Letter of Authorisation from the Vihiga County Government

When replying please quote.........
Ref. No: VCHS/CDH/RES. A/021/17
Email: ahindukhaqb@yahoo.com

THE COUNTY DIRECTOR OF HEALTH
P.O. BOX 344-50300,
MARAGOLI
Date: 12th April 2017

COUNTY GOVERNMENT OF VIHIGA
DEPARTMENT OF HEALTH SERVICES

The Sub-County Medical Officer:

- Sabatia
- Vihiga
- Luanda
- Emuhaya
- Hamisi

RE: AUTHORITY TO CONDUCT RESEARCH
STUDENT: HILLARY MUSINZI WAFULA- GEO/G/0014/15

Authority is hereby granted to the above named student from Masinde Muliro University of Science and Technology (MMUST), to collect data on ***"Malaria Prevalence among children under age of 5 years for the last 20 years research in Vihiga County***" to enable him write a Thesis as required of him by the institution.

The student is advised to report to the **Sub-County, Medical Officer for Health** (**SCMOH**) **Vihiga, Sabatia, Luanda, Emuhaya and Hamisi before** embarking on the research project.

Dr. Ahindukha Quido,
County Director of Health- Vihiga.

COUNTY GOVERNMENT OF VIHIGA
COUNTY DIRECTOR OF HEALTH SERVICES
12 APR 2017
P. O. Box 344-50300, MARAGOLI
Sign...