

**EFFECTS OF VARIABILITY OF SELECTED CLIMATIC
ELEMENTS ON MALARIA PREVALENCE IN AWENDO
DIVISION, RONGO DISTRICT, MIGORI COUNTY, KENYA**

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DECLARATION

This thesis is my original work and has not been presented for a degree or any other award in any university.

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DEDICATION

To my father Joshua Olela, my late mother Turfosa Ojwang' and my family.

May the father live long to enjoy the fruits of his labour.

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OPERATIONAL DEFINITION OF TERMS AND CONCEPTS

Annual Trends – the trends observed during the years within the study(surveillance) period.

Climate Variation – Slight changes in the atmospheric conditions as may be observed on annual or decadal basis.

Endemic Disease – Always present as is the case with malaria in the study area.

Epidemicity – Having the nature of an outbreak then disappears within a relatively short period as is the case with malaria in the study area during the months of June-July and January.

In patients – The number of patients admitted to a health facility for proper treatment, nursing and monitoring.

Malaria Prevalence – The frequency of occurrence and spread of a disease in a given geographical region.

Monthly Trends- the occurrences that are observed during the months in a year.

Morbidity – Unhealthy or disease mood. It refers to the number of the sick individuals e.g. due to malaria per 1000 of the total population in an area over a given period.

Mortality - The number of deaths in a given period i.e. due to a disease per 1000 of total population over a given period of time.

Optimum Temperature – The best quantity of temperature conducive to the survival of vector and parasite - mosquito and *Plasmodium* respectively

Over the Years- During the study period.

Within the Years- Individual years during the study period.

ACRONYMS AND ABBREVIATIONS

ARMA-	Autoregressive Moving Averages
AMR-	Africa Malaria Report
CCM-	Climate Change and Malaria
CRM	Climate Risk Management
DOMC-	Division of Malaria Control
IISD	International Institute for Sustainable Development
IPCC-	Intergovernmental Panel On climate Change
ITN	Insect Treated Nets
KNBS-	Kenya National Bureau of Statistics
KNH-	Kenyatta National Hospital
MARA-	Mapping Malaria Risk in Africa
MoS –	Ministry of State
NMCP-	National Malaria Control Programmes
NMCS-	National Malaria Control Strategy
RBM-	Roll Back Malaria
RDDP –	Rongo District Development Plan
SONYSUGAR-	South Nyanza Sugar Factory

ABSTRACT

Malaria burden continues to increase in the tropical developing countries of the world such as Kenya. In Kenya, it is blamed on climatic influences on the environment. The historically high rainfall, temperature and relative humidity encourage prevalence in Western Kenya especially around Lake Victoria. This study investigated the effect of seasonal variation of selected climatic elements on malaria morbidity and mortality in Awendo Division, Rongo District, Migori County, Kenya. It was based on the Kate's basic impact and the MARA/ARMA world models. Awendo Division is in the transition zone between the lake region endemic and the epidemic Kisii Highlands, an altitude of between 1450m and 1700m above sea level. This means that it must have characteristics independent of the two areas yet it is categorized under the endemic lake region. Using a case study design, the study relied on secondary data obtained from Sonysugar meteorological station and Awendo Division Health facilities from 2001-2010. The target population was the at-risk population of Awendo Division (108,913). A flooded sampling was done consisting of all recorded malaria morbidity and mortality cases from the health facilities. Descriptive and inferential statistics were used. Pearson's moment correlation coefficient was used to investigate the strength of the relationship between malaria cases and the selected climatic elements, ANOVA was used to study the variation of malaria morbidity within and over the years. The selected climatic elements and malaria morbidity did not show clear patterns during the surveillance period. The elements however formed two seasons within the years. They also showed insignificantly positive trends during the ten-year period. Malaria on the other hand had a significantly positive trend during the same period. Although all the selected climatic elements correlated negatively with malaria morbidity, they constantly offer optimal malaria transmission windows throughout the year except rainfall which drops below the optimal ranges. The study further revealed both endemic and epidemic characteristics of malaria in Awendo. Although malaria was found to be persistently present in Awendo, it annually peaks in the months of July and January. In summary although malaria was seen to be present throughout the year, its occurrences patterned with the selected climatic elements. The study recommends that intervention measures be in place throughout the year. The medical personnel and the meteorologists should hold frequent consultative forums to lay early strategies against epidemics. There is need for further research to unearth more information on the pereniality and the positive significant trends of malaria in the study area. If no action is taken to control the significant growth, then malaria will have worse consequences in future. This study will provide the latest information on the malaria situation in Awendo which will be very useful to the National Malaria Control Programmes and the epidemiological service providers in formulating policies that may promote the mitigation of malaria in Awendo Division and the rest of the country.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

The Intergovernmental Panel on Climate Change contends that there is proof that much of the warming observed over the last 50 years has led to the emergence of large-scale environmental hazards affecting human health such as the global spread of infectious diseases (IPCC, 2007). Beginning in the mid-1970s, there has been an emergence, resurgence and escalation of infectious diseases arising from global warming (De Savings et al., 2002). Vector-borne diseases are a major cause of illnesses and deaths in tropical countries (AMR, 2003). One of the most important vector-borne diseases in the world is malaria transmitted by the mosquito vector of the genus *Anopheles* most abundant in tropical/subtropical regions (WHO, 2003). Climatic variations directly influence mosquito development, feeding-frequency and longevity, as well as the time in which the parasite develops inside the mosquito (Patz et al., 2003; Suthersts, 2004). The optimal temperature (15⁰C - 30⁰C) associated with the incubation rate of the pathogen within vectors leads to the differential risks of outbreaks by regions (Campbell-Lendrum et al., 2003). Increased precipitation can increase mosquito population indirectly by expanding the larval habitat and food supply. A relative humidity of below 55% and above 80% shortens the lifespan of a mosquito so much that the scope of malaria transmission diminishes as there is no time for a complete development of *Plasmodium* (Bhattacharya et al., 2006).

Malaria is endemic to more than 100 countries, causes 300 million new infections and represents the greatest burden to human health among all vector-borne diseases and it is estimated that the annual number of deaths resulting from malaria exceeds 1 million (WHO, 1999). Pregnant mothers, fetuses, and children are particularly vulnerable to the infections. In children, around 20% mortality are from cerebral malaria and a few residual effects are noticed after recovery such as neurological defects in 10% of surviving children, which substantially deepen children's vulnerability in future behaviour and career development (Holding & Snow, 2001). Currently, 40% of the total human population in the world is at risk of malaria and this proportion is projected to increase to 80% by 2080 (MoH, 2001). The increasing prevalence and mortality from these infectious diseases have had several negative consequences especially decreasing economic productivity, increasing medical costs, choking taxation and increasing generations of poorly educated populations (Sachs & Malaney, 2002).

Previously extremely widespread, malaria is now mainly confined to Africa, Asia and Latin America, its control being aggravated by inadequate health structures and poor socio-economic and cultural practices (WHO, 2009). In the East African countries, malaria is ranked the first cause of morbidity and mortality in both children and adults (IPCC, 2007). IPCC further reveals through its recent climatological analysis of Eastern Africa that the region is likely to experience heightened temperatures and increased rainfall, which is likely to increase malaria incidences.

Kenya experiences a number of development challenges such as environmental degradation high poverty level, economic inequality and limited access to critical services like water and healthcare. Malaria worsens the situation by being the number one cause of morbidity and mortality (UNDP, 2013). Even then, malaria situation in the country has been observed to be in the decrease and a decline has been observed in the recent years resulting in low malaria transmission in most parts of the country. Despite that, moderate to high levels of transmission remain certain in the endemic zones hence attention should remain focused on those areas (IISD, 2013). It has long been endemic to Kenya's humid coast and swampy lowlands; however, in the recent decades scientists have noted an increase in the epidemic regions. Many medical and environmental experts have attributed this to climate change in the form of warmer temperatures and the variation in rainfall patterns. The best climatic conditions for malaria are long rainy season that is warm and wet followed by a dry season that is not too hot followed by a short rainy season, conditions that are prevalent in Western Kenya (Wandiga et al., 2006) where a 0.5 increase in temperature since 1970, can explain the eight fold increase in malaria cases (Githeko, 2009).

Malaria remains a leading cause of morbidity and mortality in Kenya, especially in young children and pregnant women. It accounts for 30% of outpatient attendances and 19% of the admissions to health facilities and 3-5% of the inpatient deaths. It is the most important cause of deaths in children under 5 years of age and is estimated to cause 20% of all deaths in this age

group (MoPH, 2008; MoH, 2008). Currently, the situation is getting worse calling for urgent mitigation/adaptive strategies. As has been observed by Omumbo et al., (1997) and Githeko and Ndegua (2001), there is an urgent need to study the relationship between malaria and climate and if possible make recommendations for this country where 40,000 infant deaths are attributed to malaria every year. The above observations have prompted this study whose findings will also give an insight into the effects of climate change on the future of malaria in Kenya. The hope is that malaria is curable and preventable if detected early since there is enough technology for preventing, monitoring, diagnosing and treating it.

1.2 Problem Statement

Kenya faces a heavy disease burden. About 30% of this burden is due to malaria which is ranked as the number one cause of morbidity and mortality in both the adults and children (MoPHS, 2009). According to MoPHS (2011), 31% of the out-patient morbidity is due to malaria. The country aims to reduce morbidity and mortality from malaria by 66% by 2017 (UNDP, 2013).

Whereas malaria is endemic in the lowlands around Lake Victoria while an epidemic in the highlands, the altitude ranging between 1450 metres and 1700 metres (MoS,2008) above sea level places the study area under a transition region where it connects the lowlands of Lake Victoria with the Kisii Highlands (MARA, Collaborations 2005).

The implication is that the patterns and trends must be those that are unique to this area calling for an independent investigation of the climate - malaria trends. On the other hand, there is very little if any study about climate- malaria relationship in this division yet it is a problem to: the few available health facilities which are always packed to capacity with majority of the cases attended to being malaria-related; the households where malaria-related sicknesses and deaths are a common experience; all sectors of the economy whose labour- force is always affected by the same; education system where pupils/ students spend a lot of time out of classes due to malaria despite the measures already put in place to deal with the situation.

The purpose of this study was, therefore, to investigate the effect of variation of climatic elements (rainfall, temperature and relative humidity) on malaria morbidity and mortality in Awendo Division. Although such kinds of studies have been carried out elsewhere, Awendo area is unique to herself and her studies should reflect the uniqueness.

1.3 Justification of the Study

As climate change creates new risks, better analysis is needed to understand new levels of underlying uncertainties. To plan for disasters, there is need to understand how climate variability and change will impact on them. It is important to understand how the likely changes in temperature, precipitation and the frequency and magnitude of the future extremities of weather will affect the health sector (IISD, 2013).

Awendo Division is a sugarcane growing zone which before the year 1976 was heavily forested and has since been cleared to pave way for agricultural activities (Sonysugar Human Resource Manager 2003), this plus the presence of Sonysugar factory might have altered the climate patterns of this area necessitating this study.

Rainfall records for 25 years (1978-2003) gave an annual average of 1833mm received in double maxima with short interludes of dry periods. The long rainy season comes between March-May while the short one, September – November (Sonysugar Meteorological Station, 2003), with a mean annual temperature of 22⁰C, and a humidity of between 52%-71% (Sonysugar Meteorological Station 2003). These conditions are very conducive for the mosquito vector and pathogen survival. It was important for this study because of the high at-risk- population, large sugarcane plantations and its adverse mosquito infestation (Omumbo et al., 1997) making it vulnerable to malaria prevalence. On the other hand, this study was an effort to reach goal number six of the Millenium Development Goals which seek to combat HIV and AIDS, Malaria, TB and other diseases. It has been observed over the past few years that morbidity and mortality rates from malaria in the study area are on the increase with clearly observed fluctuations during certain periods of the year (Mariwa Health Centre-unpublished data, 2011). Given the annual variations of climatic elements, (rainfall, temperature, humidity), there could be some relationship between the two – variation of climate and malaria morbidity and mortality and these prompted the study.

Awendo was again preferred for this study because of her unique position between the hyperendemic and holoendemic regions of the Kisii Highlands and Lake Victoria respectively, and because of its urban and agricultural orientation meaning it must portray some characteristics unique to her and independent of the two neighbouring zones. On the other hand, malaria is a menace to the people of the study area despite the measures put in place to control its morbidity and mortality rates yet there has not been any study to that effect.

1.4 Research Questions

The study was guided by the following research questions:

- i. What are the patterns and trends of the selected climatic elements (temperature, rainfall and relative humidity)?
- ii. What are the patterns and trends of malaria morbidity and mortality?
- iii. What is the relationship between the variability of the selected climatic elements and malaria morbidity and mortality?

1.5 Objectives

1.5.1 General Objective

The general objective was to investigate the effect of the variation of the selected climatic elements on malaria morbidity and mortality in Awendo Division, Rongo District, Migori County.

1.5.2 Specific Objectives

- i. To compare the patterns and trends of the selected climatic elements (rainfall, temperature and relative humidity) and malaria morbidity between 2001- 2010.
- ii. To analyze the relationship between the seasonal and annual variability of the selected climatic elements and malaria morbidity and mortality.

1.6 Research Hypotheses

- i. There are no significant trends in the selected climatic elements during the surveillance period.
- ii. There are no significant trends in malaria morbidity during the surveillance period.
- iii. There is no significant co relation between the variations of selected climatic elements and malaria morbidity and mortality in the study area.

1.7 Significance of the Study

This study was significant because of the following reasons: First, from the various meetings organized by the Roll Back Malaria (RBM) technical network, it had been obvious that more comprehensive operational research was needed as part of the National and District malaria control programmes. It was proposed that field research should involve teams of experts from various backgrounds (interdisciplinary approaches) within National Malaria Control Programmes (NMCP), Epidemiological Services, Emergency/Disaster departments, Agricultural departments and others (MoH, 2001). Geographers

could not be exempted from doing the same. Second, malaria is a preventable and curable disease. However, to treat and prevent it, decision-makers need to be aware of the risk of transmission in space and time. This study will provide the necessary information for Awendo. Third, the assessment of malaria prevalence in a population is important in policy-making, monitoring service outcomes, and in designing research interventions. The findings of this study could be relevant to the policy-makers and other stakeholders such as NGOs in formulating viable policies and intervention programmes to remedy the problem of malaria burden in Kenya. Again, it was part of the nationwide campaign to control, eradicate and manage malaria in Kenya where it is expanding into the highlands which rarely experienced it before (Githeko, 1998; WHO, 1994; Tonui, 2008).

This study is again very significant as it is going to help acquire the most current existing data for both the selected climatic elements and malaria morbidity and mortality. Finally, due to the ever changing climatic conditions, there is need to keep track of its (climate) effect on malaria so as to be able to vary the strategic approaches in accordance with the given situation at a particular time and place. Omumbo et al., (2004) studied and observed a need to redefine Africa's population at risk in accordance with both climate and non-climatic determinants of malaria transmission and intensity by providing a more informed approach to estimating the morbidity – mortality consequences of infection. This research has therefore, provided information on the latest situation of Awendo Division and since the Government of Kenya (MoH,

2001) rates malaria as one of the high priority health and clinical packages whose morbidity and mortality should be reduced by 30% from 2001 – 2017 (IISD 2013) and beyond, this research becomes part of the priority.

1.8 Scope and Limitation of the Study

The study investigated the effects of the variation of selected climatic elements on malaria morbidity and mortality and did not go into such details as the mosquito feeding frequency, reproductive rates and population as such. On the other hand, only three climatic elements (rainfall, temperature and relative humidity) were selected for the study. Although prevalence is low in most parts of Kenya, malaria is re-emerging in the western highlands due to a combination of climatic and non-climatic factors. However, this study confined itself only to the climatic influence and did not go into the details of the non-climatic factors. It was further limited by: scarcity of data as most of the health facilities had records running for only ten years or less; many cases that were not reported to the health facilities which were the main sources of data; incomplete records and the fact that most of the records contained more of clinical cases than microscopic cases. For this reason, data collected had to be interpolated and compared for effective harmonization and fair representation. For more conclusive results, more geographical locations would have been studied; however, this was not possible due to financial and other logistical constraints such as time and duration of the study.

1.9 Assumptions of the Study

The study assumed that:

- i. All the officers at the meteorological station and the health facilities were cooperative and provided reliable data.
- ii. The malaria morbidity and mortality data were representative enough of the target population.
- iii. Knowledge of the relationship between the variation of the selected climate elements and malaria morbidity and mortality in the study area is true according to the research findings.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Climate Risk Management (CRM) is the systematic approach and practice of incorporating climate related events, trends and projections into development decision making to maximize benefits and minimize potential harms and losses (UNDP, 2013). Malaria is a menace in the study area and its prevalence directly or indirectly affects many development sectors. From the review of various existing literature, its prevalence is climate-dependent and is mainly driven by three selected climatic elements: temperature; rainfall and relative humidity. The effects of these elements vary from one place to another as will be revealed in the foregoing literature review. Although other climatic elements may have their influence on this disease, they do not have as much effect as the three elements mentioned. This chapter reviewed literature on the relationship between the variation of climatic elements and malaria morbidity and mortality with particular interest to Awendo Division, Rongo District, Migori County- Kenya.

2.2 Climate and Malaria Patterns and Trends

Githeko (2009) studied malaria and climate change in Asia, Canada, United Kingdom, The Caribbean, Africa and in the Western and Central Kenyan Highlands. He described malaria as a disease that involves humans, mosquitoes, the plasmodium parasite and climate. This researcher observed that the development rate of mosquito larvae is temperature-dependent such

that below 16⁰C the development of anopheles gambiae stops and below 14⁰C they die. Once they become adults, the rate at which they feed is again temperature-dependent such that at 17⁰C, the female mosquito (anopheles gambiae) feeds on human blood every 4 days while at 25⁰C, they need blood meal every 2 days. He further claims that the 0.5⁰C increase of temperature in the Western Kenya since 1970 should explain the eight fold increase in malaria cases in the area. Kenya's climate is generally warm all the year round. However, when travelling along different parts of the country, one experiences different patterns due to differing topographical dimensions. In most parts, the coolest seasons fall between July and August with the temperature dropping to as low as. Kenya does not realize particular winters and summers but the warmest months are February to March when temperatures rise to as high as 34⁰C. Rainfall increases the breeding habitat leading to increased mosquito population and the mosquito's biting rate. He says that the biology of malaria transmission is thus very sensitive to changes in weather and climate. Githeko attributes the occurrences of malaria in Western Kenya to a multiple of factors such as drug resistance, mobility of the people, lack of vector control and land use changes. In this research, he paid more attention to the highland areas and only gave blanket coverage of Western Kenya and although he recognizes and recommends that climate data be examined regularly to determine the changes or the stability of the habitat for malaria transmission, he has not done this for the western Kenyan highlands, lowlands and the transition areas like Awendo Division. It is, therefore, important to fill this gap in Awendo by carrying out this study that will provide data on climate/ malaria patterns and be a base for

future reference in the follow-ups on the same. This will be in line with his recommendations to include climate in malaria studies since climate is an important malaria driver.

2.2.1 Patterns and Trends of Climate

IISD (International Institute for Sustainable Development), (2013) under the UNDP prepared a report which examined high risk countries including Kenya. In Kenya, the study was based in four counties (Kericho, Nandi, Kisii and Trans- Nzoia) where historical analysis was done on three climate elements (temperature, rainfall and humidity). It observed that long-term climate incremental changes will mean that people everywhere must learn to adapt to weather patterns changing shifts in ecosystems that humans depend on. As climate change creates new risks, analysis is needed to understand new levels of uncertainties. To plan for these uncertainties, there is need to understand the frequency and magnitude of extremities. This study further observed that the seasonal rainfall patterns in Kenya are driven mainly by the migration of ITCZ. This brings the long rainy season between March and May and the short rains between October and December in many parts of the country. Historically, the long rainy season is responsible for 70% of the annual rainfall while the short rains are only responsible for 20%. Disparities are, however, observable and some parts receive more rains during the short rainy period.

The study also observed that in recent decades, changes have been observed in the Kenya's climate. Mean annual temperatures have increased by 1.0⁰C since

1960, an average of 0.21⁰C per decade (IISD, 2013). Changes in rainfall pattern have also been noticed since 1960 but they have not been showing significant nationwide changes. Greater rainfalls have been noticed to occur during the short rains of October- December extending into the normally dry months of January and February. However while there have been indications of heavy rainfall occurrences, no statistically significant trends have been found (IISD, 2013).

The above observations are based on the historical weather and climate experiences of Kenya in general. IISD, 2013 noticed in this study that there are disparities in some areas and this necessitates studies of specific areas if risks arising from climate factors are to be effectively managed. Historical experiences with climate hazards may no longer be a sound basis for evaluating risk. Observable trends and longer term models generated from projections must be taken into account if development is to be truly sustainable. It is also important to build studies on existing climate information to fill the critical knowledge gaps. Kenya's complex tropical climate varies significantly among regions due to topographical and influences of regional and global climate processes. Some places are warm and humid while others are arid and semi arid. It is, therefore, dangerous to assume and infer basing on blanket knowledge.

In the study, IISD further observed that higher temperatures and changes in rainfall patterns observed over the past decades are broadly consistent with the

changes projected to occur in the country due to global climate change. In the medium term, projection suggests that temperature will rise by 1.0⁰C to 3.5⁰C by 2046 to 2065 (IISD, 2013). This will be manifest through increased frequency of hot days and nights with cold days and nights becoming rare. However, regional differences will still remain. Western Kenya is projected to experience temperature increase ranging from 0.9⁰C to 1.1⁰C, Eastern by 1.1⁰C, South Coast by 0.5⁰C, North Western by 1.0⁰C while North Eastern by 1⁰C to 2⁰C. The Kenya meteorological department predicts a decrease in the average of the projected rainfall in Kenya (IISD, 2013). Again, these disparities call for spatio-temporal studies of the effect of climatic elements on malaria prevalence.

2.2.2 Trends of Malaria in Kenya

IISD, 2013 observed that malaria burden is decreasing in Kenya's endemic areas while expanding into low transmission zones where the sizes of outbreaks are increasing. The Kenya highlands (1500m and above) were malaria free from 1910 (IISD, 2013). In the western lowlands, malaria has remained endemic for many generations. Malaria epidemics in the Eastern African Highlands in general occurred from the mid-1920s to 1940s and were successfully controlled between 1950s and 1960s (IISD, 2013). However, 1980s and 1990s saw resurgence in those highlands. In Western Kenya, malaria epidemics have spread to 15 districts from 3 in 1988 (IISD, 2013). Therefore, while global and national malaria epidemics have been decreasing since 2004, the incidences in East African Highlands including Western

Kenyan Highlands have increased since the end of 1970s and this has not been controlled (IISD, 2013). Abnormal temperatures followed by rainfall exceeding certain thresholds can create conditions favorable to malaria epidemics depending on nature of the topography of a given geographical area. In the Western Kenyan Highlands, outbreaks of malaria are seasonal (IISD, 2013). Peak transmissions occur in the months of June- August after the long rains of March to May. A study of Nandi revealed that a combination of high temperature, rainfall and humidity led to major epidemics. This could be inferred to Awendo but given the topographical and Agro-ecological differences, Awendo must be studied individually (UNDP,2013).

The following observations were also made on the influence of the selected climatic elements on malaria occurrence.

2.2.3 Temperature

Development of the malaria vector (mosquito) and the parasite is temperature-sensitive (IISD, 2013). Temperature modifies the development speed of the parasite, frequency of blood feeding by adult female mosquitoes and the time it takes the malaria parasite to mature in them (IISD, 2013). The lowest temperature threshold for the anopheles gambiae to biologically act, is 8⁰C to 10⁰C. The minimum temperature for parasite transmission is 16⁰C to 19⁰C for plasmodium falciparum and the maximum is 33⁰C to 39⁰C (IISD, 2013). Outside the said thresholds, parasite development stops or slows. It takes the parasite 56 days to mature in the mosquito at 18⁰C, 19 days at 22⁰C and only 8

days at 30⁰C (IISD, 2013). A temperature of between 18⁰C and 30⁰C would precipitate malaria outbreaks as long as mean monthly rainfall is 150mm per month and the infected human population is constant (IISD, 2013).

2.2.4 Precipitation and Humidity

Humid conditions increase mosquito's life expectancy (UNDP 2013). Rainfall increases vector population by creating new breeding sites (IISD, 2013). Too much rainfall will wash away breeding sites and kill the mosquito larvae thereby reducing malaria transmission (IISD, 2013). If two of the elements are constantly optimal, then the extreme one will determine the epidemicity (IISD, 2013). This implies that each area should be studied to establish which of the elements is responsible for the variation. This study will therefore determine what happens in Awendo

2.2.5 Malaria in the Highlands

Tonui (2008) studied occurrences of highland malaria morbidity and mortality between 1998-2005 and observed a close relationship between unstable-highland malaria patterns and trends and climate variation in Kericho Highlands and observed that the occurrence of malaria cases followed seasonal patterns of climatic elements, for example increases in malaria cases occurred between January to March and between April to July each year, times that are associated with high temperatures, rainfall and relative humidity. This could be inferred to Awendo area but given the differences in climatic regimes, altitude, economic activities, cultures, it was not possible. On the other hand, the

researcher did not look at the influence of each independent climatic element to determine which of the three remained optimal and which one was responsible for the variation. It was, therefore, only fair that an independent study is carried out for Awendo by comparing each element against malaria occurrences. This should help in explaining the recommendations made for the necessary adaptive strategies suitable for this particular area.

Berrang et al., (2009) notes that malaria periodicity and outbreaks have long been recognized to be associated with climate and climate fluctuations globally. The above variations observed are responsible for the geographical aerial differences in parasite transmission and malaria prevalence. It is, therefore, very important that each geographical area be studied independently to establish the situation at each geographical region so as to effectively apply the relevant adaptive strategies in the management of malaria.

2.3 Climate Variation and Malaria Prevalence in India and Kenya

Bhattacharya et al., (2006) studied the relationship between malaria and the variation of climate determinants in India and observed a positive correlation between malaria and three climatic indicators - humidity, rainfall and temperature during a period of 30 years (1970-2000). However, they observed that malaria cases were still persistent even during months which recorded nil rainfall. Also observed was a negative correlation between rainfall and malaria in Saurashtra and Kutch. This refutes the observations that there is always a positive correlation between malaria prevalence and climate variation. Such

contradictions call for independent research in different areas concerning malaria – climate relations. It was, therefore, in order that the malaria- climate relationship in Awendo is investigated. It was not correct to assume that climate indicators would act similarly on malaria prevalence in different regions. The findings of an investigation should state whether an area experiences negative or positive rainfall-malaria relations.

MoH (2008) observed a variation of malaria prevalence in Kenya from one region to another with a wide diversity in risk largely driven by climate (temperature). It went on to specify five categories: Lakeside endemic; Coastal endemic; Highland (low risk areas); Arid seasonal (seasonal) and Central and Nairobi provinces- low malaria risk. This was kind of blanket as the prevalence rate at Homa- Bay might not be the same as that of Awendo which has more of highland orientation than Homa- Bay, yet Awendo is categorized under the lake region endemic. Nairobi Province for example, is regarded as a low risk area yet malaria is almost endemic at the Kibera slums (CCM, 2007). At the same time, it does not specifically explain the magnitude of influence these climatic factors (rainfall, humidity and temperature) pose during the high risk months in these places. The publication further observes and recommends vector control measures that are based on the intensity of the disease transmission, selective, targetive and site specific. All these would only be possible if the prevalence rate per given site in a region was established. This kind of information would really ease the work for the medical personnel and

other stakeholders in Awendo Division for the purpose of employing various vector and disease control strategies.

2.4 The Effect of Microclimate on Malaria Transmission

Malakoti et al., (1998) studied whether malaria was imported or a result of local transmission in Kericho Highlands which was initially believed to be malaria free zone-due to the high altitude and subsequently low temperatures which were presumed to be lethal for the vector survival. The scholars, however, observed the issue of microclimate such as heated houses which may promote or discourage vector and parasite survival. This further necessitated studies of specific areas. They also observed that clearing of forests for agricultural activities promoted availability of suitable breeding grounds for the mosquito vector by expanding the larval habitat through the increase of clear sun lit stagnant pools of water. Awendo being an industrial region with her expansive sugarcane plantations could be experiencing a kind of climate unique to herself necessitating an independent study.

Githeko et al., (2003) studied the relationship between malaria transmission from seven sites in the East African highlands covering Ethiopia, Kenya and Uganda. Their findings also supported- the theory of malaria-climate relations. However, this was too large a generalization considering the aspects of micro-climates as was later found by Githeko himself in the subsequent studies that a small areal environmental difference can create a big impact on malaria prevalence. However, they observed climate as a driving force for malaria.

2.5 The Multidisciplinary Research Approach

MoPH (2008) observed that malaria is a menace to many sectors: Education; Agriculture; Tourism; Provincial Administration among others all culminating in the Health Department. Malaria is responsible for 1.3% loss in economic growth in Africa including Kenya where it has three dimensions of the socio-economic impact: loss of productivity or performance; income or budget hemorrhage; social and economic insecurity (MoPH, 2008). This calls for an approach that would serve the interests of all the affected parties and not the medics alone. This publication went ahead to give a sectoral map of the dimensions of the socio-economic impact of malaria in Kenya but it failed to go down to the regions. Why we need geographical data is spatial comparison of phenomena. It should have gone down to regions lower than the national level to provide information of the scourge at various levels. This publication only gave blanket coverage with inadequate statistical data to explain the level of malaria burden which would be very useful in preventing presumptive treatment. This publication paid attention to the malaria burden up to the district levels and not the divisional levels making it necessary to study Awendo Division.

2.6 The Influence of the Non - Climatic Indicators

Berrang et al., (2009) notes that malaria periodicity and outbreaks have long been recognized to be associated with climate and climate fluctuations globally. These observations have led to development of models predicting future global malaria trends based on global climate trends. However, given the

important influence of none-climatic factors such as socio –economic, agricultural trends, level of awareness, healthcare, local habitat and vector control, global-climate malaria models cannot be used to infer risks in all the regions. More accurate modeling can only be possible if research is thoroughly conducted at regions below the national levels

2.7 Theoretical Framework

Climate impact assessment is one of the families of interdisciplinary studies that focuses on the interaction between nature and the society or the study of human environment. As such, it must draw upon theory, methods and research findings from the great domains of science. This study is based on the world's climate – malaria models (Kates - Basic Impact model 1985 and MARA/ARMA 1998). The relationship between malaria and climate cannot be ignored given the following: The biological plausibility; many examples of malaria epidemics following extreme climate events and many modeling studies reporting positive-climate malaria relationships (Ting & Ming, 2005). May (1998) also conceptualized how human behavior, social and physical, and physical environments co-vary in affecting the occurrence of a disease in humans.

2.7.1 The Basic Impact Model (Kates, 1985)

This model generally looks at the climatic effects on human health. It is part of a family of relationships based on assumptions of direct cause and effect. Climatic events impinge upon populations and cause impacts. Climatic impact

studies focus on the effects of their recurrent variation. One of the strategies is to select a geographical unit and focus on the climatic events within that selected climatic boundary. On the other hand, one may use the society as a starting point and third, there is the selection by opportunity such as determining the unit by existing model or the available data source. This study combined the first and third strategies to study the relationship between climate and malaria prevalence in Awendo Division. In choosing the impact and the consequences to study, the model found it helpful to assign an order of propagation (first, second ... nth order). According to this model, the study viewed the consequences of climate on malaria in Awendo through the second order of propagation. In this order, climate impacts on the humans by interacting with the macro organisms (vector) in their ecological environments. These organisms (malaria vector) interact with the humans to influence their health. A disease occurrence is, therefore, viewed as a consequence of interactions between climate – macro organisms (vectors) – humans. Climate variation will thus lead to variation in the vectors ecological setup eventually influencing their activities and interactions with humans (health). In the case of malaria, this will be noticed through the variability in morbidity and mortality rates. From this model, it is therefore mandatory to study climate variability in studying climate-related events.

This impact model consists of three elements: climatic variation; climatic effects on human population; activity and the causes of impact through

population activity. The Interaction Model (Kates 1985), recognizes impacts as joint products of interaction between climate and society.

2.7.2 MARA/ARMA Models

This model directly looks at temperature and rainfall as the major climatic elements that influence the variability of malaria morbidity and mortality. Temperature is crucial in determining the proliferation rate of the anopheles mosquitoes and the maturation rate of the pathogen for example the lowest temperature for the development of *P. falciperum* is 18⁰ C. As temperature declines, so does the development of malaria parasite for example, 26 days at 20⁰ C and only 13 days at 25⁰ C. (Ting & Ming, 2005; Bhattacharya et al., 2006). According to Craig et al., 1999, for most anopheles vector species of malaria, the optimal temperature range for survival lies within 20⁰C to 30⁰C. However, the transmission of *P. vivax* requires minimum of 15⁰C while *P. falciparum* a minimum of 19⁰C. The lower temperature threshold of 18⁰C is based on the time required for parasite development and length of mosquito survivorship at that temperature; below 18⁰C, few parasites can complete development cycle within the life of the mosquito. The mosquito survivorship peaks at 31⁰C. At this point less than 40% of the mosquitoes survive long enough for the parasite to complete its development cycle (Craig et al., 1999; MARA/ARMA, 1998). As temperature rises above 32⁰C, the mosquitoes' probability of survival decreases. However, higher temperatures enable the mosquitoes to digest the blood meal more rapidly which in turn increases the rate at which they bite. This increased biting rate coupled with the faster

development of the parasite leads to increased infective mosquito bites for those mosquitoes that survive (Craig et al., 1999; MARA/ARMA, 1998).

Total monthly rainfall was another climate variable used by MARA/ARMA, (1998). Mosquitoes require water for their eggs to develop into larvae and ultimately emerge as winged adults. Monthly precipitation of at least 80mm was designated as suitable for stable transmission (Craig et al., 1999; MARA/ARMA, 1998). An average monthly humidity of below 55% and above 80% shortens the lifespan of the mosquito so much that the scope of malaria transmission diminishes (Bhattacharya et al., 2006; Craig et al., 1999). Sensitivity of disease transmission to weather and climate depends on the reproductive rates of the vector and the rate of development of the pathogen within the vector or in the environment, preference for human blood feeding and suitability availability of disease habitat. Rainfall and temperature influence availability and suitability of the habitat. Short-term climate extremes like the El Niño and La Nina lead to elevated precipitation and temperatures and these have been observed to improve transmission conditions (Wandiga et al., 2006) These models assume indirect cause in effects on climatic events.

In tropical and subtropical countries, malaria continues to play a leading role in causing morbidity and mortality. About 90% of the one million deaths resulting from malaria in the world occur in Africa. In East Africa, it is transmitted by mosquito vector especially *anopheles gambiae*. Climate variability and change

have aggravated its morbidity and mortality in many parts of Kenya i.e. in the highland areas around L. Victoria. (Wandiga et al., 2006).

This study uses temperature, rainfall and relative humidity as a set of atmospheric states that influence malaria prevalence in Awendo Division. The agro – ecological zones, human population and climatic events are seen to interact and produce vectors (mosquitoes) with parasites that cause malaria in humans. This is evidenced by morbidity, anemia, still births and abortions.

2.8 Conceptual Framework

Based on the above literature, theories and models, the researcher developed the conceptual framework below to give a better understanding of the relationship between climate variation and malaria morbidity and mortality. In considering climate, he paid attention to three major components that determine climate: rainfall, temperature and relative humidity. These three are dynamic and their variation influences the prevalence of malaria in many ways. As has been observed from the theoretical framework, rainfall is basically responsible for the provision of the larval habitat through the water that remains stagnant after the rain has fallen. Temperature of between 15⁰C and 30⁰C is optimal in improving the mosquito's rate of digestion, feeding frequency (biting rate), reproductive rate and sporogeny. Humidity on the other hand ensures longevity. Variability in these elements is, therefore, responsible for variability in the mosquitoes' population which in turn determines the biting frequency and therefore, the spread of malaria.

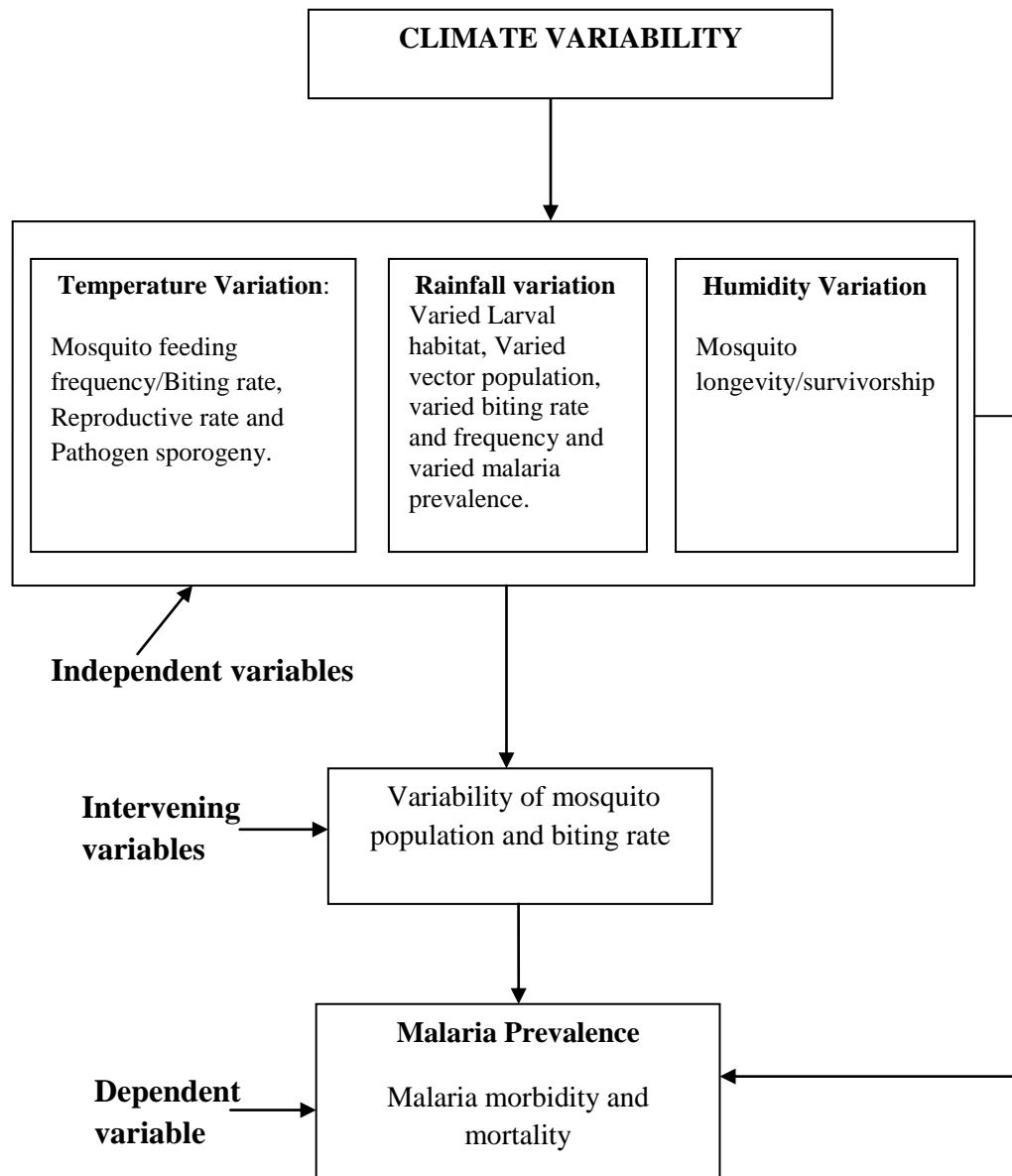


Figure 2. 1: A conceptual framework to show the relationship between the variability of selected climatic elements on malaria morbidity and mortality.

Source: Modified from MARA/ARMA mode

CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction

This chapter presented the steps for achieving the research objectives of this study. They included: the study site, the research design, target population, sample and the sampling techniques and data analysis.

3.2 Study Area

The study was carried out in Awendo Division, Rongo District, Migori County- Kenya (Figure 3.1). It is situated between latitudes $0^{\circ} 45' S$, $1^{\circ} 00' S$ and between longitudes $34^{\circ} 28' E$, $34^{\circ} 38' E$ (MoS- 2008-2012). Annual rainfall is at the average of 1833mm, temperatures $22^{\circ} C$ with humidity varying between 52% and 71% (Sony Meteorological Station unpublished data 2010). The area is marked by the presence of three hills (Rabuor, Nyamarere and Ranen) elevating the altitude to over 1700m (MoS-2008-2012) above sea level. The division is bordered by Rongo Division to the North- East, Uriri to the west, Ndhiwa to the North-West, Oyani to the South-West, and Transmara District to the South - East (MoS- 2008-2012).

Awendo Division occupies an area of about 256.2 km^2 with a population of 108,913 and a population density of 424 persons/ Km^2 (KNBS, 2009). This is divided into five locations each represented by at least a health facility. The area is drained from North East to South West by Kuja and Sare Rivers and

their tributaries. It is also divided into almost two equal halves by the Kisii – Sirare Highway.

Sugarcane is the main cash crop while maize is the main subsistence crop. Residents practise mixed farming; they rear cattle; sheep; goats and also keep poultry. Agriculture is supported by the presence of fertile soils, availability of human labour and a favourable modified equatorial climate.

Awendo was preferred for this study because of her unique position between the hyperendemic and holoendemic regions of the Kisii Highlands and Lake Victoria respectively, and because of its urban and agricultural orientation with large and expansive sugarcane plantations meaning it must portray some characteristics that are unique to her and independent of the two neighboring zones. On the other hand, malaria is a menace to the people of the study area despite the measures put in place to control its morbidity and mortality rates yet there is no study to that effect.

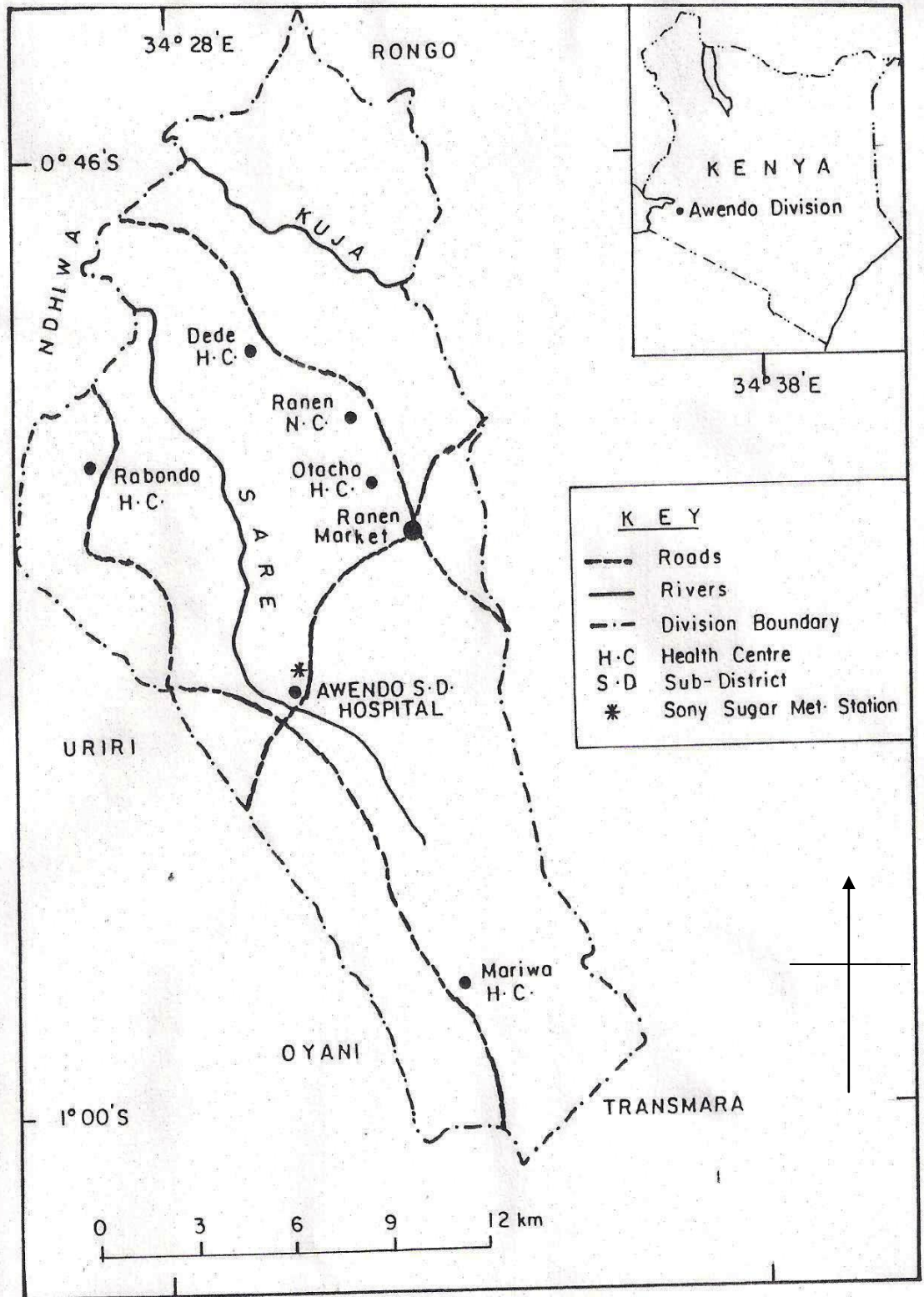


Figure 3. 1 Map of Study Area (Awendo Division)

Source: Kenya National Bureau of Statistics

3.3 Research Design

The study used the case study design to investigate the relationship between climate and malaria prevalence in Awendo Division, Rongo District Migori County. Health data were obtained from the health facilities representing five locations constituting the division while climate data were the historical rainfall, temperature and relative humidity records obtained from Sony Meteorological Station in Awendo. Both were obtained for 10 years. After processing, descriptive statistics (means and percentages) and inferential statistics (ANOVA and Pearson's product moment correlation coefficient) were used to establish variations within the years while patterns and trends were shown on graphs. The results of climate data and malaria morbidity were then compared, discussed and summarized. The two (health and climate data) were then correlated on annual basis before being correlated again for ten years using Pearson's Product moment correlation coefficient to establish the existing relationship. The methods were selected because they were quick, reliable and effective.

3.4 Target Population

The target population was the at-risk population which is the entire Awendo Division population which consisted of 108,913 people (KNBS, 2009).

3.5 Sampling Procedure and Sample Size

This study utilized data on malaria morbidity and mortality from all health facilities in Awendo Division across the 10 years in consideration. This means

that all the malaria morbidity and mortality cases recorded in the health facilities in the study area gave a flooded sample for the study. In terms of climate variability data from Sonysugar Meteorological Station were conveniently selected given her central position in the study area covering 256.2 km² which according to Linacre (1992) was climatically representative enough.

3.6 Types, Sources and Methods of Data Collection

The study utilized unpublished secondary data in report format on malaria morbidity and mortality from the health facilities in Awendo Division (Appendix I). The data were obtained from the individual health facilities – Mariwa Health Centre (Appendix V), Ranen SDA, Dede Dispensary, Kuoyo Kódalo Dispensary, Nyakuru Dispensary, Rabondo Dispensary, Kuja- Nyokal Dispensary, Otacho Dispensary, Jevros Clinic, Awendo Sub-District Hospital (Table 3) where monthly reports for all the health facilities in the division were submitted to, on monthly basis. Since all these facilities apart from Awendo Sub- District Hospital operated on out- patient basis, they could not provide mortality data. Even the Sub-District Hospital which handled the in- patient cases had data on mortality for only three years, (2008-2010).

Malaria morbidity data combined both clinical and confirmed cases. As most of the facilities did not have labs and lab equipment, majority of the cases were clinical. Almost all the facilities save for Awendo Sub-District were managed by nurses and community health workers who were not qualified enough to

handle serious clinical matters. It was difficult to categorize data in terms of gender and age because most of the facilities combined them and those that separated did not do so for the whole surveillance period. Records taken were harmonized and used. Climate data on the other hand included: mean monthly relative humidity, total monthly rainfall and mean monthly temperatures obtained from Sonysugar (Appendices II, III and IV). For both Malaria and climate, the data were collected via desk top review of records to acquire both monthly and yearly entries.

Table 3. 1: Distribution of Health facilities in Awendo Division

	HEALTH FACILITY	TYPE
1	Awendo	Sub – District Hospital
2	Mariwa	Health Centre
3	Dede	Health Centre
4	Ranen S D A	Dispensary
5	Kuoyo Kodalo	Dispensary
6	Nyakuru	Dispensary
7	Rabondo	Dispensary
8	Nyokal Kuja	Dispensary
9	Otacho	Dispensary
10	Jevros	Dispensary

Source: Rongo District Development Plan 2009

3.7 Data Analysis

Data collected from the field were cleaned and a dataset developed. The data were subjected to both descriptive and inferential statistics. Descriptive statistics comprised means such as the mean monthly rainfall; mean monthly

relative humidity (%). The descriptive statistical results were presented in graphs and tables. Inferential statistics used were ANOVA to determine the variation of malaria morbidity within and over the years. Regression was used to give the various trends while Pearson's product - moment correlation coefficient to test the strength of the relationship between malaria morbidity/mortality and the selected climatic elements. All the data were entered into the Microsoft excel and analyzed using the SPSS computer programmes.

Table 3. 2: Summary of Research Methodology

Objectives	Variables	Sources of Data	Methods of Data Collection	Data Analysis
1. Patterns and Trends of Climate Elements	Climate elements- (rainfall, temperature, humidity)	Sonysugar Meteorological Station	Desk top review from Sonysugar	Graphs, Descriptive statistics (means and percentages) and Inferential statistics (regression and ANOVA)
2. Patterns and Trends of Malaria	Malaria morbidity and mortality	Health facilities in Awendo Division	Desk top review from the health facilities in the study area	Inferential statistics (regression) and graphs
3. Climate-Malaria trend relations	Climate Elements/ Malaria morbidity and mortality	Sonysugar Meteorological Station Health facilities in Awendo	Desk top review from Sonysugar Meteorological Station and the health facilities in the study area	Pearson's product moment correlation coefficient and regression

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses the results of the various analyses done on the data collected from the field. It begins by comparing the temporal patterns, trends, of each selected climatic element with that of malaria morbidity and mortality, then goes to an overview of the kind of relationship that exists between each climatic element and malaria morbidity and mortality. The chapter ends by discussing the hypotheses.

4.2 Comparing Patterns of the Selected Climatic Elements and Malaria Morbidity

The table below (Table 4.1) compared morbidity cases with the annual total population. During the ten - year period it was established that on average, for every 1000, 250.6 (25.06%) people suffered from malaria morbidity every year. The year 2005 had the highest value of 316/1000 (31.6%) followed very closely by the year 2007 which had 286/1000 (28.6%). The rise experienced during the year 2005 could be explained by the pre - elnino conditions which saw the temperatures rise sharply from the year 2005 to the year 2007.

Table 4. 1:: Malaria morbidity per thousand and percent (2001-2010)

Year	Pop	T/Morb.	Per/1000	%
2001	93795	24682	263	26.3
2002	95671	19420	203	20.3
2003	97584	21932	225	22.5
2004	99536	20013	201	20.1
2005	101527	32035	316	31.6
2006	103558	21039	203	20.3
2007	105629	30250	286	28.6
2008	107742	28611	266	26.6
2009	108913	28652	263	26.3
2010	111081	31118	280	28
Mean	102503.6	25775.2	250.6	25.06

Source: Kenya Bureau of Statistics (2009)

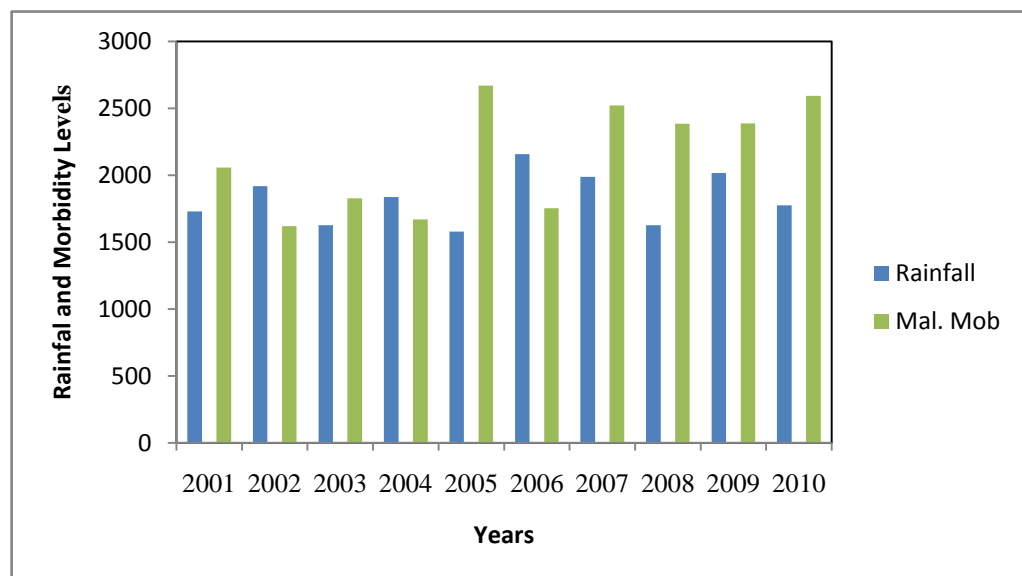
4.2.1 Annual Patterns of Rainfall and Malaria Morbidity

In this period (2001 – 2010), the annual rainfall recorded was as in appendix III, which shows the monthly totals, annual totals and the monthly means for all the months within the surveillance period while data received from all the health facilities showing malaria morbidity were summed up and tabulated under individual months as in appendix I, where the table shows both annual and monthly means over the surveillance period. When analysis of variation in morbidity was carried out, the result established that there was a significant variation in morbidity within the years of study with $F = 6.326$ while $P = 0.000$. The mean morbidity in the years was as shown in Table 4.2. Table 4.1 further confirms the variation established by ANOVA in Table 4.2. As can be observed, each year showed different values which also showed variations as the years progressed from 2001 to 2010.

Table 4. 2:ANOVA table for morbidity (2001-2010)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	179963.748	9	19995.972	6.326	.000
Within Groups	347707.864	110	3160.981		
Total	527671.612	119			

As can be seen from Figure 4.1, there was no consistency in the temporal patterns of rainfall during the surveillance period. There was a relatively high annual rainfall in the year 2006. This was followed by the year 2009 and 2007 in that order. The year 2005 had the least recorded rainfall during the surveillance period. On the other hand, high morbidity was noted in the year 2005 (mean 2670), year 2010 (mean 2593) and year 2007 (mean 2521) again in decreasing order. The lowest morbidity was recorded in year 2002 (mean 1619), year 2004 (mean 1669) and year 2006 (mean 1753) in ascending order.

**Figure 4.1:Patterns of annual of rainfall and malaria morbidity (2001-2010)**

Generally, both rainfall and morbidity showed inconsistency in their temporal patterns. Of utmost interest is the fact that the year 2005 which registered the lowest rainfall during the surveillance period also registered the highest malaria morbidity. This directly corresponds to the observation made by Bhattacharya et al., (2006) at Shaurashtra and Kutch – India, where rainfall correlated negatively with malaria morbidity as high rainfall always resulted into low malaria occurrences.

4.2.2 Seasonal Patterns of Rainfall and Malaria Morbidity

During the ten year surveillance period, the patterns of mean monthly rainfall were established as in figure 4.2. More rainfall was recorded in the month of April, May and November. The pattern however, divided a year into two rainy seasons of March – May and September – December (Figure 4.2). This conforms to the observation made by IISD (2013) which claims that the seasonal rainfall patterns in Kenya are driven by the migration of the ITCZ bringing the long rainy season between March and May and the short season between October and December. Rainfall declined consistently from May to July and from December to February. Based on the ten year surveillance period, the mean monthly results showed that there was no month without malaria morbidity, the months of June- July and January registered higher cases than the rest of the months. The result also showed that morbidity rose steadily from the month of April to July after which it declined steadily towards December. The month of January registered a sharp rise again steadily declining towards April.

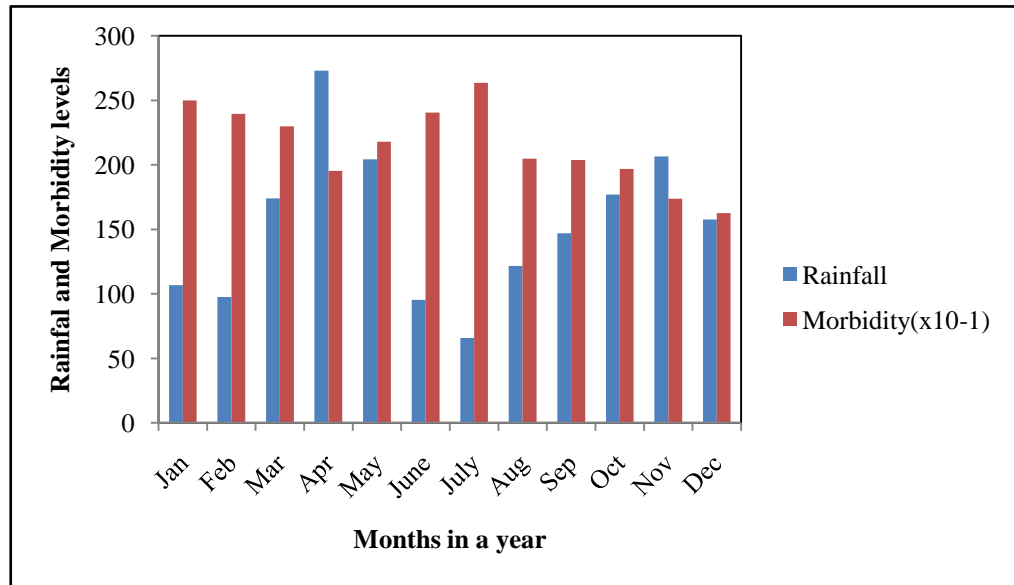


Figure 4.2: Patterns of mean monthly rainfall and malaria morbidity (2001- 2010)

Comparing the monthly malaria patterns with the monthly rainfall patterns, it was established that the two tended to divide a year into two seasons. However, it should be noted that while rainfall peaks in the months of April and November, malaria peaks in the months of June- July and January that is about one month after the rains reduce in the months of June and December. This is true according to Wandiga et al., (2006), who claims that malaria epidemics occur about two months after the peak of rainfall. Of interest again is the fact that the months of June- July and January which registered the least amount of rainfall on the other hand registered the highest morbidity. However, from the above observation, although there is periodicity in both malaria and rainfall, the periodicity of malaria is not as sharp as that of rainfall. It can be noted that while rainfall has more defined seasons, malaria remains high throughout the

year, an indication that the impact of variability of rainfall on malaria is not that great. This clearly indicates that there could be other factors promoting the occurrence of malaria morbidity in the study area.

4.2.3 Annual Patterns of Temperature and Malaria Morbidity

The mean monthly records used to compute the patterns of temperature during the period (2001 – 2010) were as in appendix IV. The table shows mean monthly temperatures for each year, mean monthly temperatures for the surveillance period and mean annual temperatures for the surveillance period. Mean annual temperatures in the period 2001- 2010 showed that the temperature was highest in 2005 (22.35°C) followed by 2009 (22.21°C). The lowest temperature was recorded in the year 2001 (21.03°C). As can be seen in figure 4.3, temperature and malaria morbidity remained very inconsistent during the surveillance period though temperature had a very small range (1.32°C). It significantly ($P = 0.001$) varied over the years ($F = 3.54$). High morbidity was noted in the year 2005 (mean 2670), year 2010 (mean 2593) and year 2007 (mean 2521). The lowest morbidity was recorded in year 2002 (mean 1619), year 2004 (mean 1669) and year 2006 (mean 1753).

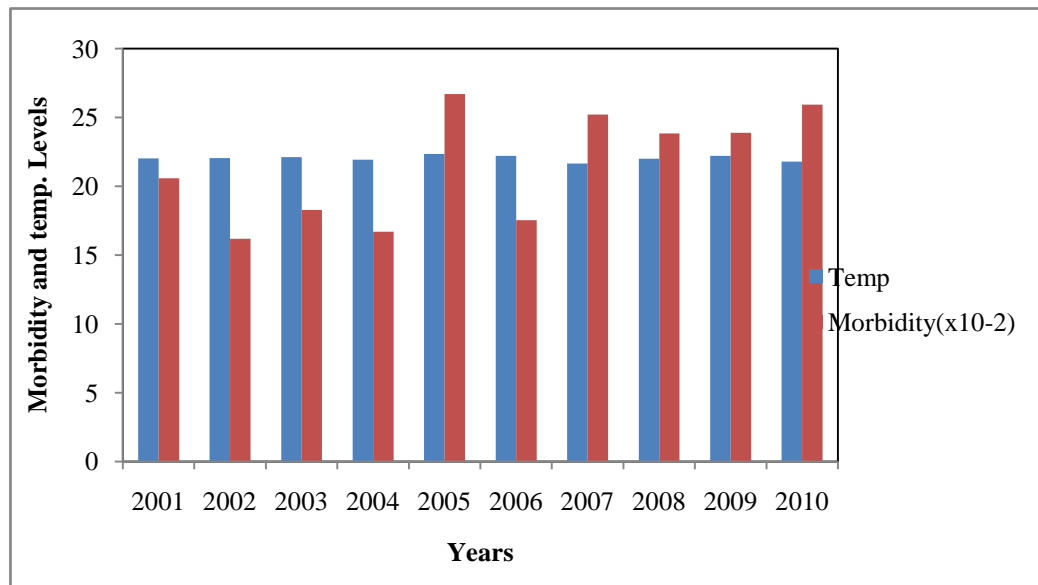


Figure 4. 3: Patterns of mean annual temperatures and malaria morbidity (2001-2010)

Although there was nothing to show any clear relationship, one very striking feature was in the year 2005 which registered the highest temperature while at the same time registering the highest morbidity. Interestingly, this is the year that also registered the lowest rainfall during the surveillance period. While it calls for further investigations, this could be the year that provided the most optimal atmospheric conditions for malaria prevalence. While the temperature was very high, rainfall which has been observed to negatively correlate with malaria was relatively low. Temperature is crucial in determining the proliferation rate of the anopheles mosquitoes and the maturation rate of the pathogen for example the lowest temperature for the development of *P. falciparum* is 18⁰ C. As temperature declines, so does the development of malaria parasite for example, 26 days at 20⁰ C and only 13 days at 25⁰ C. (Ting & Ming, 2005; Bhattacharya et al., 2006). Rainfall total for the year 2005 was 1579.5mm while the average temperature was 22.35⁰C. It takes the parasite 56

days to mature in the mosquito at 18⁰C, 19 days at 22⁰C and only 8 days at 30⁰C (Githeko, 2010). Compared to the other years within the surveillance period, the year 2005 therefore provided the best atmosphere for malaria prevalence.

4.2.4 Seasonal Patterns of Temperature and Malaria Morbidity

As in the case of rainfall, monthly patterns of temperatures were found to divide the year into two seasons, (January – May and August – December.). The month of June registered the lowest temperature (21.1⁰C), followed by July (21.36⁰C). Temperature was highest in the month of March (22.685⁰C). Annual range was however not great (1.585⁰C). As opposed to the case of rainfall and morbidity, the periodicity of temperature does not compare well with that of malaria morbidity. (Figure 4.4).

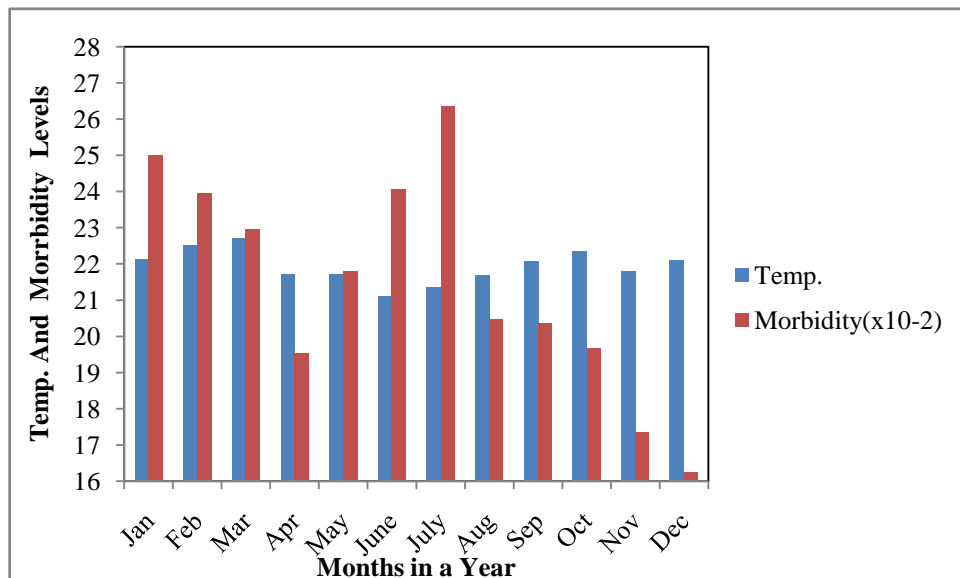


Figure 4. 4:Patterns of mean monthly temperature and malaria morbidity (2001-2010)

In comparing the seasonal temperature performance with that of malaria morbidity, it can be seen that they appear to alternate in occurrence. The months of June, July and January had the lowest temperatures yet they registered the highest morbidity. On the other hand, the months with the highest temperatures had very low morbidity. From the results, it can be seen that temperatures are high shortly before the rains start and diminish with the setting in of the rains. It is the rains that are responsible for the provision of the suitable larval habitat. The habitat is at its best immediately after the rains. Temperature remains optimal while there are plenty of the larval habitats. This leads to high vector population such that according to Wandiga et al, (2006), malaria escalates around two months after the rains, a time when the temperatures are relatively at their lowest, but optimal given that the optimal temperature ranges for both the vector and the parasite is between 15⁰C and 31⁰C (Campbell-Lendrum et al., 2003). The lowest temperature (21.1⁰C) for Awendo therefore remains optimal and conducive for malaria transmission.

4.2.5 Annual Patterns of Relative Humidity and Malaria Morbidity

Relative humidity during the 10 year period (2001 – 2010) recorded in % was as in appendix II. The table shows the mean monthly relative humidity within a year, mean monthly relative humidity during the surveillance period and mean annual relative humidity during the surveillance period in %. These are the data that were used to compute the patterns for humidity within that period of 2001-2010. Patterns of annual relative humidity in (%) during the period 2001- 2010 showed that the relative humidity was highest in 2007 (66.71%)

followed by 2006 (65.13%). These could be explained by the occurrence of the elnino rains in 2006. However, it is important to note that there was no year that registered a relative humidity of less than 62%. The lowest was recorded in 2003 - 62.58%. On the other hand, high morbidity was noted in the year 2005 (mean 2670), year 2010 (mean 2593) and year 2007 (mean 2521). The lowest morbidity was recorded in the year 2002 (mean 1619), the year 2004 (mean 1669) and the year 2006 (mean 1753), (Figure 4.5).

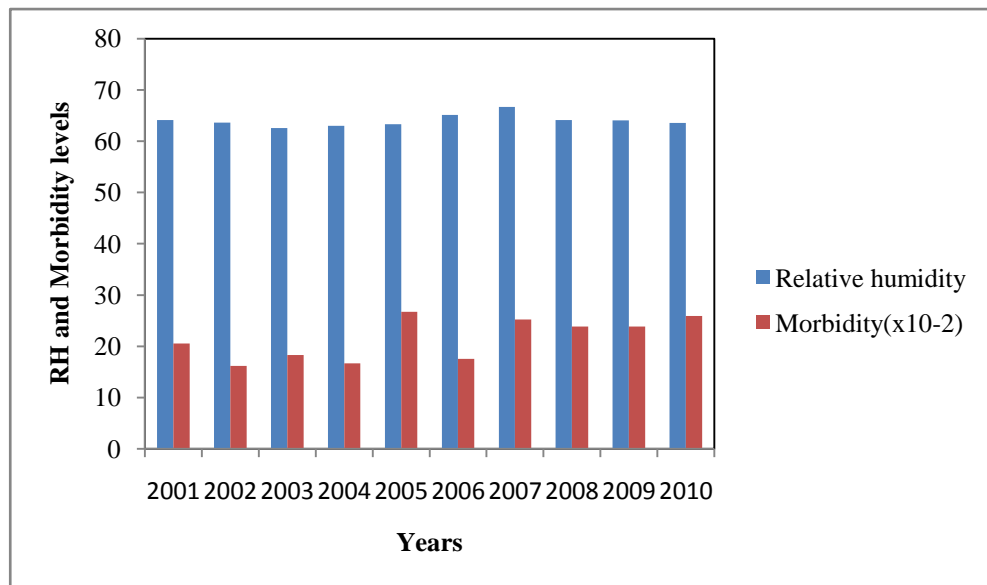


Figure 4. 5: Patterns of mean annual relative humidity and malaria morbidity (2001- 2010)

From the above analyses, it can be noted that in most cases, relative humidity patterned well with malaria morbidity over the years. Humidity produced a very interesting pattern – consistently descending from 2001 to 2003 then steadily ascending to 2007 before again steadily descending to 2010. Morbidity, on the other hand, did not show a well-defined pattern but

consistently indicated a rise from 2001 toward 2010. It (morbidity) was, however, very high in the year 2007 when humidity was at the peak.

4.2.6 Seasonal Patterns of Relative Humidity and Malaria Morbidity

Patterns of mean monthly relative humidity were found to divide the year into two seasons, (March – June and September – January). Relative humidity was highest in April (66.65%) followed by March (66.3%) and May (66.15%) the lowest relative humidity occurred in February (61.0%) which is a dry month. This pattern conforms to that of rainfall and temperature which also divided the year into two seasons with humidity being higher just before and highest during the rains. The result of malaria morbidity showed that morbidity rose steadily from the month of April to July after which it declined steadily up to December. The month of January registered a very sharp rise again steadily declining towards April (Figure 4.6).

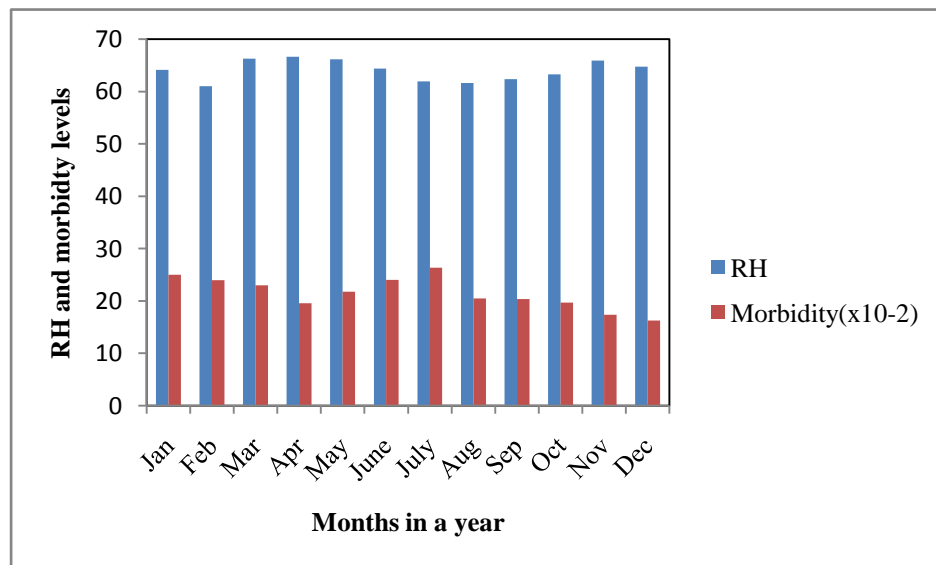


Figure 4. 6:: Patterns of mean monthly relative humidity and malaria morbidity (2001- 2010)

In comparing the seasonal humidity pattern with malaria morbidity patterns, it was observed that malaria morbidity is highest in June – July and January while humidity peaks between March and May, and between November and December. This shows that morbidity is at its lows when humidity is at its peak. The patterns are thus temporally alternated. It should also be observed that humidity peaks with rainfall at the same time. This implies that the two could have similar impacts on morbidity. However, at its lows, humidity is still optimal for malaria transmission in the study area.

4.3 Comparing Trends of the Selected Climatic Elements and Malaria Morbidity

4.3.1 Annual Trends of Rainfall and Malaria Morbidity

Rainfall trend in the ten year surveillance period was positive ($y=12.964x+1754.5$). This means rainfall increased at the rate of 12.964% per annum during the surveillance period (2001-2010). With the co-efficient of determination of $R^2=0.0417$, this time accounted for 4.17% of the changes in the spatio – temporal rainfall occurrences observed. However, at a P value of 0.521, this trend was not significant. During this period of ten years, the overall mean malaria morbidity in this area showed an increase in trend (Figure4.3b). It grew at the rate of 8.8703% per annum. The co-efficient of determination of $R^2 = 0.4328$ implies that the period (2001-2010) accounted for 43.28% of the temporal variation in malaria morbidity observed. Correlating morbidity

against the years, the researcher found an r-value of 0.658 and a P-value of 0.039. From that observation, morbidity had a significantly positive trend.

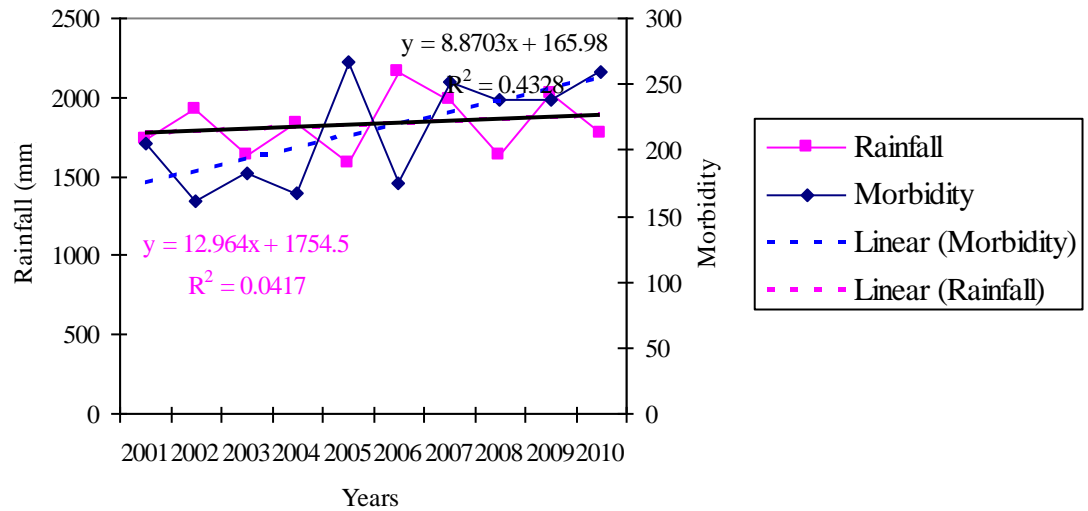


Figure 4. 7:Trends of annual rainfall and annual malaria morbidity (2001-2010)

In comparing the two trends, it can be observed that while malaria morbidity had a significantly positive trend, rainfall had an insignificant one. This means that while rainfall promotes malaria prevalence by providing suitable larval habitat (Bhattacharya et al., 2006), in Awendo Division, there must be other factors that are responsible for the increase in malaria over the years.

4.3.2 Seasonal Trends of Rainfall and Malaria Morbidity

Mean monthly trends of rainfall during this period of time as was the case with the annual trend, showed a positive trend (Fig.4.4a). At $y = 2.2745x + 137.37$, rainfall increased at the rate of 2.2745% per month within the years. With a coefficient of determination of $R^2 = 0.0194$, the implication is that on average,

one year accounted for 1.94% of the changes observed. Again, as was the case with the annual trends, the seasonal trend was insignificant at a P value of 0.666. In establishing the trend of malaria morbidity within a year, the results based on the ten-year period was used as a predictive model using mean morbidity for each month within the surveillance period. The trend showed that malaria cases decreased significantly ($P = 0.008$) towards the end of the year at the rate of - 6.1612% per month during the surveillance period ($y = 6.1612x + 254.82$). During the same period, a co-efficient of determination of $R^2 = 0.5178$ implied that the period of twelve months every year during the surveillance period accounted for 51.78% of the temporal variations observed (Fig.4.8).

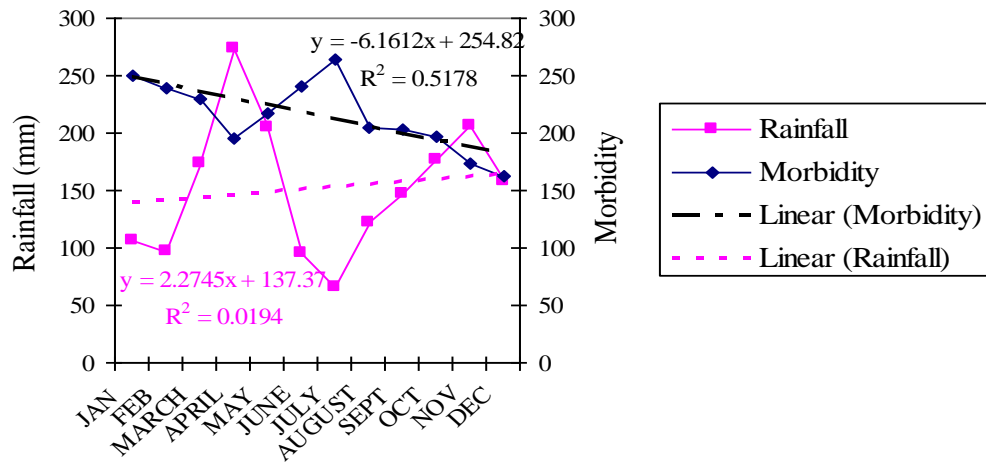


Figure 4. 8:Trends of mean monthly rainfall and malaria morbidity (2001-2010)

In this case, while rainfall had a positive trend towards the end of the year, malaria morbidity had a negative one. An increase in rainfall therefore, meant a decrease in malaria morbidity and because the increase in rainfall was not significant, there could be other factors contributing to the negative trend in

morbidity towards the end of the year. Here again, the negative rainfall-malaria correlation observation made by Bhattacharya et al., (2006) in Shaurashtra and Kutch is manifested.

4.3.3 Annual Trends of Temperature and Malaria Morbidity

Temperature during the ten year surveillance period was established to have a positive trend. A regression of $y = 0.0391x + 21.718$ means that temperature increased at the rate of 0.0391% per annum during the surveillance period (2001-2010), this is normal according to UNDP (2013) predictions of an increase of between 0.9⁰C- 1.1⁰C in Western Kenya. A co-efficient of determination of $R^2 = 0.0981$ implied that the period 2001-2010 accounted for 9.81% of the temporal changes observed. However, with a P value of 0.378, this trend was not significant. Similarly, during this period, the overall mean malaria morbidity also showed a positive trend. It grew at the rate of 8.8703% per annum. The co-efficient of determination of $R^2 = 0.4328$ implied that the period (2001-2010) accounted for 43.28% of the temporal variation in malaria morbidity observed. With an r- value of 0.658 and a P-value of 0.039, morbidity had a significantly positive trend.

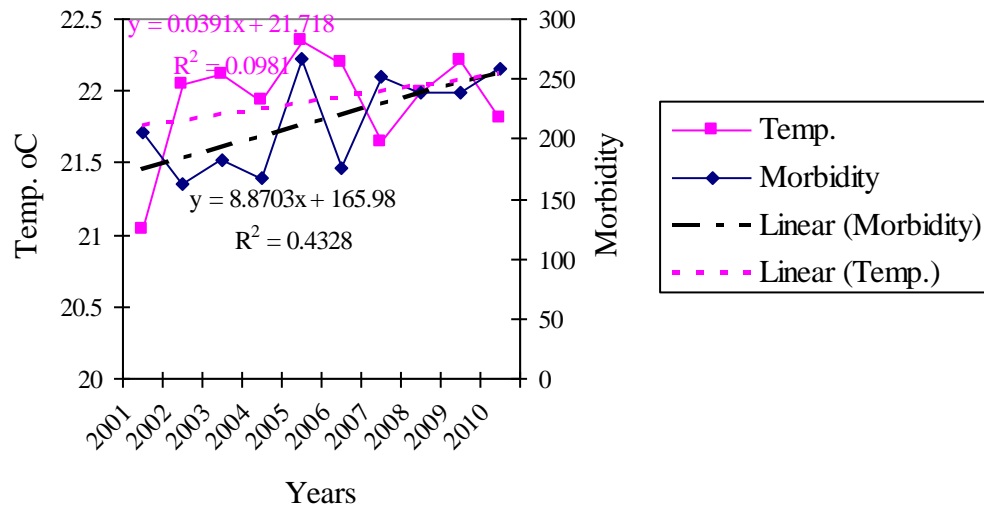


Figure 4. 9:Trends of annual temperature and annual malaria morbidity (2001-2010)

From the above observations, both temperature and malaria morbidity had positive trends. While temperature had an insignificant trend, malaria morbidity had a significant one. It must also be noted that even a very small increase in temperature can greatly increase malaria occurrence. It takes the parasite 56 days to mature in the mosquito at 18⁰C, 19 days at 22⁰C and 8 days at 30⁰C (Githeko, 2010). This implies that even a difference of 0.5⁰C can create a big impact just as Githeko (2009) claims that the 0.5⁰C increase of temperature in the Western Kenya since 1970 should explain the eight fold increase in malaria cases in the area. It can, therefore, be said confidently that the positive trend of temperature explains the positive trend in malaria during the study period. This also predicts the future of malaria in relation to the changing climate.

4.3.4 Seasonal Trends of Temperature and Malaria Morbidity

Mean monthly trends of temperature during this period of time were negative. Temperatures reduced as the months progressed from January to December. The equation $y = 0.0249x + 22.095$ implies that temperature decreased at the rate of 0.0249% per month during the time (2001-2010). A co-efficient of determination of $R^2 = 0.0377$ means that one year accounted for 3.77% of the temporal variations observed during that period. At a P value of 0.545, this trend was not significant.

As was in the case of temperature, malaria morbidity decreased towards the end of the year at the rate of - 6.1612% per month in a year during the surveillance period ($y = 6.1612x + 254.82$). During the same period, a co-efficient of determination of $R^2 = 0.5178$ implied that the period of twelve months every year during the surveillance period accounted for 51.78% of the temporal variations observed (Fig.4.10).

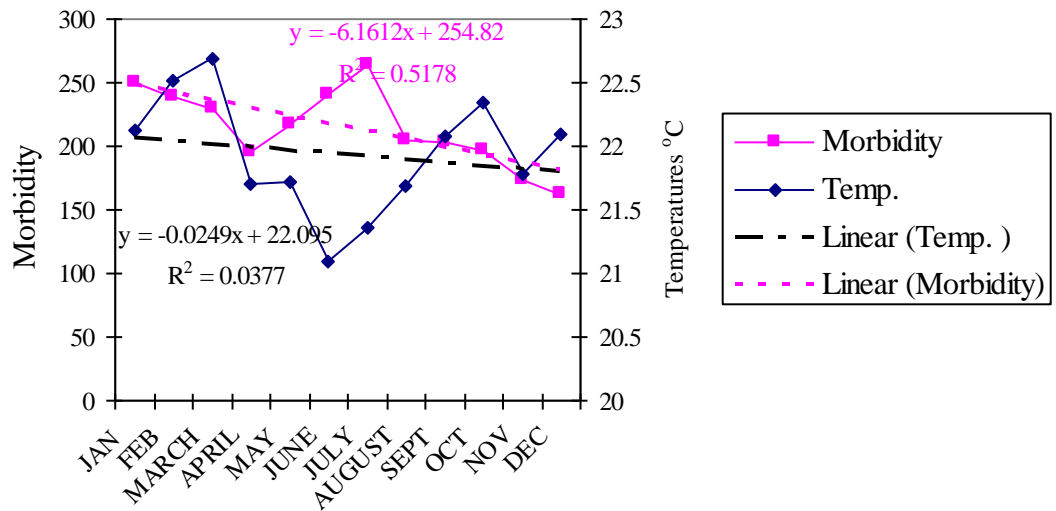


Figure 4. 10:Trends of mean monthly temperature and mean monthly malaria morbidity (2001-2010)

Both temperature and malaria morbidity had negative trends within the years. The rate at which they reduced towards the end of the year was however different as has been observed above. Unlike in the case of temperature whose trend was not significant, malaria morbidity trend was significant at a P value of 0.008. Again, it must be noted that even a very small decrease in temperature can greatly decrease malaria occurrence and the decreasing trend of temperature in this case explains the decreasing trend of malaria in the year.

4.3.5 Annual Trends of Relative Humidity and Malaria Morbidity

Relative humidity trend in the ten year surveillance period was positive. During this period (2001-2010), humidity increased at the rate of 0.1123% per annum ($y = 0.1123x + 63.414$). The co-efficient of determination was $R^2 = 0.0845$ meaning that the period 2001-2010 accounted for 8.45% of the

temporal variation observed. As had been said earlier, morbidity also had a positive trend growing at the rate of 8.8703% per annum. The coefficient of determination of $R^2 = 0.4328$ implies that the period (2001-2010) accounted for 43.28% of the temporal variation in malaria morbidity observed. Given that relative humidity is optimal for malaria transmission between 55% and 80%, any small increase could equally impact on malaria prevalence by increasing the transmission rates.

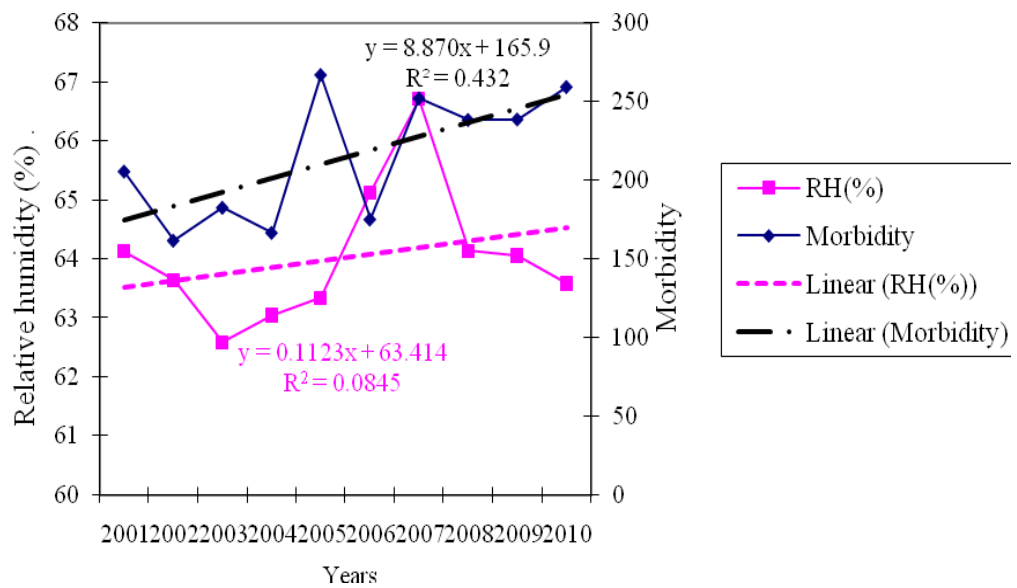


Figure 4. 11:Trends of annual relative humidity and malaria morbidity (2001-2010)

Both humidity and morbidity had positive trends. However it was noted that while humidity had an insignificantly positive trend, malaria had a significant one.

4.3.6 Seasonal Trends of Relative Humidity and Malaria Morbidity

When looking at the trends of monthly relative humidity, the overall trend showed a slight decrease as from January to December (Figure 4.12a). The months of April to August showed a sharp decline while there was a steady increase in the months of August to November. In general, there was a negative trend. The equation $y = -0.0294x + 64.223$ means that humidity decreased at the rate of -0.0294% per month as the year progressed towards the end. A coefficient of determination of ($R^2 = 0.0028$) means that a year was accountable for the 0.28% of the temporal variations observed within one year. The trend showed that malaria cases are higher during the first half of the year decreasing towards the end of the second half at the rate of -6.1612% per month in a year during the surveillance period ($y = 6.1612x + 254.82$). During the same period, a coefficient of determination of $R^2 = 0.5178$ implied that the period of twelve months every year within the surveillance period accounted for 51.78% of the temporal variations observed (Fig. 4.12).

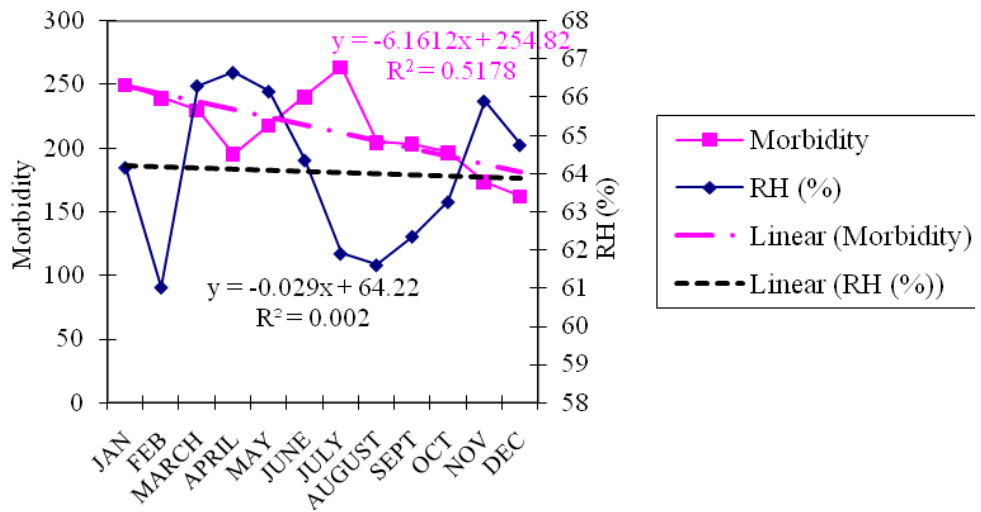


Figure 4. 12:Trends of mean monthly relative humidity and malaria morbidity (2001-2010)

Both relative humidity and malaria morbidity had negative trends within the years. However, while malaria had a significantly negative trend, relative humidity had an insignificant one.

4.4 Trends in Malaria Morbidity for Each Month (2001-2010)

In establishing the general trend of malaria morbidity for each month during the surveillance period, individual monthly data was regressed for the ten-year period. The results showed that there was a significant progressive increase by year in malaria morbidity in the months of May, July, September, October and November. This implied that, in May, each year, the number of malaria cases as compared to May the previous year had an increasing trend. This was also the case in the months of July, September, October and November (Table 4.3).

Table 4. 3:Trends in malaria morbidity for individual months (2001-2010)

Months	Relationship (r- value)	P-value
January	-0.156	0.668
February	0.296	0.406
March	0.537	0.109
April	0.304	0.393
May	0.737	0.015*
June	0.475	0.165
July	0.715	0.020*
August	0.556	0.095
September	0.653	0.040*
October	0.660	0.036*
November	0.629	0.051*
December	0.347	0.326

NB: P-value denoted by * showed there was a significant increase

4.5 Malaria Mortality

In establishing malaria mortality, data were captured for only three years (2008 – 2010) given that all the health facilities except sub-district hospital did not have wards (appendix VI). They only operated on the out-patient basis so the researcher could not follow up the mortality cases. The sub-district hospital itself had only been operating a ward facility for the three years mentioned (2008-2010). Therefore, the mortality situation could only be worked using the three year data that was available. For that reason, it was not easy to give a ten-year trend and this inhibited the comparisons.

4.5.1 Patterns of Malaria Mortality

Based on the means for the three year period, the result showed that there is no month without malaria mortality (Fig. 4.13a). The months of May / June and

November/ December registered higher cases than the others. From this pattern, it can again be seen that more of the cases occur during the first half of the year than during the second half. Majority of the cases occur in the months of May-June while October had the least number of cases. In comparing mortality to the total population, it was revealed that at least for every 1000, 1(0.01%) person dies of malaria every year (Table 4.4). However, this may not be very realistic given that mortality data were collected for only three years and not from all the health facilities in the study area.

Table 4. 4:: Mortality per thousand and percent (2008-2010)

Year	Population	T. Mortality	Per/1000	Percent
2008	107742	67	0.6219	0.06219
2009	108913	34	0.3122	0.03122
2010	111081	34	0.3122	0.03122

In relating morbidity with mortality the findings showed that there was a positive relationship between the two ($r = 0.235$). Whenever there was high morbidity there were high cases of mortality

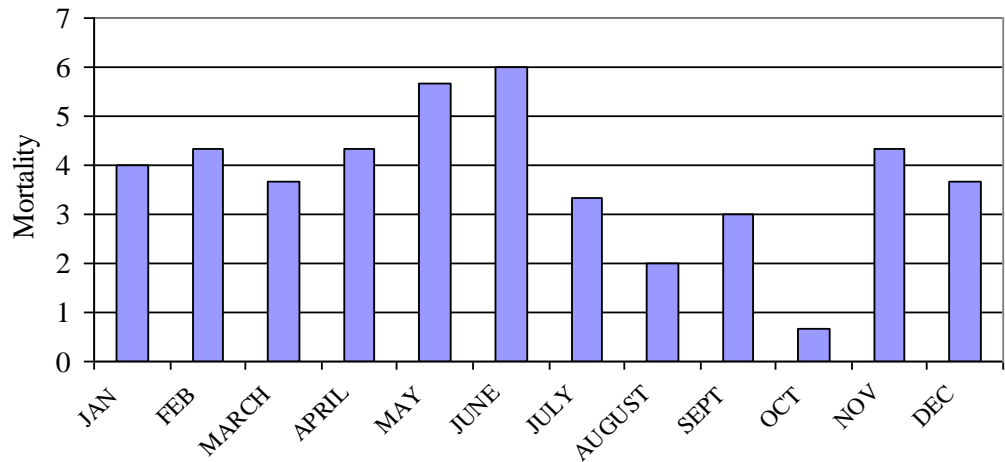


Figure 4. 13:Patterns of mean monthly malaria mortality (2008-2010)

4.5.2 Trends of Malaria Mortality

Mortality trend in a year were found to be decreasing at the rate of -0.16% per month towards the end of the year during the three year period (2008-2010). This period accounted for 15.28% of the decrease observed ($R^2 = 0.1528$). This was in conformity to the morbidity trend during each given year over the three-year period (Figure 4.14).

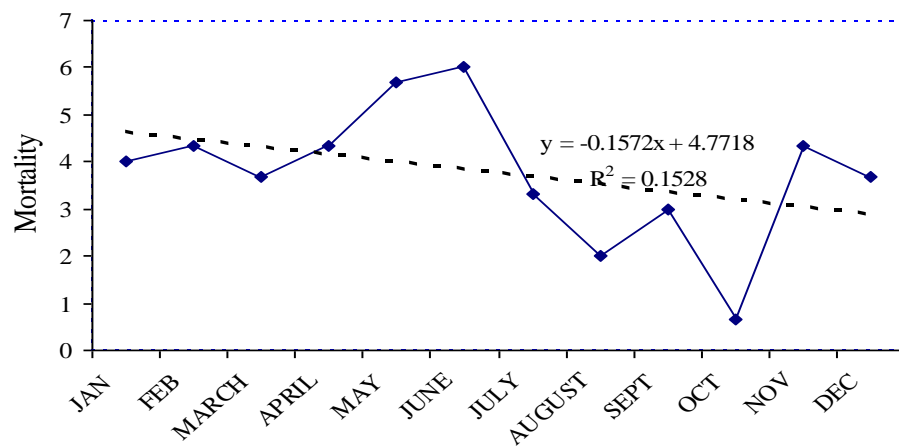


Figure 4. 14:Trends of mean monthly malaria mortality (2008-2010)

4.6 Relationship Between the Variability of the Selected Climatic Elements and Malaria Morbidity

Table 4.5, explains the relationships that were found to occur between malaria morbidity and the selected climatic elements during the surveillance period.

Table 4. 5:Relationships between annual malaria morbidity and the selected climatic elements (2001-2010)

	Morbidity
Rainfall	r = 0.289 p = 0.419
Temperature	r = 0.008 p = 0.983
Relative Humidity	r = 0.272 P = 0.447

Table 4.6, explains the relationships that were found to occur between malaria morbidity and the selected climatic elements during the months within the surveillance period.

Table 4. 6: Relationships between monthly malaria morbidity and the selected climatic elements (2001-2010)

	Morbidity
Rainfall	r = 0.654 p = 0.021
Temperature	r = 0.143 p = 0.600
Relative Humidity	r = 0.345 P = 0.271

4.6.1 Relationship Between Rainfall and Malaria Morbidity

Over the ten year surveillance period, the study established a general increase in the amount of rain and a general increase in malaria morbidity. However, a year with high rainfall had low morbidity and vice versa. Therefore, the overall relationship of annual rainfall to malaria morbidity was negative (r = -0.289,). This relationship was, however, not significant – P =0.419 (Table 4.5).

Monthly rainfall and malaria morbidity trend within the years was negatively correlated in the study area (r = -0.654), and the relationship was significant at P = 0.021. Months having high rainfall significantly had low malaria morbidity and vice versa (Table 4.6).

During the surveillance period and within the years, the study revealed a negative correlation between rainfall and malaria such that the two alternated in occurrences with malaria rising drastically soon after the rainy season while diminishing during the rains. The year 2005 had the lowest rainfall and this is

the year that had the highest malaria prevalence during the surveillance period. The year 2006 which registered the highest rainfall on the other hand registered the lowest malaria cases. This trend became consistent within the years such that the months that had high rainfall usually had low malaria cases. Although the fluctuation in malaria morbidity is not as high as that of rainfall, malaria cases always diminish during the peaks of rainfall while rising during the lows of rainfall. From these results, malaria cases are always high in Awendo in the months of June - July and in January. These are normally dry months. The cases are low in the months of April and November- December which are normally wet months.

According to IISD (2013), rainfall increases vector population by creating new breeding site. However, when it is too high, rainfall will wash away those breeding grounds and kill the mosquito larvae thereby reducing the transmission. Rainfall threshold for effective transmission is between 80mm and 150mm per month (Craig et al., 1999; MARA/ARMA, 1998; IISD, 2013). Rainfall in Awendo area rises from 173.96mm in the month of March to 272.99mm in April then falls to 204.28 in May. It again rises from 176.95mm in October to 206.35mm in November then falls to 157.45mm in December (Sonysugar Meteorology unpublished data). These are too high for conducive larval habitat and should explain the negative correlation between rainfall and malaria morbidity occurrences in Awendo. While studying malaria/climate relationship in India, Bhattacharya et al., (2006) observed a positive correlation between the rainfall and malaria morbidity while in Saurashtra and Kutch, they

observed a negative correlation. Given that in Awendo, the result has also given a negative correlation, it is obviously important to study the relationship between climate and malaria occurrences in space and time.

4.6.2 Relationship Between Temperature and Malaria Morbidity

During the ten-year surveillance period, the study established a general increase in temperature as well as in malaria morbidity. However, most years with high temperatures had low morbidity and vice versa. The overall relationship between temperature and mean malaria morbidity was negative ($r = -0.008$) but not significant ($P = 0.983$) (Table 4.5).

Relationship between mean monthly temperatures and monthly malaria morbidity in the ten-year period showed a negative correlation ($r = -0.143$) as can also be seen in (Table 4.6). Months with high temperatures had low morbidity while those with low morbidity had higher temperatures. In both cases, the trends were negative. According to IPCC (2006), rainfall influences temperature and humidity and as can be observed from this study, temperature rises from the month of January and peaks in March but drastically declines from April to June following the onset of rainfall in March. It begins to rise from the month of June to peak in October and again declines to December. Although this is also a factor of ITCZ, the influence of rainfall cannot be ignored. However, temperature remains optimal during this period hence little impact on malaria morbidity performance.

Both temperature and malaria morbidity had positive trends over the years ($R^2 = 0.0981$ and $R^2 = 0.4328$ respectively). Even though, all the years with high morbidity had low temperature and the two alternated in occurrence apart from the year 2005 when they were equally high. This was the year just before the elnino rains of 2006. It was, however, observed that like in the case of rainfall, temperature correlated negatively with malaria morbidity over the years. Within the years, both had negative trends and correlated negatively. The months of January and June for example, had low temperatures but high morbidity cases. The negative correlation can be explained from the point that temperature begins to rise long before the onset of rainfall. It continues during the rains but both diminish at the same time. Rainfall negatively influences the larval habitat by washing away the stagnant sunlit pools of water hence the negativity (IISD 2013). Campbell - Lendrum et al., (2003) observed the optimal temperature associated with incubation rates of the pathogen within vector to be $15^{\circ}\text{C} - 30^{\circ}\text{C}$. Temperature is very crucial in determining the proliferation rates of mosquitoes such that the lowest for *Plasmodium falciparum* is 18°C while for *Plasmodium vivax* is 15°C (Ting & Ming 2005). As the temperature decreases or increases below and above the optimum, so does the development of the malaria parasites which is 26 days at 20°C and only 13 days at 25°C (Ting & Ming, 2005). Awendo area had a mean temperature of 21.93°C throughout the year over the ten – year period. This implies that the proliferation rates for Awendo are constantly high thereby providing constant transmission windows.

4.6.3 Relationship Between Relative Humidity and Malaria Morbidity

During the ten year period, this study found that there was a general increase in relative humidity with an increase in malaria morbidity. Most of the years with high relative humidity equally had high morbidity. The overall relationship between percentage relative humidity and malaria morbidity was positive ($r = 0.272$) but not significant ($P = 0.447$) (Table 4.5).

During the twelve months of the surveillance period, this study established that there was a general decrease in relative humidity as the months advanced into a year with a decrease in malaria morbidity. The overall relationship between monthly percentage relative humidity and malaria morbidity was negative ($r = -0.345$) but not significant ($P = 0.271$) (Table 4.6).

Annual humidity trends indicated an increase over the ten-year period ($R^2 = 0.0845$). This conforms to the increasing trends of rainfall and malaria morbidity over the same period. Mean monthly pattern over the ten-year period divided the year into two seasons of March – June and September - January. These very closely linked with the rainfall seasons. Relative humidity correlated positively with malaria morbidity over the years. The trend during a year was found to be decreasing ($R^2 = 0.0028$) and this also conformed to the decreasing trends of malaria morbidity. The overall correlation within the years was negative ($r = 0.345$). This was due to the fact that relative humidity closely followed the annual patterns and trends of rainfall which negatively impacted on it. According to Bhattacharya et

al., (2006), a relative humidity below 55% and above 80% shortens the lifespan of the mosquito so much that the scope of transmission greatly diminishes. This means that Awendo area with a mean relative humidity of 64.65% over the ten-year period would remain persistently conducive for mosquito longevity and subsequently an increased scope of transmission. This answers the question of persistent presence of malaria in the area since there is no month with less than 62% and above 67 %.

4.7 Relating Morbidity in the Individual Years to the Selected Climatic Elements

A correlation analysis done in establishing the relationship in malaria morbidity to rainfall patterns showed that there was a significant relationship in the year 2003 ($r = -0.834$, $P = 0.001$) and year 2004 ($r = -0.654$, $P = 0.021$). In these years, an increase in rainfall resulted to a decrease in malaria morbidity. When a correlation analysis was done to establish the relationship in malaria morbidity to temperature patterns, the findings showed that there was no significant relationship in malaria morbidity to temperature in any year.

Relationship in malaria morbidity to Relative humidity patterns in each individual year however, showed that there was a significant relationship in the year 2001 ($r = 0.617$, $P = 0.033$). In this year there was an increase in malaria morbidity with an increase in relative humidity. See table 4.7. From these observations, it can be said that rainfall is chief determinant of the variability

observed in malaria occurrences in Awendo area as all the other elements do not show any significant correlation with malaria except rainfall.

Table 4. 7:Relationship between malaria morbidity and the selected climatic elements within individual years

		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Rainfall	r-value	-0.257	-0.374	-0.834	-0.654	-0.244	-0.340	-0.420	0.196	-0.508	-0.228
	P-value	0.419	0.232	0.001*	0.021*	0.444	0.279	0.174	0.540	0.092	0.476
Temp	r-value	-0.101	-0.155	-0.035	-0.226	-0.062	-0.086	-0.268	-0.521	0.123	-0.316
	P-value	0.754	0.630	0.914	0.480	0.849	0.791	0.400	0.082	0.704	0.317
RH (%)	r-value	0.617	-0.123	-0.309	-0.465	-0.141	-0.326	-0.275	0.147	-0.114	0.342
	P-value	0.033*	0.704	0.326	0.128	0.663	0.301	0.388	0.647	0.724	0.277

NB: * significant difference at $P \leq 0.05$. r – values (–) indicate a negative relationship.

Malaria mortality trend in relation to climatic conditions were similarly evaluated and the result noted for the three years (2008 - 2010). Malaria mortality was not significantly related to any of the climatic conditions in these years (Table 4.8).

Table 4. 8: Malaria mortality and climatic elements 2008-2010

Climatic element	r/P value	Year 2008	Year 2009	Year 2010
Rainfall (mm)	r-value	0.037	0.001	0.146
	P-value	0.908	0.997	0.650
Temp. (°C)	r-value	0.012	0.460	0.456
	P-value	0.971	0.132	0.136
RH (%)	r-value	0.197	0.032	0.309
	P-value	0.539	0.920	0.329

4.8 Temperature, Rainfall and Relative Humidity

It was noticed that temperature rises in the months of March to April then declines steadily to the month of June. Rainfall and relative humidity follow immediately climaxing in April. All the elements diminish between June and July. In the next season, temperature climaxes in October while rainfall and humidity follow in November. From the above observations, it can be concluded that temperature triggers relative humidity and rainfall which then trigger malaria prevalence. However, IPCC (2006) observes that rainfall impacts on both temperature and humidity hence the immediate lowering of temperature. Given that the epidemicity follows the patterns of these elements and although they constantly offer transmission windows, it can confidently be claimed that the three climate indicators especially rainfall have an effect on malaria prevalence in Awendo Division.

4.9 Mortality

From the analysis, it was observed that there was no month that passed without mortality cases. The months of May – June and November – December experienced higher cases in a year. From the three- year monthly average pattern, it was observed that most of the cases occur in the first half of the year. On average, it was observed that the month of October had the least number of cases.

4.10 Hypotheses Testing

The hypotheses were tested using regression and the Pearson's product moment correlation co-efficient techniques. By regression, rainfall ($R^2 = 0.0417$), temperature ($R^2 = 0.0981$) and relative humidity ($R^2 = 0.0845$), revealed positive trends during the period (2001-2010) but they were insignificant. Malaria morbidity had a significantly positive trend ($R^2 = 0.4328$). These selected climatic elements also showed variations over the years and each tended to divide a year into two seasons within the years.

From the above observations, the researcher rejected the null hypothesis, H_0 , "There were no significant trends in the selected climatic elements during the surveillance period." and adopted the alternative, H_1 , "There were insignificant trends in the selected climatic elements during the surveillance period." He also rejected the null hypothesis, H_0 , "There were no significant trends in malaria morbidity and mortality during the surveillance period." and instead adopted the alternative, H_1 , "There were

significant trends in malaria morbidity and mortality in the study area during the surveillance period.”

The relationship between monthly rainfall and monthly malaria morbidity was significantly negative ($r = - 0.654$, $P=0.021$). Annual rainfall, temperature and malaria morbidity also showed a negative correlation during the study period. Similarly, monthly rainfall and temperature had a negative correlation with monthly malaria morbidity. During the ten years, relative humidity and malaria morbidity had positive correlation ($r = 0.272$). Monthly, the relationship between the two was negative ($r = - 0.345$). From these observations, the researcher rejected the null hypothesis, H_0 , “There is no significant co relation between the variation of the selected climatic elements and malaria morbidity and mortality in Awendo Division.” and instead adopted the alternative, H_1 , “There is a significant co relation between the variation of selected climatic elements and malaria morbidity and mortality in Awendo division”.

IISD 2013 argues that the potential impact of climate on malaria remains uncertain due to the fact that it is difficult to determine which factor is most responsible for influencing the distribution and intensity of the disease. However, the other factors constant, the seasonality of malaria in Awendo Division could be a factor of rainfall given that while all the other climatic factors remain optimal throughout the year, it is rainfall that significantly fluctuates.

CHAPTER 5: SUMMERY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

This study investigated the relationship between malaria prevalence and the variability of selected climatic elements in Awendo Division, Rongo District, Migori County, Kenya. Data were obtained through the desktop review from Sonysugar Metrological station which provided the historical records for the selected climatic elements and the ten health facilities which provided data on malaria morbidity and mortality. Data were then entered into the micro-excel computer program and analyzed using the SPSS computer program.

The results showed that all the selected climatic elements varied over the years. Malaria morbidity significantly varied over the same period. None of them indicated any consistent pattern during that period. All the variables tended to divide a year into two seasons during the surveillance period with the temperature reaching its peaks between February and March and in October while at its lowest between June and July. Rainfall on the other hand peaks in April and November, just a month after the peaks of temperature. Humidity peaks together with rainfall in the same months. Malaria morbidity follows by peaking in June – July and January - times when temperature, rainfall and humidity are at their lowest.

The study established that both malaria morbidity and all the selected climatic elements had positive trends over the years but only malaria morbidity had a significant trend. This is an indication that malaria cases will continue to rise as the years advance into the future if no proper mitigation measures are put in place. On the other hand, all the variables had negative trends within the years except rainfall. Of all these negative trends, only malaria morbidity was significantly negative. The months of May, July, September, October and November had significantly increasing trends of malaria morbidity during the surveillance period. It was further established by this study that there were negative correlations between malaria morbidity and all the selected climatic elements over and within the years except a positive correlation with relative humidity over the years.

5.2 Conclusion

Based on the above results of this study, both the selected climatic elements and malaria morbidity did not show clear patterns over the years while they consistently divided the years into two seasons. They also showed insignificantly positive trends during the ten-year period. Malaria, on the other hand, had a significantly positive trend during the same period. Although all the selected climatic elements correlated negatively with malaria morbidity, they constantly offer optimal malaria transmission windows throughout the year except rainfall which drops below the optimal ranges. Rainfall significantly correlated negatively with malaria

morbidity and should, therefore, be blamed for the epidemic characteristics of malaria occurrences. The Awendo results revealed that malaria morbidity escalates about one month after the peak of rainfall. That is to say, alternating wet and dry periods create a very conducive atmosphere for malaria prevalence. From the observed results, it can further be concluded that malaria is both endemic and epidemic in Awendo Division as there is no month that goes without malaria completely during a year (endemicity) while the cases of malaria increase twice a year in the months of June –July and in January (epidemicity).

5.3 Recommendations

Adaptive strategies should be in place throughout the year. Members of the community should be encouraged to drain the pools of water that remain soon after the rains and to clear their compounds of the unnecessary vegetation that has been promoted by rainfall so as to discourage the availability of the larval habitats. They should avoid planting crops like maize too close to residential houses as this will also increase mosquito breeding grounds during and soon after the rains. The medics and meteorologists should constantly hold consultative forums in order to predict and be able to control epidemics. There is need to educate and counsel the public to seek medical attention before and whenever they suspect attacks. There should be awareness campaigns to help alert the population of when to expect malaria escalations especially following weather events conducive for malaria transmission.

To contain the endemicity, the health facilities should always be well-equipped with both the drugs and qualified staff. Particular attention should be paid to the months of May, July, September, October and November. These are months that showed progressive malaria increase within each year of the surveillance period. Mobile clinics should also be introduced in the area. Indoor residual spray should be encouraged alongside provision of ITNs. These have been done in the past but without proper consistency and with very long time lag which may encourage drug and insecticide resistance. Record keeping in the health facilities should also be improved as to support effective monitoring. Members of the community should be empowered to self administer antimalarials on minor cases. The fact that the selected climatic elements did not show significance in their positive indications clearly tells that there are other factors promoting the significance in the positive indication of malaria morbidity and these should be investigated.

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APPENDIX I: MALARIA MORBIDITY IN AWENDO DIVISION (2001-2010)

Year	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Mean Morbidity
2001	2825	2415	2350	1850	1910	2691	1913	1785	1561	1705	1525	2152	2057
2002	2495	1475	1330	1665	2180	1628	2150	1395	1293	1315	1073	1421	1619
2003	2945	2408	1980	1295	1378	1448	2631	1950	1851	1610	1121	1315	1828
2004	1680	1872	2038	1557	1575	2202	2675	1557	1210	1390	1102	1155	1669
2005	4590	3779	3075	3385	2322	3412	2632	2348	2047	1712	1421	1312	2670
2006	1885	1675	2225	1450	1982	1814	2971	1111	1789	1617	1255	1265	1753
2007	1749	2730	2324	1947	2465	2415	2861	3001	3230	2604	3225	1699	2521
2008	1273	2334	2198	2063	2289	2423	3152	2726	3004	3084	2225	1841	2384
2009	2248	2318	2367	1905	2481	2811	2691	2161	2055	2795	2586	2234	2388
2010	3308	2940	3086	2425	3195	3208	2681	2439	2320	1834	1822	1860	2593
Mean	2500	2395	2297	1954	2178	2405	2636	2047	2036	1967	1736	1625	2148

Source: Awendo Divisional Health Facilities (2001-2010)

APPENDIX II: RALATIVE HUMIDITY IN % (2001-2010)

Year	Jan	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
2001	69	64	62.5	66	65	66	62.5	60.5	64	62	63	65	64.125
2002	65	50.15	76.5	67.5	67	63.5	55.5	60	59	63	69	67.5	63.6375
2003	59.5	62.5	63.5	65.5	66	65	63	64	59.5	60	60.5	62	62.58333
2004	66	62	65.5	56.5	64.5	62.5	58	60	67	60	70	64.5	63.04167
2005	62.5	54	69	63.5	68	64	66	66	61	60	62.5	63.5	63.33333
2006	59	65.5	69	71	64.5	64.5	61	59	59	63.5	75	70.5	65.125
2007	65	64.5	67.5	67.5	68	68.5	68.5	65	66.5	70.5	62	67	66.70833
2008	60	65	63	76	64	63.5	63.5	60.5	65.5	65.05	66	57.5	64.12917
2009	67.1	61.5	63.5	68	68.55	61.5	59	59	62	66.5	66.5	65.5	64.05417
2010	68.45	61	63	65	66	64.5	62	62	60	62	64.5	64.5	63.57917
Mean	64.155	61.015	66.3	66.65	66.155	64.35	61.9	61.6	62.35	63.255	65.9	64.75	64.03167

Source: SONY Metrological Station (2001-2010).

APPENDIX III: RAINFALL IN MM (2001-2010)

Year	Jan	Feb.	March	April	May	June	July	Aug	Sept.	Oct	Nov.	Dec.	Totals
2001	99	93.5	150.8	278.5	233.8	142.3	60.5	64.1	180.4	132.1	153.8	141.2	1730
2002	54.5	52.5	218.8	403.7	168	33	62.9	60.3	84.2	245.2	380.4	154.5	1918
2003	52.8	71	174	167.7	140.1	133.8	57	140.3	155.6	186.5	159.3	189	1627.1
2004	110	162.5	92.5	316	166.7	56.3	56.3	108.3	191.5	174.5	267.8	135.3	1837.7
2005	87.3	50	261	149	181	71.9	56.5	170.3	131	199.5	174.3	47.7	1579.5
2006	108.6	187	206	315.2	330.4	77.3	42.9	57.5	136.1	77	267.7	351	2156.7
2007	260.3	77.4	140.9	178.5	176.6	196.6	89.1	159.3	130.4	320.5	106.8	152	1988.4
2008	73.8	108	212.5	268.2	125.9	57.2	114.6	199.2	149.5	139.5	134.4	45	1627.8
2009	113.4	78	97.4	386.9	303.7	89	51.7	152.1	179.5	122.2	222.2	221.7	2017.8
2010	106.6	96.5	185.7	266.2	216.6	95.1	66.6	104.6	131	172.5	196.8	137.1	1775.3
mean	106.63	97.64	173.96	272.99	204.28	95.25	65.81	121.6	146.92	176.95	206.35	157.45	1825.83

Source: SONY Metrological Station (2001-2010)

APPENDIX IV: TEMPERATURE IN °C (2001-2010)

Year	Jan	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
2001	20.55	21.75	21.75	21.2	21.15	20.2	20.15	20.8	20.65	21.7	21	21.5	21.03333
2002	21.6	23.25	22.15	21.35	21.85	21.3	22.7	22.15	22.7	22.1	21.8	21.65	22.05
2003	22.5	21.85	23.1	22.25	22.65	21.7	21.25	21.5	22.5	22.65	21.85	21.55	22.1125
2004	22	22.55	22.85	21.15	21.85	21.45	21.1	21.7	21.8	22.6	21.3	22.85	21.93333
2005	22.85	23.15	22.65	23.2	21.5	20.25	21.75	21.6	22.4	22.95	22.75	23.15	22.35
2006	23.3	23.6	22.65	21.95	22.05	21.65	21.35	22.1	21.9	22.3	21.85	21.7	22.2
2007	21.45	21.7	22.65	22.1	22.3	20.7	21.05	21.2	21.7	21.65	21.45	21.75	21.64167
2008	22.2	22.15	22.75	22	22.15	21.3	21.35	21.5	22.05	21.95	21.95	22.55	21.99167
2009	22.7	22.45	23.55	19.85	21.85	21.3	21.75	22.7	23.1	23.35	21.65	22.3	22.2125
2010	22.05	22.65	22.75	22	19.85	21.15	21.15	21.65	21.95	22.25	22.25	21.95	21.80417
Mean	22.12	22.51	22.685	21.705	21.72	21.1	21.36	21.69	22.075	22.35	21.785	22.095	21.93292

Source: SONY Metrological Station (2001-2010)

APENDIX V: MARIWA HEALTH CENTRE MALARIA MORBIDITY

Year	Jan	Feb	March	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Mean
2001	256	224	153	75	90	128	138	117	63	62	99	132	128
2002	190	54	44	76	124	129	222	98	87	63	71	59	101
2003	214	151	160	82	85	90	148	159	104	97	63	84	112
2004	120	130	129	114	55	91	130	77	45	53	56	87	91
2005	270	220	180	151	126	93	61	78	67	45	44	49	115
2006	75	60	97	47	35	54	62	44	36	12	8	26	46
2007	19	32	31	23	26	20	15	5	11	22	22	5	19
2008	10	24	32	25	49	52	63	28	45	113	110	50	50
2009	73	96	45	87	90	139	89	26	60	79	74	100	80
2010	153	105	117	81	151	116	84	98	90	33	37	38	92
Mean	138	110	99	76	83	91	101	73	61	58	58	63	84

Source: Mariwa Health Centre

APPENDIX VI: MALARIA MORTALITY DATA

Yr/Mnt	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2008	7	6	7	7	9	10	4	3	7	1	3	3
2009	3	4	4	4	2	6	2	1	1	0	3	4
2010	2	3	0	2	6	2	4	2	1	1	7	4
Mean	4	4	4	4	5	6	3	2	3	1	4	4

Source: Awendo Sub-District Hospital (2008-2010)