ASSESSMENT OF THE INFLUENCE OF ENVIRONMENTAL AND ANTHROPOGENIC FACTORS ON MALARIA TRANSMISSION IN NGOMA DISTRICT, RWANDA

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A THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY OF THE OPEN UNIVERSITY OF TANZANIA

2020

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Open University of Tanzania, a thesis titled: **"Assessment of the Influence of Environmental and Anthropogenic Factors on Malaria Transmission in Ngoma District, Rwanda"** in fulfillment of the requirements for the degree of Doctor of Philosophy (PhD) of the Open University of Tanzania.

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DECLARATION

I, **James Kant Kamuhanda,** do hereby declare that, the work presented in this thesis is my original product. It has never been nor will it be presented to any other University or Institution for the same or similar award. Where other people's works have been reviewed due references have been provided. It is in this regard that I declare this work as originally mine and is presented in fulfillment of the requirement for the Degree of Doctor of Philosophy of the Open University of Tanzania.

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Signature

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Date

DEDICATION

I dedicate this work to almighty God and my family and friends who supported me during this course. Especially, I dedicate this work to father Isidore Kalinijabo, Mr. Edward M. Kabare Mr. Kalimba John and Mrs Kamashamba Claudine for their contribution to my studies since I was in primary school up to this level. Thank you my parents I dedicate to my lovely wife Joy Mutoni and my daughters Olga Kamuhanda Atete and Ornella Kamuhanda Teta for their support and patience during this tiresome journey we walked together with hunger but they kept encouraging me to continue the journey. Thank you my family.

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ABSTRACT

Malaria continues to remain a major health problem in Ngoma district and Rwanda at large despite of various measures that have been geared towards treatment and control of the disease. The present study was aimed at determining the influence of environmental and anthropogenic factors on malaria transmission in Ngoma district, Rwanda. A cross-section survey employing Questionnaires, observation and interviews were used to collect primary data while secondary data on seasonality of malaria transmission were collected from published and unpublished hospital reports and nearby weather station. The results showed that hospital admission rates for malaria in adults and children was highest in 2014 at 51.0% and 64.6%, respectively. Hospital admission rates in adults was lowest in 2016 at 18.5% and lowest in children in 2017 at 13.2%. There was a positive relationship between malaria admission rates and rainfall and temperature ($p = 0.001$). The most appreciated night-time outdoor activities were evening parties (Chi-squared value 184.068, $p = 0.000$) where it is ranked by 3.57). The main reason for not owning the LLINs was that the LLINs were not available as noted by 26.0% ($p = 0.000$). Irrigation for Rice cultivation and slow flowing fresh water from the extensive anastomosis of tributaries of River Kagera were the most dominant malaria transmission factor (66.1%, $p = 0.000$). Malaria transmission was significantly associated with non-windows screening (92.9%, $p = 0.000$). General sanitation is effective in reducing malaria transmission (55.9%). Livestock keeping had a significant impact on malaria transmission increase (38.6%) (Chi-square: 81.506, Std. Dev = 0.489 and $p = 0.000$) due to increasing mosquitoes density. This study validates anthropogenic factors notably rice farming, poor housing, inappropriate use of bed nets, night parties, irrigation agriculture and improper waste management as the main malaria causing factors in Ngoma district in Rwanda.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACT	Artemisinin-based Combination Treatment
An	Anopheles
CHWs	Community Health Workers
FGD	Focused Group Discussion
HC	Health Centre
HP	Health Post
IRS	Indoor Residual Spraying
ITNs	Insecticide Treated Nets
LLINs	Long-Lasting Insecticide-Treated Nets
MOH	Ministry of Health
PE	Participatory Epidemiology
HMIS	Health Management Information System
RH	Referral Hospital
SSA	Sub-Saharan Africa
SEM	Standard Error of the Mean
USD	United States of America Dollars
WHO	World Health Organisation

CHAPTER ONE

INTRODUCTION

1.1 General Introduction

Malaria affects many people in the world each year (Lai *et al.,* 2017), and millions of deaths occur every year (Kovats *et al.,* 2016). Despite considerable national and international control efforts, malaria is still the major human health threat. Malaria is a now a major disease in Africa (Konji *et al.,* 2015). WHO (2003) estimates that between 300 to 500 million people are affected by malaria each year worldwide, with one to three million deaths mainly occurring in children under five years of age. According to Wesolowski *et al.,* (2015), malaria-endemic areas are found in 108 countries populated by approximately three billion people representing over 40% of the world population. *Plasmodium vivax* and *P. falciparum* are accountable for 80-95% of all malaria cases worldwide.

Malaria is endemic in 87 countries worldwide, 43 of them being African countries south of the Sahara where about 500 million cases of malaria are observed yearly with deaths up to 2.7 million (Wesolowski *et al.,* 2015). Among the contributing reasons for the increasing malaria burden is the appearance of drug-resistant of malaria parasites and the presence of mosquitoes that are resistant to pesticides. In addition, ecological factors and increased population inclusive environmental factors are also some of the reasons (Saddler *et al.,* 2015). Other factors include urbanization, imposed migration and poor environmental hygiene are also some of the major reasons for the appearance and recurrence of malaria in developing countries (Polson *et al.,* 2012).

According to Afrane *et al.,* (2011), malaria is partly linked with land use patterns since they cause changes in micro-environment of malaria vector which in turn alters malaria transmission patterns. Again agriculture and urbanization are reasons for complexity of malaria transmission in Africa (Wielgosz *et al.,* 2012a).

In Rwanda, malaria transmission cannot be attributed to one factor as there are many factors that play a role in the transmission and reoccurrence of malaria epidemics. Climate is considered to be a major determinant factor. Temperature, rainfall and humidity affect breeding and survival of vector mosquitoes and development of malaria parasites within the mosquitoes (Bizimana, 2014b). Apart from climatic factors, human activities such as irrigation (agricultural) and land use patterns, housing construction, net bed use are also considered as among of the major factors responsible for malaria transmission (Gryseels *et al.,* 2015). The National Malaria Control Programme has an ambitious goal of making Rwanda malaria free. This goal aims at decreasing malaria morbidity to pre-elimination levels of less than 5% malaria positivity by 2018 (Prudêncio *et al.,* 2012).

In Rwanda, severe malaria is due to the species of malaria known as *Plasmodium falciparum.* Other species found in Rwanda include *P. malariae, P. Ovale* and *P. vivax* (Bi *et al.,* 2013). Malaria is the leading public health problem in Rwanda (Asingizwe *et al.,* 2015). Most areas of the country have reported outbreaks of malaria (Zemene *et al.,* 2018). Intense malaria transmission occur in eastern province of Rwanda. Other areas have intense transmission but are mainly seasonal transmission (Loevinsohn, 1994).

As in most areas of Africa, *Anopheles gambiae* complex is the major malaria vector species. In Rwanda, it is the fraternal species *An. gambiae* sensu stricto and *An. arabiensis* which are the most important (Afrane *et al.,* 2011). Despite several years of malaria research and related control programs, knowledge about climatic factors (rainfall and temperature), land use, irrigation and their effect on malaria transmission is still inadequate in Ngoma district where malaria transmission is still intense.

A theoretical model based on climate (rainfall and temperature) shows the eastern province as an area with endemic and perennial malaria (Henninger, 2013). *P. falciparum* is the predominant malaria parasite in eastern province, accounting for > 90% of all cases, with a very wide range of infections among all ages (Githeko et *et al.,* 2000). However, there is little information on environmental factors and their impacts on malaria transmission in eastern province of Rwanda.

The current interventions for malaria in Rwanda are mainly based on effective treatment and the reduction of human-vector contact through insecticide treated bed nets and long lasting treated bed nets, prevention of malaria in pregnancy, and prevention of malaria epidemics. Malaria intervention campaigns sometimes involve the use of laws to enforce intervention measures (Karema *et al.,* 2013). Despite these efforts, malaria shows little signs of reduction and this has been attributed to many factors including biological factors, environmental factors, and inadequate technology and lack of awareness for the community. In general, the intensity of transmission depends on factors related to the parasite, the vector, the human host, and the environment.

The objective of the present study was the assessment of the influence of environmental and anthropogenic factors on malaria transmission in Ngoma district. To achieve this, a cross-sectional study was carried out to establish the epidemiological trends of malaria transmission in Ngoma district, to assess the anthropogenic factors that influence malaria mosquito abundance and the effect of environmental factors and human behaviour that influence malaria transmission.

1.2 Statement of the Research Problem

Malaria in Rwanda showed increase in prevalence from 13% in 2012 to 18.2% in 2015 among children under-five years of age (RBC, 2016). The current interventions for malaria in Rwanda are mainly based on: effective treatment and the reduction of human-vector contact through insecticide treated bed nets and long lasting treated bed nets, prevention of malaria in pregnancy and prevention of malaria epidemics. Improved medical service, free diagnosis and treatment, changes in the morbidity of the disease (Karema *et al.,* 2013). Despite these efforts, malaria shows little sign of reduction as 16,521 cases per months were reported out of 336,928 total population of Ngoma district (5% of the total population of the district, RBC, 2016). Lack of knowledge as regards the influence of risk factors such as rice growing and irrigation, human-malaria vector interaction, parasite and climatic factors on malaria transmission, exacerbates the problem. Climate is known to be one of the major factors for malaria transmission in Rwanda, but the specific climatic factors are not well known.

In addition, environmental and anthropogenic factors influencing malaria transmission in Ngoma have not been extensively studied. It is therefore, important to identify environmental and anthropogenic factors influencing malaria transmission in Ngoma district. Such information is important for the designing of appropriate control strategies in the district and the country in general.

1.3 Objectives of the Study

1.3.1 General Objective

The general objective of the study was the assessment of the influence of environmental and anthropogenic factors on malaria transmission in Ngoma district, Rwanda.

1.3.2 Specific Objectives

(i) To determine the status of malaria transmission in the study area

(ii) To identify the environmental factors affecting malaria transmission

(iii) To assess anthropogenic behaviour activities influencing malaria transmission in the study area

(iv) To suggest intervention strategy for control of malaria transmission in the study area.

1.4 Significance of the Study

The study assessed the influence of environmental and anthropogenic factors on malaria transmission in Ngoma district, Rwanda. This knowledge provide information which may be used in the formulation of effective and appropriate control strategies to reduce malaria transmission in the district. Understanding the local epidemiological factors affecting malaria transmission in Ngoma are of great importance to health planners, policy makers and the public in general in terms of the formulation of an integrated control strategies for malaria control in the study area. This is categorically critical as the future plans are to eliminate the malaria transmissions, and these should be linked with understanding of the dynamics of malaria transmission and malarial risk factors, which ranges from environmental to non-environmental factors. The results of the present study form the basis for improvement of the interventions to reduce malaria in the study area.

1.5 Research Hypotheses

(i) The status of malaria in the study area is high and seasonal

(ii) The most environmental factors that affect malaria transmission in the study area are nature of housing and rice farming activities.

(iii) Human behaviour activities that affect malaria transmission in the study area are bed net use, outdoor activities and livestock keeping.

(iv) Epidemiological intervention strategy for malaria transmission in the study area based on vector and human interaction is the best malaria control in the study area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the related review of the research entitled “the influence of environmental and anthropogenic factors on malaria transmission in Ngoma district, Rwanda”. This part focuses on the review of relating topic and the background of studies done in different countries and places.

2.2 Climatic Factors

Scientific evidence suggests that malaria varies seasonally in endemic areas. Malaria is probably the vector-borne disease most sensitive to long-term climate change (Badu *et al.,* 2013). Malaria thus provides several illustrative examples (based on historical studies) of the link between infectious disease and climate change (de Souza *et al.,* 2010). Patz *et al.,* (2008) studied the effect of soil moisture to determine the effects of weather on malaria transmission (Asareet *et al.,* 2016). Compared to low weather data, hydro-logical modelling has several potential advantages for determining mosquito-breeding sites.

The results showed that high soil moisture conditions and vector breeding habitats can remain long after precipitation events, depending on factors such as watershed, run-off and evapotranspiration rate (Badu *et al.,* 2013). For *An. gambiae*, the soil moisture model predicted up to 45% and 56% of the variability of human biting rate and entomological inoculation rate, respectively (Fornace *et al.,* 2016).

The link between malaria and extreme climatic events has long been the subject of study in the Indian subcontinent (Patz *et al.,* 2008). Early in the twentieth century, the Punjab region experienced periodic epidemics of malaria (Kovats *et al.,* 2016). Irrigated by five rivers, this geographical plains region borders the Thar Desert. Excessive monsoon rain- fall and resultant high humidity were clearly identified as major factors in the occurrence of epidemics through enhancement of both the breeding and life favours (Manuscript and Proximity, 2011).

Most observed associations between climate and water-borne diseases are based on indirect evidence of seasonal variations. However, several studies provide quantitative evidence of water-borne diseases' associations to climatic factors such as precipitation and air temperature (Gubler *et al.,* 2001). Better understanding of the adaptive capacity of individuals affected by health outcomes of climate change is needed, as well as the capacity for populations to prepare a response to projected health outcomes of climate change (Kweka *et al.,* 2016). In Rwanda the mean temperature is 20^0C and the mean rainfall ranges from 900 to1400 mm per annum.

2.2.1 Temperature

Climatic factors greatly influence the pattern and level of malaria transmission in Rwanda, in Africa and the world at large. The most important climatic factors that directly affect malaria transmission are temperature, rainfall and humidity (Caminade *et al.,* 2014). Temperatures that range from minimum to maximum greatly affect the development of the malaria parasite and its mosquito vector, which determines malaria transmission (de Souza *et al.,* 2010). Temperature affects the life cycle of the malaria parasite. The time required for the parasite to complete its development in the gut of the mosquito is about 10 days, but it can be shorter or longer depending on the temperature. As the temperature decreases, the number of days necessary to complete the development increases for a given *Plasmodium* species. *P. vivax* and *P. Falciparum* have the shortest development cycles and are therefore more common than *P. ovale* and *P. malariae* (Iwmi, 2003).

The maximum temperature for parasite development is 40°C. Below 18°C, the life cycle of *P. falciparum* in the mosquito body is limited. The minimum temperatures are between 14 and 19°C, with *P. vivax* surviving at lower temperatures than *P.falciparum* (Ebi *et al.,* 2006). Malaria transmission in areas colder than 18°C can sometimes occur because the *Anopheles* often live in houses, which tend to be warmer than the outside temperature. Mosquitoes grow more quickly at higher temperatures. Higher temperatures also increase the number of blood meals taken and the number of eggs laid by the mosquitoes, which increases the number of mosquitoes in a given area hence increasing malaria (Ebi *et al.,* 2006). Mosquito body functioning depends on temperature hence any change in temperature alter mosquito body functioning directly (Afrane *et al.,* 2011).

According to meteorological data from Ngoma district weather station, in Rwanda the annual mean temperature is around 20^0C. Ngoma has four seasons of which two are rainy and other two are dry. A short rainy season extends from October to December, and a short dry season runs from January to February, and a long rainy season from mid-February to mid-May and a long dry season from mid-May to early October. Generally, the dry season begins earlier and ends later compared to other regions of the country. Temperature affects the life cycle of the malaria vectors as the minimum temperature ranges between 14^0C and 19^0C. Rainfall also affects malaria vectors life cycle in both negative and positive aspects, where it can flush away mosquito larvae where it rained heavily (An, 2011).

2.2.2 Rainfall and Precipitation

Rainfall can flush away breeding habitats temporarily, but mosquitoes start breeding as soon as the heavy rain declines. In most cases, flushing has a bigger impact on vector breeding habitats in the highlands and hilly areas than in the lowland plains. Not all water collections are suitable for the mosquito life cycle. In Rwanda, rain water collections and monthly precipitation data from meteorological stations are the most important breeding grounds, as the anopheles mosquitoes prefer to breed in fresh water collections created after the rainy season. Such water bodies may be clear or muddy but they are not polluted (Asingizwe *et al.,* 2015).

There are also places where less rainfall and drought can favour mosquito breeding and malaria transmission. Such places are usually covered by vegetation throughout the year and where streams and rivers often flow rapidly. When the rains fail or are delayed, the flow of streams is interrupted and pooling occurs along the stream. Pooling creates a favourable environment for mosquito breeding. Malaria vectors mainly breed in stagnant water collections, rarely in slightly moving waters and never in rapidly flowing rivers and streams (Chirebvu *et al.,* 2016). In drier areas, rainfall can also affect malaria transmission indirectly through its effect on humidity. Vegetation cover increases after rainfall, which in turn increases the relative humidity of the environment. The effect of humidity on malaria transmission is high (Van Geertruyden *et al.,* 2005*)*.

2.2.3 Relative Humidity

Relative humidity refers to the amount of moisture in the air expressed as a percentage Zero (0%) humidity would mean the air is completely free of moisture and 100% humidity would mean the air is completely saturated with moisture. Relative humidity affects malaria transmission through its effect on the activity and survival of mosquitoes (Van Geertruyden *et al.,* 2005). Mosquitoes survive better under conditions of high humidity (Ebi *et al.,* 2006). They also become more active when humidity rises. This is why they are more active and prefer feeding during the night. The relative humidity of the environment is higher at night and where the average monthly relative humidity is below 60%, it is believed that the life of the mosquito is so short that very little or no malaria transmission is possible (Patz *et al.,* 2008).

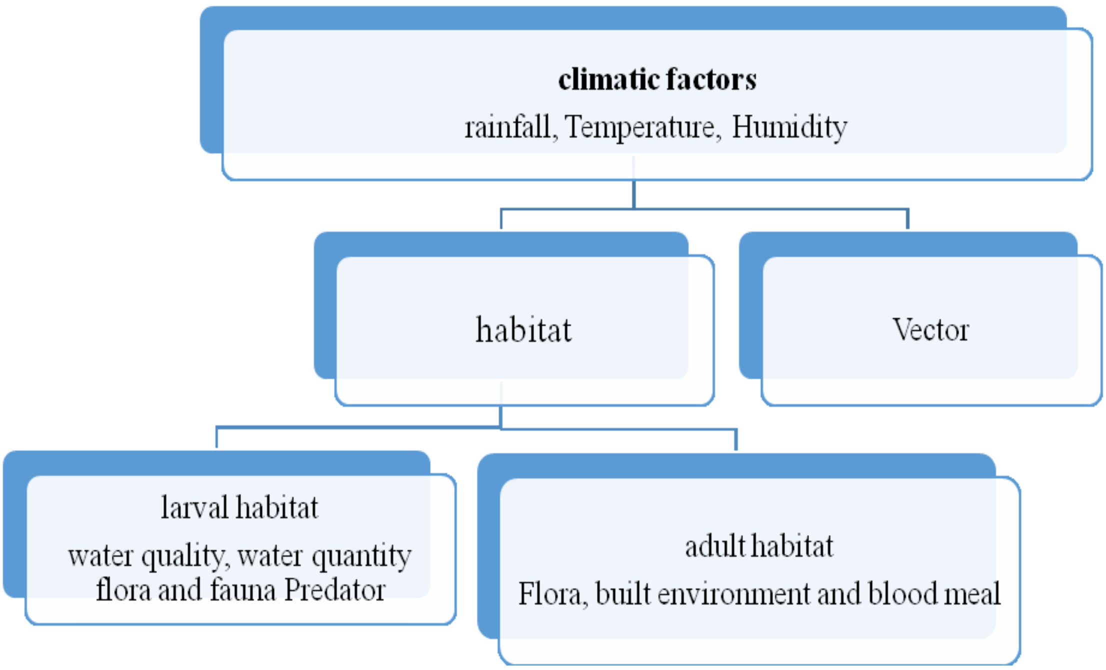


Figure 2.1: Malaria Transmission Patterns Due to Climatic Factors

Source: Robert *et al.,* (2003)

Rainfall brings stagnant water, which favours mosquito larvae development and acts as breeding site for mosquitoes. Pooling creates a favourable environment for mosquito breeding and malaria vectors mainly breed in stagnant water collections.

According to Ebi *et al.,* (2006), relative humidity affects malaria transmission through its effect on the activity and survival of mosquitoes and mosquitoes survive better under conditions of high humidity while the temperature affects mosquito life cycle directly. When the temperature decreases, the number of days necessary to complete the development increases for a given Plasmodium species. For example, *P. vivax* and *P. Falciparum* have the shortest development cycles and are therefore more common than *P. ovale* and *P. malariae* (Badu *et al.,* 2013).

2.2.4 Altitude Affects Temperatures Hence Malaria

Altitude (elevation above sea level) is also most important factors that determine the pattern of malaria transmission in tropical highlands like in Ethiopia (Muhire *et al.,* 2015). Altitude in Rwanda varies from 950 metres above sea level to more than 4,000 metres above sea level. Altitude influences the distribution and transmission of malaria indirectly, through its effect on temperature. As altitude increases, temperature decreases, so highlands are colder and lowlands are warmer. With altitudes between 2,000 and 2,400 metres, malaria transmission occurs for short periods only when temperatures rise unusually high (Himeidan and Kweka, 2012).

2.3 Malaria Etiology and its Distribution

Malaria transmission depends on temperature which is currently in warming phase, geographic distribution (Reiter, 2001) and malaria parasite lifecycle under climatic influence (Martens *et al.,* 1995). *P. falciparum*, account for severe and fatal cases of malaria through biting (Kelly *et al.,* 2015).

2.3.1 Parasite Spectra

Table 2.1 Presentation of Different Plasmodium Species at each Development Stage

Duration of different *plasmodium* species at each development stage

	Plasmodium species			
	P. vivax	*P. ovale*	*P. malariae*	*P. falciparum*
Pro-erythrocytic phase (days)	6-8	9	14-16	5-7
Erythrocytic cycle (hours)	48	50	72	48
Incubation period (days)	12-17 or even 6-12 months	16-18 or more	18-40 or more	9-14
Sporogony (days)	8-10	12-14	14-16	9-10

Source: (Koella *et al.,* 1987)

Life cycle of malaria vector is always affected by temperature in any way, where *P. falciparum* and *P. Vivax* has threshold temperature at their anopheles hosts of 18°C and 15°C, respectively (Gubler *et al.,* 2001).

2.3.2 Malaria Vectors

Different species of *Anopheles* mosquitoes differ in their capacity to transmit malaria. This depends on the biology and behaviour of the mosquitoes. Mosquitoes in the *Anopheles gambiae* group (which includes *An. arabiensis)*, are the most efficient malaria vectors in Africa. These mosquitoes are found only in Africa. In fact, the higher incidence of malaria in Africa compared to other parts of the world is mainly due the efficiency of these mosquitoes in transmitting the parasites (Badu *et al.,* 2013).

Mosquitoes need a blood meal to develop and reproduce. They can take their blood meal either from humans or animals. Mosquitoes that mainly feed on humans are more efficient carriers of malaria than those that feed on animals (Ebi *et al.,* 2006). That is why mosquitoes in the *An. gambiae* group are very good vectors of malaria. They prefer to bite humans more than animals (Sinka, 2013). Mosquitoes that feed on humans and animals equally are much weaker vectors of malaria transmitters (Rebollar-Téllez, 2005). Others feed exclusively on animals and are not malaria vectors. Therefore, *P. falciparum* mosquitoes and their feeding behaviour influence the intensity of transmission in an area (Danis-Lozano *et al.,* 2007).

Mosquitoes that are adapted to breeding close to human settlements and are able to breed in a wide range of environments, are also better vectors of malaria than mosquitoes that breed away from human habitation. Some mosquitoes breed in small pools that are partially or completely exposed to the environment (Heggenhougen *et al.,* 2003). Human behaviour in endemic countries also determines in part how successful malaria control activities will be in their efforts to decrease transmission.

2.3.3 Regional Distribution of Malaria Vectors and Host Preference

Table 2.2 Presentation of Regional Distribution of Malaria Vector and Host Preference

Species	Intra RBC Schizont period in (Hours)	Type of RBC	Relapse (hypnozyte)	Global distribution
P. vivax	48	Reticulocytes	Yes	Everywhere except sub-Saharan Africa
P. ovale	48	Reticulocytes	Yes	Africa
P. malariae	72	Older RBCs	No	Everywhere (different parts)
P. falciparum	48	All	No	Tropical regions

Source: (Sinka, 2013)

The governments of malaria-endemic countries often lack financial resources. In Rwanda, the most virulent malaria species is *P. falciparum* (Heggenhougen *et al.,* 2003).

P. vivax and *P. ovale* prefer reticulocytes (immature erythrocytes) whereas *P. malariae* prefers senescent erythrocytes (Old red blood cells) and *P. falciparum* exhibits no preference that is why it attacks all.

2.3.4 Distribution of Malaria

Dominant vector species distribution worldwide in respect to geographical area show that, America has 9 Dominant Vector Species, Europe & Middle-East has 6, Africa has 7 and Asia has 19 Dominant Vector Species, which totals to 41 Dominant Vector Species and all are ranked according to their importance (Sinka *et al.,* 2012).

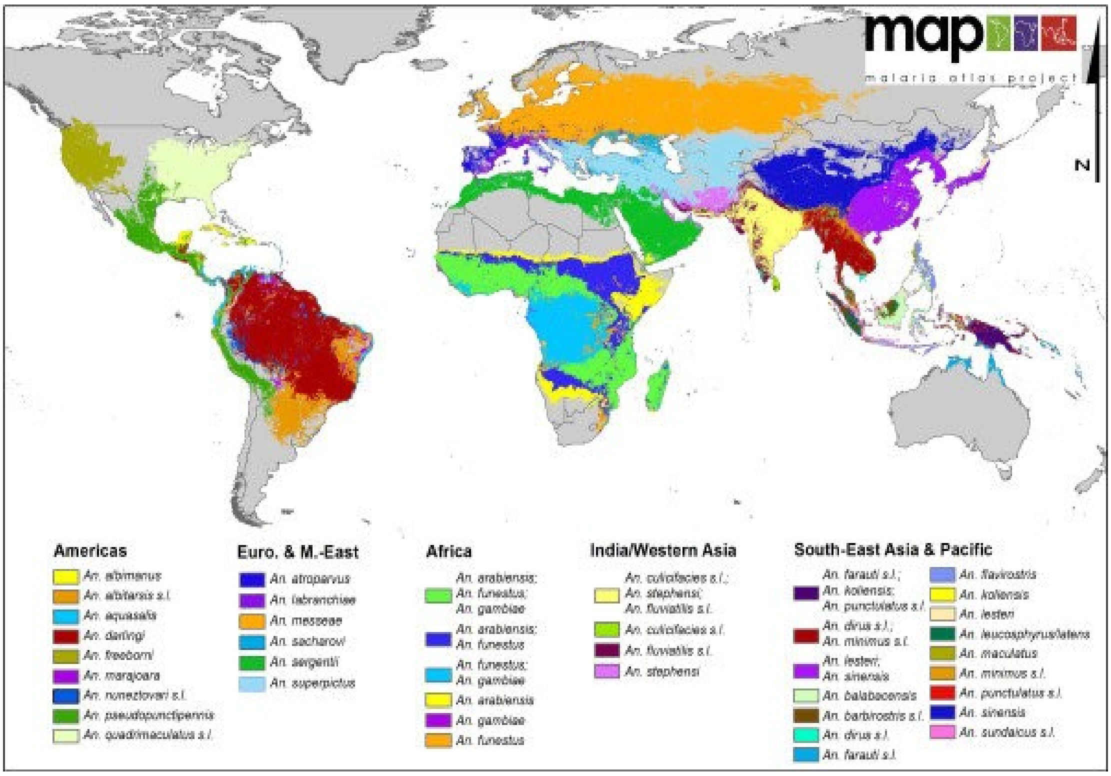


Figure 2.2: Distribution of Malaria in the World

Source: (Sinka *et al.,* 2012)

In Africa, the most important species are *An. arabiensis, An. gambiae, An. funestus* which are ranked and emerged. High lands are always laboratory of malaria study, where malaria is characterized by seasonal peaks and unstable transmissions (Bizimana, 2014a).

Table 2.3 Distribution of Malaria Cases and Deaths in the World

WHO region	Malaria cases (%)	Malaria deaths (%)
African Region	81	91
South East Asia	13	6
Eastern Mediterranean Region	5	3
Others	1	<1

Source: (Autino *et al.,* 2012)

2.3.5 Lifecycle of Malaria Parasite

Change in climate leads to change in temperature as it was noticed that warming in Rwanda was at 0.35^0 C per decade in past 40 years (Haggag & Kalisa, 2016) which affect water borne diseases especially malaria by changing the lifecycle of malaria parasite then becoming global burden (Huynen *et al.,* 2013).

Plasmodium life cycle has three stages which include infection of a human with sporozoites, asexual reproduction and sexual reproduction and this is life cycle of plasmodium is same for all five species. Two stages take place in human body whereas sexual reproduction starts in human body and ends in mosquito organism (Marshall & Taylor, 2009).

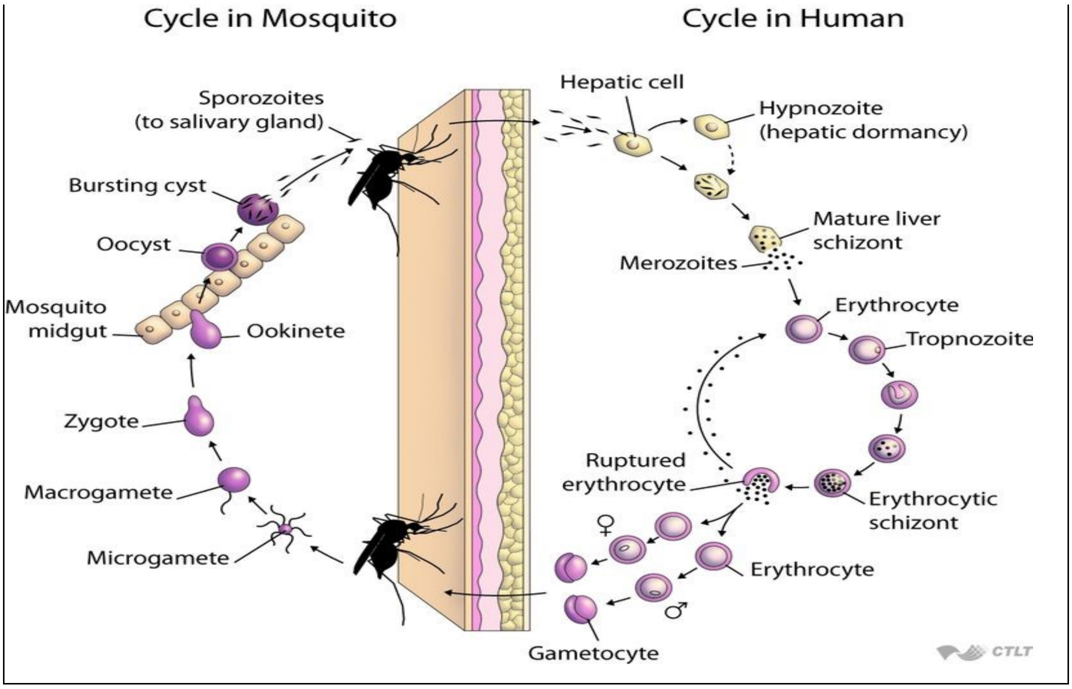


Figure 2.3: Lifecycle of Malaria Parasite

Source: (Richard., 2007)

2.3.6 Vectorial Capacity

Is the best way of predicting transmission risk, which is given by the formula, and it is affected by temperature change and the most affected part in the equation is n where it is inversely proportional to temperature. As p is less than one p^n will increase with increase in temperatures but p may decrease due to other factors. P is dominant in the equation due to exponential nature of denominator.

$$V = \frac{ma^2 p^n}{-ln(p)}$$

Where:

m is the mosquito density per human,

a is the average number of bites per day for each mosquito p is the probability of the mosquito surviving through any one day, and n is the extrinsic incubation period the time taken for the pathogen to develop in the mosquito until the insect becomes infective (Ceccato *et al.,* 2012).

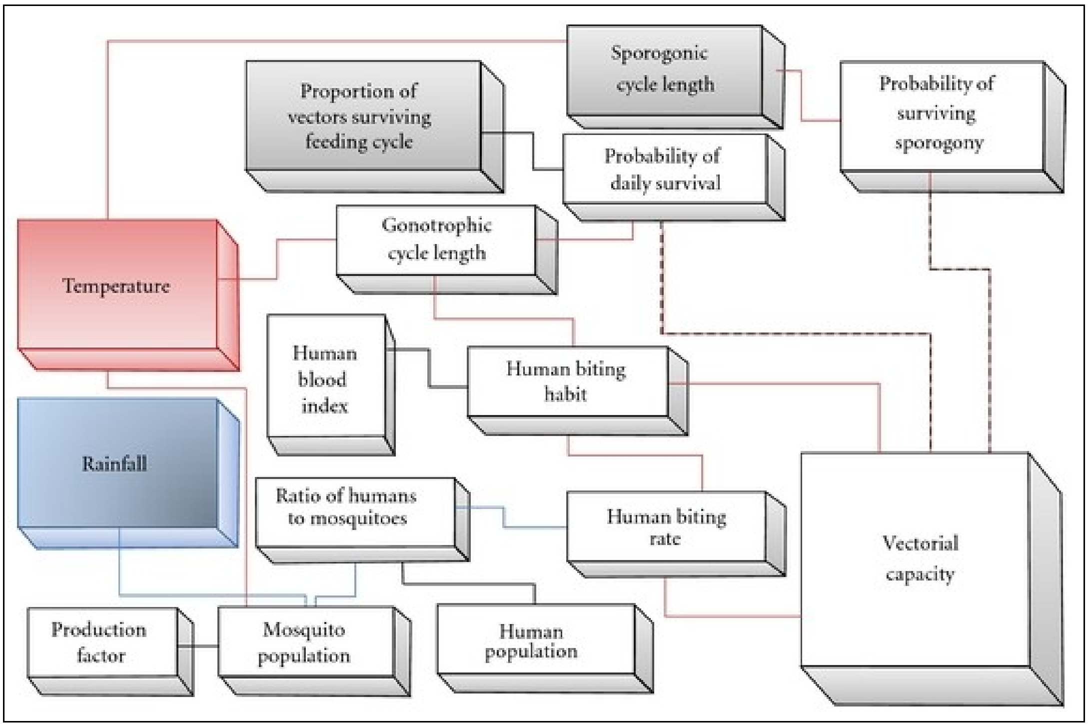


Figure 2.4: Diagrammatic Representation of "Expanded" Vectorial Capacity (VCAP) Model
Source: (Ceccato *et al.,* 2012).

2.4 Malaria Epidemiology

2.4.1 Population Dynamics of the Vector

Malaria as disease depend on vector ecology, mosquitoes transmit more infectious disease (Godfray, 2013), vector abundance increase is influenced by eco-hydrological conditions (Baeza *et al.,* 2013). Malaria vector abundance and intensity depends on hydro climatological, biological, and environmental complex arena (Endo & Eltahir, 2016). Malaria transmission due to increase in malaria vectors has increased even in places where protective interventions such as long-lasting insecticidal treated nets and indoor residual spraying are set due to increase in malaria vector abundance (Mmbando *et al.,* 2015).

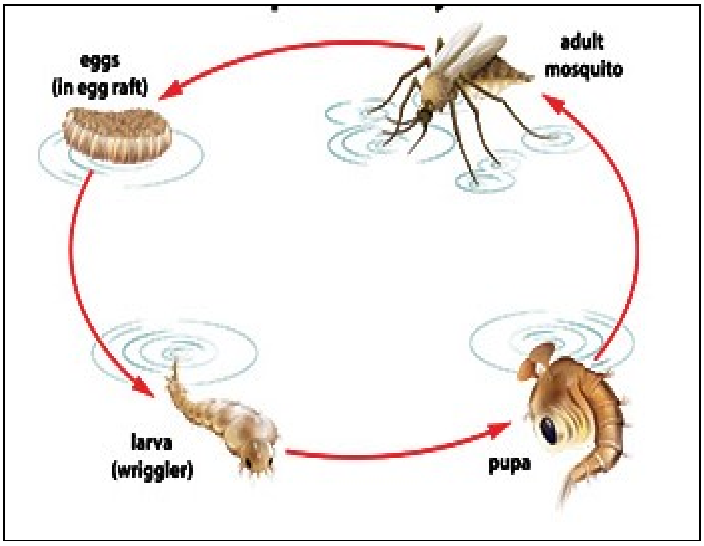


Figure 2.5: Life Cycle of Mosquito

Source: www.northlineexpress.com/mosquito-life-cycle.html

The life cycle of mosquito has four stages and these stages are affected by environmental aspects. Rainy season splash eggs of mosquitoes

2.4.2 Human Mosquito Interactions and Exposure to Infection

Although malaria is entirely transmitted by anophelines - only certain species are important vectors of the disease (Sinka, 2013). Several factors determine both the importance of each species as a vector of malaria (or other diseases) and the options for control (Oakley *et al.,* 2011). A good understanding of the biology and ecology of the principal vectors is essential to the development of an integrated vector control approach (Sinka *et al.,* 2012) and these factors include time of biting (evening, dawn, night), flight range of the vector (usually 3 kilometers [km]) feeding preferences of adult female mosquitoes (humans or animals, Ndenga *et al.,* 2016), adult behaviour particularly, preference for biting and resting indoors (endophagic, endophilic) or outdoors (exophagic, exophilic) and resistance to insecticides (Walker and Ph, 2002).

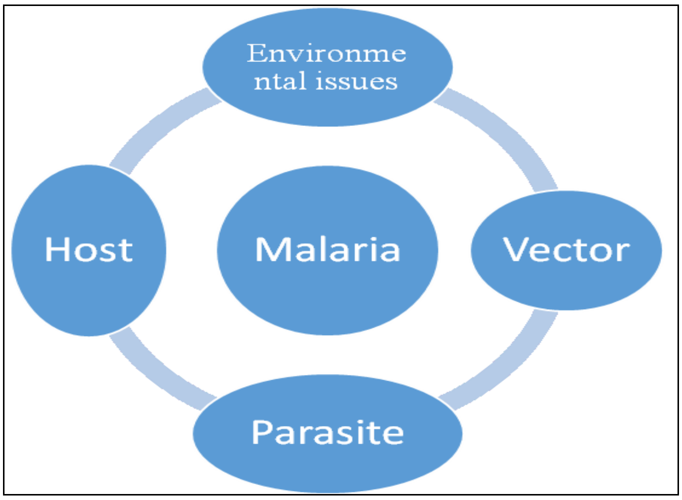


Figure 2.6: Model of Malaria Development (Walker and Ph, 2002)

Malaria development model is described above, if one factor is removed malaria will not occur and this is called from the host to the host model. Different mosquitoes types have different interaction behaviour according to their feeding behaviour, some mosquitoes that may feed on alternative (other animals) which are not humans may not interact heavily to humans (Protopopoff *et al.,* 2009). Human-vector interaction and mosquito density are key facts for malaria transmission in African region and Rwanda in particular (Protopopoff *et al.,* 2009).

2.4.3 Indices of the Human Infection

Malaria prevalence has been reduced in a couple of years in African highlands (Afrane *et al.,* 2011), in African and Americas, malaria prevalence is due to increasing deforestation where as in South East Asia deforestation reduces malaria prevalence (Guerra *et al.,* 2006).

According to a retrospective studies done in Tubu village of Botswana in 2016 showed that malaria prevalence was high in >5 years (adults) for five consecutive years and this was similar to results from Ngamiland district, Botswana where malaria was higher in old age (>5Years) (Chirebvu *et al.,* 2016). And this is important evidence that the area has low transmission rate because where there is high transmission rate, malaria prevalence is high in young (<5years) than in adults (Ndenga *et al.,* 2016).

In East African countries mostly in Kenya, malaria prevalence was high where there was high distribution and use of long lasting insecticidal treated nets (LLIN). But it was observed that malaria has reduced due to alternative blood meals (Ndenga *et al.,* 2016).

2.5 Malaria Disease in the Community

2.5.1 Biological Factors and Malaria

Biological characteristics and behavioural traits can influence an individual's risk of developing malaria and the intensity of transmission in a population. Biological characteristics present at birth can protect against certain types of malaria (Tachibana *et al.,* 2012). Two genetic factors are sickle cell trait and Duffy blood group. Genetic factors are associated with human red blood cells and have been shown to be epidemiologically important. Persons who have the sickle cell traits (Kwiatkowski, 2005) are relatively protected against *P. falciparum* malaria. Because *P. falciparum* malaria has been a leading cause of death in Africa since distant times and in Rwanda in particular, the sickle cell trait is now more frequently found in Africa (Bradley, 2016). Persons who are negative for the Duffy blood group have red blood cells that are resistant to infection by *P. vivax*. Since the majority of Africans are Duffy negative, *P. vivax* is rare in Africa south of the Sahara, especially West Africa. In that area, the niche of *P. vivax* has been taken over by *P. ovale*, a very similar parasite that does infect Duffy-negative persons. Other genetic factors related to red blood cells also influence malaria, but to a lesser extent (Guo *et al.,* 2015).

2.5.2 Human Behaviour and Activities

Several studies have shown that, hours residents spend indoors and outdoors at night without protection measures had been linked with residual malaria transmission in the community (Killeen *et al.,* 2006). Poorly constructed houses, such as those with an open eaves and with limited space become a barrier to appropriate net use (Tusting *et al.,* 2015). Poorly maintained water supply, sanitation, and drainage systems and irrigated farming contribute to the transmission of malaria by providing potential breeding sites for mosquitoes (DFID, 2010) and (Boelee, 2003) within are close to human dwellings (Wielgosz *et al.,* 2012b).

In Tanzania, it was found that, mosquito nets were in use by women who had a source of income. Their use depended on individual characteristics, house type and characteristics of net itself (Worrall *et al.,* 2002). In addition, Reddy *et al.,* (2011) reported that, even where the distribution of free mosquitoes nets existed, many households did not use them. Approximately 30 percent of the nets were unused in Kenya and likewise in southern Tanzania. A year after the nets were freely distributed it was found that the nets were stored in bags (in Kagera region) and had not been utilized by a number of households. Similarly Mboera *et al.,* (2011) reported that, Community members in Northern Tanzania resisted against their houses being sprayed with IRS. The reasons of rejecting IRS were mainly the bad smell of the insecticides and the fear that insecticides might kill their domestic animals (Greenwood and Targett, 2009).

It has been also stated by Kisinza *et al.,* (2008) and Kovats *et al.,* (2016) that, although LLINs have significantly decreased malaria in Sub-Saharan Africa, some of unforeseen consequences of distribution of nets have been reported. LLINs have been used for constructing chicken pens and fences around vegetable gardens; improvise as wedding veils, drying fish and for fishing rather than malaria prevention.

Apart from coverage, important components for reducing new cases of malaria and deaths as reported by Breman, (2009) include more sensitive diagnostic tools, effective use of antimalarial drugs and improved personal protection by LLINs (Breman, 2009). Consequently, (Yadav *et al.,* 2007) revealed that, cultural and social economic factors have positive and significant effect to the risk of malaria morbidity and mortality and poverty rates are directly associated with social economic status (Heggenhougen *et al.,* 2003).

Hence, these attitudes may not alone inhibit effective preventive measures and economic development, but also economic loss (Mia *et al.,* 2011). This situation constitutes a major challenge to the goal of malaria eradication by 2030 as described by Greenwood *et al.,* (2008), especially where species have divergent complex interactions between anthropological and entomological factors that drive and maintain resilient high malaria transmission (Al-Eryani *et al.,* 2016).

Human behaviour, often dictated by social and economic reasons, can influence malaria prevalence for individuals and communities. For example, poor rural populations in malaria-endemic areas often cannot afford the housing and bed nets that would protect them from exposure to mosquitoes. These persons often lack the knowledge to recognize malaria and to treat it promptly and correctly. Often, cultural beliefs result in use of traditional, ineffective methods of treatment known as local remedies in Rwanda such as **umubirizi, umuravumba, ibumba** and **rakatsi**. Travellers from non-endemic areas may choose not to use insect repellents or "medicines" to prevent malaria. Reasons may include costs, inconveniencies, or a lack of knowledge. Human activities can create breeding sites for larvae (standing water in irrigation ditches or burrow pits, Endo and Eltahir, 2016).

2.5.3 Population Movement and Migration

War, migrations (voluntary or forced) and tourism may expose non-immune individuals to an environment with high malaria transmission. Population movements have significant implications for malaria transmission. The majority of the population movements in Rwanda involve people moving from the highlands to the malaria-endemic lowlands as seasonal labourers. Migrant labourers from malaria-free areas are at increased risk of malaria during harvesting in lowland malaria-endemic areas (Cohuet et *al.,* 2010).

According Ingabire *et al.,* (2016) malaria in Rwanda cannot be attributed to one factor but many factors and these may be psychosocial, socio-demographic and environmental factors. Because disease transmission possibilities persist in Rwanda, national malaria control program has put in place an aspiring goal of making Rwanda a malaria free country but it remains to be successful (Bizimana, 2014a). It is therefore, important to understand the effect of land use patterns, human behaviour and climatic factors on malaria transmission and possible interventions in Ngoma district. Such information is important for the designing of appropriate control strategies in Ngoma District and Rwanda in general.

2.5.4 Socio-economic Factors

The vast majority of malaria deaths occur in sub Saharan Africa, where malaria presents major complications to socio-economic development of the region. Malaria has been estimated to cost Africa more than US$ 12 billion every year. There are at least 300 million acute cases of malaria each year globally, resulting in more than a million deaths and around 90% of these deaths occur in Africa, mostly in young children WHO (2003). Malaria is Africa's leading cause of under-five mortality (20%) and constitutes 10% of the continent's overall disease burden (DFID, 2010). It accounts for 40% of public health expenditure, 30-50% of inpatient admissions, and up to 50% of outpatient visits in areas with high malaria transmission in Rwanda (Karema *et al.,* 2012).

There are several reasons why Africa endures an overwhelming proportion of the malaria burden. Most of malaria infections in sub Saharan-African are caused by *Plasmodium falciparum* (Kovats *et al.,* 2016). This region is also home to the most efficient, and deadly species of malaria parasite (*Plasmodium falciparum, Plasmodium vivax*, and *Plasmodium malariae* and *Plasmodium ovale*), which transmit the disease. Moreover, many countries in Africa lack the infrastructures and resources necessary to mount sustainable campaigns against malaria and as a result few benefited from historical efforts to eradicate malaria (Chan *et al.,*1999).

2.6 Livestock Keeping and Malaria Transmission

Malaria transmission may be influenced by different levels of heterogeneity, at the village, family or even individual level. A complex network of interactions between the human host, parasite, mosquito vector and environmental factors is known to play a key role in such heterogeneity. However, the relative contribution of each of these elements is still unclear. For instance, in areas where the vector feeds on both livestock and humans, the presence of livestock close to the household, may affect the probability of human-vector contact, and hence the risk of malaria transmission to humans. It has recently been suggested that in these areas, the treatment of livestock with insecticide could be a complementary tool for controlling malaria vectors, and hence reducing the incidence of human malaria (Franco et al., 2006).

The effect of insecticide-treated cattle on malaria risk is unexpected. Treated cows were associated with a statistically significant increase in malaria risk, suggesting a repellent effect that might have diverted the mosquito vector from treated cows to nearby humans. Previous investigations conducted not far from our study area (Habtewold *et al.,* 2004) suggested that treating cattle with insecticide reduced feeding success and landing times on cattle but did not divert mosquitoes from cattle to humans. Furthermore, a trial conducted in Pakistan showed that by regularly treating livestock with insecticide a substantial reduction in malaria was achieved (Rowland *et al.,* 2001).

2.7 General Sanitation

Rwanda's strategy to reduce malaria transmission is aligned with PMI guidance and is achieved - in part, through cleaning of house hold surroundings, removal of plastics and bottles and environmental management that keeps rain water, bush and grass clearing, drainage of stagnant water, construction of insect proof latrines and all activities that reduce existence of mosquito breeding habitats. These are used as general sanitation and bush clearing, environmental management are important aspects in reducing malaria mosquito entry into houses.

2.8 Distance from Breeding Sites

Control of malaria in Africa presents a significant challenge (Greenwood *et al.,* 2002). Targeting existing methods for malaria control to populations at greatest risk could increase the effectiveness of interventions (Carter *et al.,* 2000). Urbanization is occurring rapidly in sub-Saharan Africa and may have a significant impact on the epidemiology of malaria (Robert *et al.,* 2003). Although malaria transmission is lower in urban than in rural areas of Africa where the distance from breeding sites is shorter, transmission and parasite prevalence may be heterogeneous within densely populated areas and distance from breeding sites are important determinant, clustering near mosquito breeding sites (Donovan & Thompson, 2001). Risk of malaria, as measured by parasite prevalence, estimated annual malaria incidence, and risk of clinical illness, has been shown to increase with mosquito exposure (Trape *et al.,* 1998). However, some data suggest that parasite prevalence (Thomas and Lindsay, 2000) and clinical illness (Clarke *et al.,* 2002) are less common in more exposed children, possibly due to increased acquired immunity.

A gradient in incidence of clinical episodes of malaria was observed with distance of residence from a swamp (0.41 episodes per person year for residence >100 meters from a swamp increasing to 2.22 episodes per person year for residence within a swamp), or a stream (0.61 episodes per person year for residence 500 meters from a stream versus 1.76 episodes per person year for residence <500 meters from a stream (Franco *et al.,* 2006)). Multivariate analysis showed that distances of residence from a swamp or from a stream were independent predictors of malaria incidence, controlling for age, use of preventative measures, and primary source of water. Distance from a swamp was the strongest predictor, with an incidence rate ratio of 4.3 (95% confidence interval 2.6 to 6.9, $P < 0.001$) between residence within a swamp and >100 meters from a swamp. In the urban setting, incidence of clinical episodes of malaria was strongly associated with proximity of residence to potential mosquito breeding sites (Nkhoma *et al.,* 2007).

2.9 Malaria in Rwanda

Malaria transmission in Rwanda varies widely. Traditionally, the central plateau (altitude 1,500 to 1,800 m) is considered as one of four distinct ecological zones with overall *P. falciparum* prevalence rates of 5% to 15%. While transmission in Rwanda is regarded to be stable with seasonal peaks in the valleys and unstable (and potentially epidemic-prone), at higher altitude a linear correlation between altitude and transmission would be over-simplified (Gahutu *et al.,* 2011). In a recent tabulation of the years 2001-2007, endemicity at 1,600-2,000 m above sea level ranged from hypo-to holo-endemic and annual malaria incidences (presumed and confirmed) from 2.4 to 20.4 per 1000 capita (Gahutu, 2011). Recent increases in resources in Rwanda, political will, and commitment have led again to discussion of the possibility of malaria elimination and, ultimately, eradication (Asingizwe *et al.,* 2015).

In recent years, substantial increase in malaria control activities were introduced particularly in East Africa. Growing evidence suggests a decline in malaria transmission, morbidity and mortality over the last decade due to control measures. And those measures considered vital deployment of artemisin in-based combination treatment (ACT), distribution of long-lasting insecticide-treated nets (LLINs), and indoor residual spraying (IRS, Okumu *et al.,* 2013).

Rwanda is a prime example for the impact of malaria control measures. Since 2000, several million insecticide treated nets (ITNs) have been distributed (mostly LLINs) increasing the percentage of population (10 million) covered by nets to potentially ≥70%. In parallel, ACTs have been dispensed on a large scale. In 2007, 56% of households were considered to own a net and 56% of children to sleep under one.

Surveillance and health facility based data indicate that by 2007-2008 these efforts were associated with approximately 50% or higher declines in confirmed outpatient cases, inpatient cases, and deaths due to malaria in children <5 years old (Karema *et al.,* 2013).While this progress does not appear to be questionable, the extent of the declines as deduced from facility-based data might differ at community level. For instance, community-level case management programmes have been reported to shift primary treatment from health (Gahutu *et al.,* 2011).

Theoretically it has been suggested that scaled intervention coverage with ITN is least likely to impact on disease incidence where starting transmission intensity is highest (Okiro *et al.,* 2013). The combination of different malaria control methods has been proved efficient. These approaches contributed to the reduction of malaria microscopically confirmed cases by 72% for all ages and by 82% for under five year (U5Y) children. Malaria death decreased by 47% for all ages and 77% U5Y children (Karema *et al.,* 2013).

2.10 Control of Malaria

Malaria control models and vector-based interventions are the major factor of a programme targeting to decrease malaria and these include use of insecticide treated bed nets and long lasting treated bed nets, rapid treatment and diagnosis. The current interventions for malaria in Rwanda are mainly based on effective treatment and the reduction of human-vector contact through insecticide treated bed nets and long lasting treated bed nets, prevention of malaria in pregnancy and prevention of malaria epidemics (Karema *et al.,* 2013). Despite these efforts, malaria shows little signs of reduction and this has been attributed to many factors which include biological factors, environmental factors, lack of community motivation and involvement, and political will for sustainable vector control and inadequate technology and awareness of the community.

2.10.1 Intermediate Host Control

Malaria control measures are based on chemical control using different chemicals and plants like repellents, biological controls and environmental manipulation.

2.10.2 Environmental Manipulation

Anthropogenic factors such as deforestation, agriculture expansion, change in microclimate and change in vegetation has affected malaria vector population and abundance and hence global incidence (Fornace *et al.,* 2016). Environmental manipulation is the most influential driving component of vector borne disease like malaria globally and even locally (Mia *et al.,* 2011).

Factors that affect malaria transmission, but which are not related to the climate, are called non-climatic factors. These are as follows: The type of vector, the type of parasite, environmental development and urbanization (Kimbi *et al.,* 2013), population movement and migration, the level of immunity to malaria in the human hosts (Gubler *et al.,* 2001), insecticide resistance in mosquitoes, and drug resistance in parasites (Protopopoff *et al.,* 2009). All These have a role in affecting the severity and incidence of malaria (de Souza *et al.,* 2010). In Rwanda non-climatic factors include land use, biological, housing and others (Protopopoff *et al.,* 2009).

2.10.2.1 Agriculture Patterns and Malaria Transmission

According to studies in Kenya, survivorship rate of mosquito in farmland habitats is significantly greater than in swamps and forests and larval to pupal growth ratio is significantly smaller (Wielgosz *et al.*, 2012a). Land use patterns, may affect larval survivorship and adult productivity through its effects on water temperature and nutrients in the aquatic habitats (Afrane *et al.,* 2011). The results of the studies recommend that deforestation and cultivation of natural swamps in the western Kenyan highlands create conditions favourable for the survival of *An. gambiae* larvae, and consequently increasing the risks of malaria transmission to the human population (Afrane *et al.,* 2011).

Other land cover changes such as swamp reclamation have been shown to have similar effects as deforestation on malaria vectors development. This has the potential to increase the population of mosquitoes and to which could also potentially cause an increase in malaria transmission if infected humans are available (Kovats *et al.,* 2016).

Since carbon dioxide is known to activate and attract mosquitoes compared to any other compounds, it means that living with other animals that produce carbon dioxide like human beings, can increase or decrease malaria outbreak due to feeding habit of mosquitoes (Kelly *et al., 2015)*. This explains why in Rwanda malaria was less rampant in the past than is today (Verhulst *et al.,* 2010).

2.10.2.2 Water for Agriculture Activities and Irrigation Effects on Malaria Transmission

Expanded agricultural development in many parts of the world has increased the need for water for crop and animal production. Water for agricultural production has been sought from dams constructed and serviced from canals, sprinkler systems, boreholes, wells, dugouts, and bunds used as receptacles to collect water during the rainy season. Although water projects can lead to increased agricultural production, they have created suitable conditions for the breeding of mosquitoes (Diuk-Wasser *et al.,* 2007). This is because the mosquito vectors are in constant contact with the population throughout the year because of the availability of water from the irrigation system or water ponds, resulting in high anopheline density. Evidence abounds in the literature to link malaria transmission to agricultural water resources development in Africa. For instance, the construction of micro-dams for irrigation in the Tigray region of Ethiopia resulted in a seven-fold increase in malaria among children residing near the dams (Ghebreyesus *et al.* 1999; Keiser *et al.,* 2005).

A global review of the effect of irrigation and large dams on the burden of malaria found that irrigation exposes non-immune populations in areas of unstable malaria transmission to high risk of acquiring the disease in Africa (Keiser *et al.,* 2005). The report cites a study in Burundi, which found that irrigated villages in the Rusizi Valley had higher malaria prevalence and a 150-fold higher vector capacity of *An. arabiensis* compared with the situation in a neighbouring village. This effect of irrigation creating conditions for the transmission of malaria to non-immune populations may be one of the most severe negative consequences of these water projects. In the future, policies for agricultural water development need to take these likely consequences into account.

In Ghana's Upper East Region, a study in the Kassena-Nankana district, which has one of the largest irrigation sites in the country, observed that malaria transmission was highly seasonal but the intensity of transmission was higher for people in the irrigated communities than in the non-irrigated ones. The results indicated that significant numbers of anophelines were captured from compounds in the irrigated areas (Appawu *et al.,* 2004). In the same study site, a prevalent study carried out by Koram *et al.,* (2003) also showed that prevalence of parasitemia was significantly higher among children living in irrigated areas than those residing outside the irrigated areas.

One area of intense research in Africa to assess the links between irrigation and malaria transmission has been in the area of rice cultivation. This is because rice fields are often flooded for longer periods and therefore create puddles of water that allow a considerable multiplication of malaria vectors of the *An. gambiae* species. Yasuoka and Levins (2007) observed that "many irrigation schemes in Africa have resulted in increases in established malaria vectors such as *An. gambiae* and *An. arabensis* and thus increased the transmission of malaria. The construction of large-scale irrigation projects led to an increase in human malaria incidence (Robert *et al.,* 1992).

Another study conducted in the North Southern region of Mali also reported that irrigation for rice cultivation increases the production of *An. gambiae*, which happens to be the main vector of malaria in Mali, and that mosquito abundance was linked to malaria transmission in the region (Diuk-Wasser *et al.,* 2007). More malaria outbreaks due to irrigation schemes have been reported elsewhere in South Asia. Lowland irrigated rice production in South Asia is reported to be associated with malaria transmission through the creation of conditions favourable for perennial malaria transmission (Koram *et al*., 2000). Yasuoka and Levins (2007) further report that irrigation for rice cultivation in Java-Bali in Indonesia and in the Kunduz Valley in northern Afghanistan resulted in increased mosquito-breeding places and subsequently led to increase in malaria incidence in the regions. In Sri Lanka, the introduction of the Mahaweli Systems H and B is reported to have led to a five-fold increase in malaria in the region (Mutuwatte, 1997, cited in Keiser *et al.,* 2005).

In India, evidence of the impact of irrigation on malaria transmission has been observed in several studies. For example, the annual parasite index increased from 0.01 in 1961 to 37.9 in 1976, following the construction of the Mahi-Kadana irrigation project. Malaria incidence in the canal-irrigated villages increased up to 9 fold in Meerut and Gurgaon. Again, a 2.4 fold increase in malaria cases and a more than 4 fold increase in the annual parasite incidence among children were recorded in villages closer to the Bargi Dam compared with the more distant villages (Keiser *et al.,* 2005).

Malaria has also become a major public health problem in the Thar Desert in Rajasthan state of India, with several reported epidemic outbreaks following the massive irrigation developments since the 1980s. The 8,000-km canal system in the Thar Desert region has transformed the desert physiography, vector preponderance, distribution, and vectorial capacity with *An. stephensis*, *An. culicifacies*, and the parasite *Plasmodium falciparum* invading the region (Tyagi *et al*., 2004; Keiser *et al.,* 2005; Joshi *et al.,* 2011; Sissoko *et al*., 2004; Shiva and Shiva n.d.). Also in the Punjab region of India, irrigation schemes have made the region endemic for malaria, though it was only known for epidemic outbreaks (WHO/SEARO 2008).

A review by Keiser *et al.,* (2005) also showed that in Peru, houses in villages located closer to fields and irrigation canals in the dry coastal areas recorded a five-fold increase in malaria incidence compared with those further away from fields and irrigation in the dry areas (Panigrahi & Mahapatra, 2013). Though higher malaria incidence has been reported at three large dam sites in Brazil (Balbina power plant, the Itaipu Dam, and the Tucurui hydropower dam), the review by Keiser *et al.,* (2005) did not link it to irrigation activities. In general, we can conclude that irrigation and water harvesting and storage projects provide habitats for mosquitoes and increased malaria infection (Boelee, 2003).

It is, however, important to understand that though irrigation areas are known to have high densities of mosquitoes, in exceptional cases, this may not automatically lead to higher malaria incidence among the inhabitants. In many areas of sub-Saharan Africa where malaria transmission is stable, the introduction of irrigated agriculture has little impact on the disease. In fact, several studies have documented that there is less malaria in communities living in close proximity to irrigation schemes when compared with populations living further away, which is partially explained by enhanced incomes that facilitate better protective measures to be taken (Drakeley *et al.,* 2000; Ijumba & Lindsay, 2001).

This is the so-called paddies paradox, where agricultural development resulting in increased income for the community is likely to improve access to malaria treatment and may support an increased use of malaria preventive devices. For instance, the Mwea District in Kenya, where rice is cultivated and irrigation is used, was found to have a 30–300 times higher prevalence of the local malaria vector compared with those districts and villages without irrigation, but the irrigated areas had lower prevalence of malaria (Mutero *et al.,* 2004).

Similar observations have been made in studies in Burkina Faso, Senegal, Mali, and Tanzania, among others (Keiser *et al.,* 2005; Diuk-Wasser *et al.,* 2005; McCartney *et al.,* 2012; Matthys *et al.,* 2006). Several factors have accounted for this but include, most importantly, effective vector control programs, effective water management, and prevention interventions in the irrigated communities. According to Keiser *et al.,* (2005) irrigation keeps more challenges to community as far as the malaria is concerned worldwide and Africa in particular, as a result of agriculture promotion. Control of malaria in the irrigated areas requires drainage of dams every month especially during dry months (Wielgosz *et al.,* 2012).

An estimated 40,000 large dams and 800,000 small dams have been built, and 272 million hectares of land are presently under irrigation worldwide (Keiser *et al.,* 2005). The creation and operation of water projects has had a history of enabling modification in the occurrence and transmission dynamics of malaria, but analyses of these environmental risk factors are scanty (Keiser *et al.,* 2005). Most of the studies revealed that the development of irrigation schemes in sub-Saharan Africa has been blamed for the increase of malaria risk through creating favourable breeding sites for malaria vectors (mosquitoes, Kibret *et al.,* 2014).

Human health, especially near reservoirs and canals for irrigation - are always affected by waterborne diseases in both humans and animals. However, the above potentially adverse impacts identified are mostly manageable in nature through different mitigation measures. In Rwanda, studies about malaria particularly targeted malaria control policies and programmes. The focus was on the contribution of anti-malaria drugs, mosquito and residual sprays, the prevalence of malaria in pregnant

HIV positive women and the resistance of Plasmodium falciparum to antimalarial drugs (Karema *et al.,* 2013).

Most studies assessing irrigation and its impact focus on rice irrigation and its productivity without proper understanding of how water management could be applied for malaria vector control in different irrigation practices.

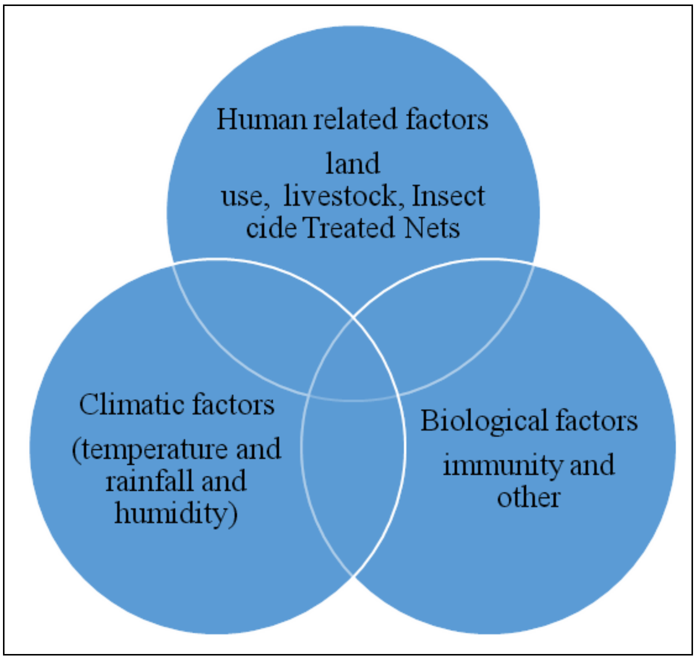
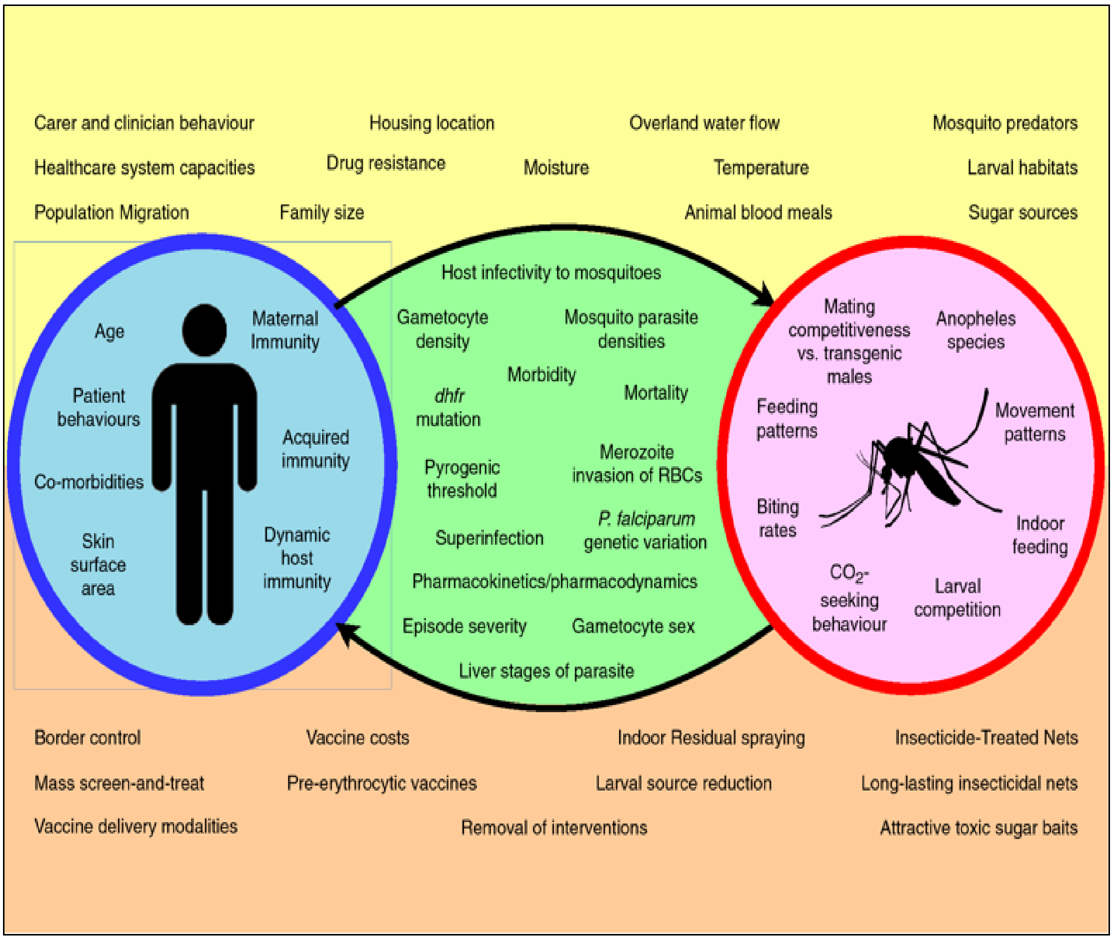


Figure 2.7: Malaria Prevalence Risk Factors Relationship in Africa

Source: Protopopoff *et al.,* 2009

Vanek *et al.,* and Dongus *et al.,* 2006, 2016 respectively) found that, the preferential breeding habitats of malaria vectors are within and around agricultural areas such as marshes and furrows. These have significant effect on receptive for Anopheles larvae than non-agricultural habitats, especially irrigated rice whereas agro-ecosystems are associated in creating “hotspots” for water-borne diseases (Keiser *et al.,* 2005). Agro-ecosystems provide breeding habitats to the numerous mosquito species proximate to human dwellings, Muriu and Steadkeet *et al.,* (2003 and 2008 respectively). In addition, Overgaard *et al.,* 2008, and Philebert *et al.,* 2014) detected that, many disease vectors breeding in agricultural areas of intensive pesticide use of agricultural pesticide had been resulted on the insecticides exerted selective pressure on malaria vectors.



(Ayele *et al.* , 2012)

Figure 2.8: Malaria Transmission Model

2.10.2.3 Land Use Practices and Malaria Transmission

According to studies in Kenya, survivorship rate of mosquito in farmland habitats is significantly greater than in swamps and forests and larval to pupal growth ratio is significantly smaller. Land use patterns, may affect larval survivorship and adult productivity through its effects on water temperature and nutrients in the aquatic habitats. Their results recommend that deforestation and cultivation of natural swamps in the western Kenyan highland create conditions favourable for the survival of *An. gambiae* larvae, and consequently increase the risks of malaria transmission to the human population (Afrane *et al.,* 2011).

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Since carbon dioxide is prone to mosquito activation and attraction more than any other compound, it implies that living with other animals can increase malaria outbreak and this may explain why in the past Rwanda had less malaria outbreaks than is the case today. Thus raising domestic animals near households may provide alternate sources of blood meals for Anopheles mosquitoes and thus decreasing human exposure (Verhulst *et al.,* 2010). Agricultural development in Africa has contributed immensely to land use changes and has resulted in the upsurge of malaria transmission in several places, especially in unstable malaria transmission areas. Significant agricultural practices such as urban agriculture, wetland cultivation, clearing of tropical forest lands and its associated deforestation and agricultural encroachment on highlands, have been the primary drivers of malaria transmission in the affected areas (Patz *et al.,* 2004).

2.10.2.4 Housing Construction and Malaria Transmission

Housing improvements, traditionally a key pillar of public health, remain underexploited in malaria control. Yet in sub-Saharan Africa (SSA), where up to 80-100 % of malaria transmission occurs indoors at night, the home can be a high risk place. In Italy housing was first intermediation lagged due to window screening after the link between malaria and mosquitoes was discovered (Tusting *et al.,* 2015). Recent studies indicate that well-built modern housing can be protective in many tropical countries and that simple features, including closed eaves (the gap between the top of the wall and the over-hanging roof), brick walls, tiled or metal roofs, or ceilings can reduce mosquito house entry (Tusting *et al.,* 2015).

2.10.2.5 Other Control Methods

Other control methods for malaria are public education and vaccination and not only in Rwanda but also in world as large.

2.10.2.5.1 Public Education

Public education on malaria disease such as causes, symptoms and signs, eradication campaigns through public and private media, schools, and sport is important aspect of eliminating malaria in any area due to counselling (Schubert *et al.,* 2009).

2.10.2.5.2 Vaccination

Malaria vaccine progress and analysis are progressing rapidly and a recombinant protein (RTS, S/AS02A, Breman, 2009), using malaria rapid diagnostic tests (MRDTs) procedures are currently being focused on for chemical control of malaria in Rwanda in particular and world in general (Peletiri, 2013).

2.11 Research Gap Identified

In Rwanda, most studies on malaria have focused on climatic effects on malaria and drug resistance in treatment phase. There is therefore limited information on the influence of environmental and anthropogenic factors on malaria transmission in Ngoma district, Rwanda. There is an urgent need of understanding the status of malaria (prevalence), to identify the environmental manipulation patterns affecting malaria transmission to assess and anthropogenic behaviour and activities influencing malaria transmission in Ngoma district and to design intervention strategy for control of malaria transmission in in Ngoma district. This will assist in designing an appropriate model for control of malaria transmission in Ngoma district and also at national level and at global level.

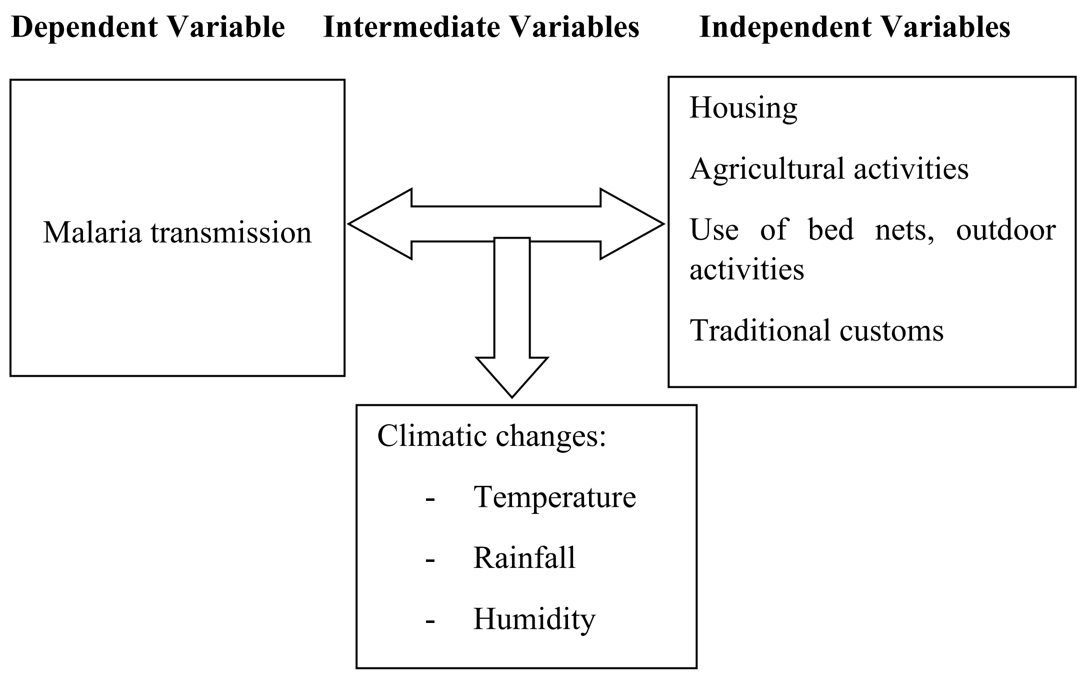

Figure 2.9: Conceptual Framework

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview

The chapter covers the methodology which the researcher used in studying "the influence of environmental and anthropogenic factors on malaria transmission in Ngoma district". It covers the following; the description area of the study area, study design, study population, sample size, data analysis and ethical.

3.2 Description of Study Area

Ngoma district is one of the seven Districts of Eastern Province. It is divided into 14 administrative sectors namely: Gashanda, Jarama, Karembo, Kazo, Kibungo, Mugesera, Murama, Mutenderi, Remera, Rukira, Rukumberi, Rerenge, Sake and Zaza. It is also divided into 64 cells and 473 villages "imidugudu" covering an area of 867.74 km^2 with 338, 562 inhabitants - according to 2012 census, and a population density of 393/Km^2. The district borders Rwamagana in North-West, to the Kayonza district in North-East Bugesera district in West, Kirehe district in East and in the south boarders Muyinga (Burundi). Ngoma district has one referral hospital known as district hospital (Kibungo Hospital), 12 health centres and 9 health posts.

Figure 3.1 shows the corresponding district (number 5) where the research was carried out. The study was conducted in 3 randomly selected sectors, namely: Kibungo, Remera, and Rukira this was done by cluster of sectors with similar chatecteristics cluster one (Jarama, Murama, Remera, Zaza and Karembo) cluster two (Gashanda, Kibungo, Mutenderi, Rurenge and Kazo) and cluster three (Mugesera, Rukira, Rukumberi and Sake).

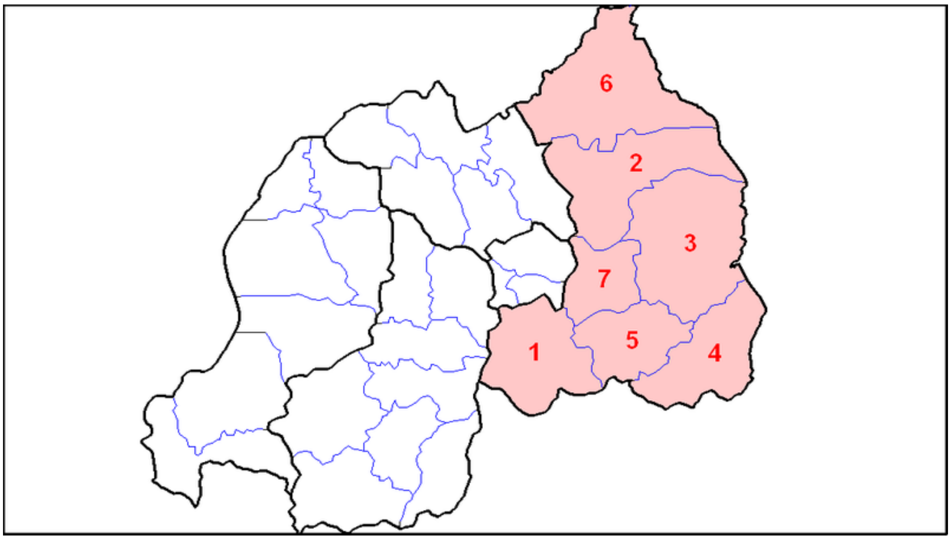

Figure 3.1: Map of Study Area

3.3 Agricultural Activities

Agriculture is the main source of income for 57% of households compared to 21% of the households whose source income is wages. With regard to the income from the agricultural products, in Ngoma District, 23.6% of the agriculture products are sold compared to 20.9% sold at national level. This shows to what extent the agricultural products are used for subsistence rather than for the market. Main food crops grown in Ngoma District according to their order of importance are: dry beans (96.2%), green bananas (92.1%), maize (90%), sweet potato (84.4%) and cassava (76.8%), peanuts (45%) and rice (8.5%). Main fruits and vegetables cultivated in Ngoma District are fresh beans (92.2%), avocado (53.7%), and papaya (41.3%) while main export and cash crops are coffee (18.3%), sunflower (28.1%), sugar cane (24.6%) and pepper (12.6%).

Ngoma district is located in the lowlands of the East, a region essentially dominated by hills with low slopes, with an average altitude between 1400m and 1700m above sea level. The climate (temperate) especially in low altitudes is important factor. The annual mean temperature is around 20^0C. Ngoma district has four seasons of which two are rainy seasons and other two are dry seasons.

A short rainy season extends from October to December, and a short dry season runs from January to February, and a long rainy season from mid-February to mid-May and a long dry season from mid-May to Early October. Generally, the dry season begins earlier and ends later compared to other regions of the country. The volume of annual precipitations on the whole of the district lies between 900 and 1400 mm of rains. In terms of flora and fauna, the natural vegetation of Ngoma District is dominated by savannah landscapes (District and Planning, 2014).

3.4 Study Design, Research Methods and Data Collection Tools

The study was cross sectional and it employed prospective longitudinal study. Both quantitative and qualitative methodological approaches which included questionnaires; interview guides focus group discussions and participatory epidemiology and observation. The questionnaires and participatory epidemiology approaches were administered to the local community from the selected sectors. The interview guide was given to the health officers at Health Centres and district hospital. Focus group discussions were undertaken with the community health workers. Secondary data review was done on the documentation of diagnosis cases collected from health centres and the district referral hospital.

In general, this study aimed to assess the influence of environmental and anthropogenic factors on malaria transmission in Ngoma district.

3.5 Sampling Procedure

This study used a multistage sampling method to obtain a sample of 127 respondents (households and community health workers). First stage used was simple random selection of three sectors out of 14 sectors in Ngoma district from three clusters of sectors with similar characteristics and the second stage employed simple random selection of one (1) village in each of three selected sector (three villages). The third stage was done at household level to choose interviewees from each village where 23 households (one from one family) were selected by simple random and with proportion of 1 household to 10 households 10%.

This study used probabilistic sampling technique where all had equal chance for being selected for the general survey notably regarding the total sample size of individual's subject to the survey and simple random sampling to the selection of community health worker and malaria in charge at district hospital.

3.6 Study Population

The district has a total population of 338,562 inhabitants with an average of 16,521, (4.9%) malaria cases per year (Rwanda Biomedical Centre, 2016). The study covered only one village from each selected sector and involved households (one per family mainly head of family). 1:10 proportion of households. Therefore, a total of 16,521 people participated in section of 67 respondents and 946 community health workers (CHWs) were included in selection of respondents of 59 community health workers. The households targeted for the study were those who had a person who suffered from malaria in at least one year before research. In addition, community health workers and officers in charge of malaria at district hospital were selected for the study because of their knowledge of malaria.

3.6.1 Sample Size

The sample size of the study population was estimated to be 127 persons by using Alain Bouchard formula (1989, p. 30)

$$n.c = \frac{N}{1+\frac{N}{n}} \Rightarrow \frac{N}{\frac{N+n}{n}} \Rightarrow \frac{N \times n}{N+n}$$

With:

n.c = The size of the sample corrected (for the finished statistical universe)

N = The size of our statistical universe

n = The size of the sample for the finished statistical universe (Bouchard, 1989)

Table 3.1 Distribution of Individuals According To The Districts

District	Community Health Workers	Persons suffered from malaria in one month	Hospital Person In Charge of Malaria
NGOMA	946	16521	1
TOTAL	946	16521	1

Source: NISR, 2012)

Table 3.2 Distribution of Respondents by Category

Category	Number of people who can be interviewed	Number of people interviewed
CHWS	946	59
Persons Suffered by malaria	16521	67
Hospital person in Charge of malaria	1	1
Total	17468	127

Source: (NISR, 2012)

By replacing N and n by their respective values, one finds the exact value of n.c (the size of the sample).

$$\Rightarrow \frac{946x63}{946+66} = 59$$

$$\Rightarrow \frac{16521x67}{16521+67} = 67$$

The sample size of the survey was 127 individuals (59 individuals for CHWs and 67 individuals for persons who suffered from malaria as the targeted group and 1 person in charge of malaria at district level).

In order to obtain the sampling interval this formula had to be used: I = $\frac{N}{n}$ where

I= sampling interval

N= the total population

n= the sample size; then the sampling interval was: 17468/127= 138

3.6.2 Data Types Collected

The study was based on both primary and secondary data where secondary data consisted of the records from Health Medical Information System (HMIS). The variables like climatic and ecological factors (temperature and rainfall), agriculture patterns, livestock keeping, general sanitation, housing construction, distance from breeding site, human behaviour activities was collected as primary data from the field using observation and questionnaire, guided interview through group discussions.

3.6.3 Secondary Data

Secondary data were obtained from health centres and hospitals of Ngoma district through health management information system (HMIS) where clinical diagnosis cases/ data were used for general status and trend of malaria in Ngoma district. The HMIS data focused on outpatients, malaria morbidity and mortality. These data were collected for the purpose of determining the prevalence and seasonality of malaria transmission in Ngoma district- Rwanda. Data of malaria positive cases were collected from medical records of the health centres, with the name of patient's village and the period of data recording not revealed. Retrospective secondary data of hospital malaria cases and climatic factors at monthly bases for the past five years were collected to see the trend of malaria with respect to climatic factors (Rainfall and temperature).

3.7 Malaria Prevalence and Seasonality

To determine malaria prevalence and seasonality in this study, secondary data/ clinical records after diagnosis from Gasetsa HP, Gashanda HP, Gituku HC, Jarama HC, Kazo HP, Kibungo HC, Kibungo RH, Kirwa HC, Muhurire HP, Mutenderi HC, Nyagasozi HP, Nyange HC, Remera (Ngoma) HC, Rubona (Ngoma) HP, Rukira HC, Rukoma Sake HC, Rukumberi HC, Sangaza HC and Zaza (whole district's health centres, health posts and referral hospital) through HMIS were analysed using SPSS version 21 from 2012 to 2017.

3.8 Climatic and Ecological Factors Affecting Malaria Transmission

Meteorological data (rain fall and temperature) from Kibungo weather station were collected. In addition to that data from questionnaire related to determine the influence of environmental and anthropogenic factors on malaria transmission in Ngoma district, Rwanda. The factors needed from meteorological station were temperature, rainfall data which was used to correlate malaria with temperature and annual rainfall hence determining the seasonality of malaria in the study area.

3.8.1 Agriculture Patterns/Rice Farming

The data regarding agriculture patterns were collected by using observation and personal measurement of the distance between rice fields and first house and interview using guided questionnaire containing the agricultural activities, water for agriculture and irrigation, dam construction, micro-dams, rainfall collection dams, rice field and how the people living near the dams and effect of river Akagera tributaries.

3.8.2 Livestock Keeping

The data regarding livestock keeping were collected by observation looking at where and how the animals were kept, and their contribution about malaria transmission in Ngoma district. And other information were collected using questionnaires containing the type of animals, how are they being fed and time for keeping those animals and observation.

3.8.3 General Sanitation

The observation and recording of data through questionnaires relating to the cleaning of the surroundings of living house, draining and filling ditches and residual indoor spraying were collected in Ngoma district.

3.8.4 Housing Construction

Monthly visit for observation of housing and housing conditions for a period of six months for collection of data about housing and housing constructions and 10% proportional piling was used to determine the number of participants in the study through which identification of the data relating to the poor housing roof materials, poor housing wall materials, closed eaves, non-window screening and over hanging roof.

3.8.5 Distance from Breeding Site

Monthly visits of Murama and Rukira sectors for monitoring of rice growing and measurement of distance from rice field to the first house for a period of six months. The data relating to the distance from breeding sites/rice growing were collected through direct observation and measurement of distance from rice field to the first house were measured for both Murama and Rukira sectors. The data noted were the distance measured in kilometres or meters from living house and breeding sites such as swamps and rice growing fields.

3.9 Human Behaviour Activities Influencing Malaria Transmission in the Study Area

The data related to the human behaviour activities were collected through the structured questionnaire for the randomly selected sectors to identify human behaviour activities that affect malaria transmission in the study area such as bed net use, outdoor activities, traditional customs, animal keeping, cultural customs (traditional ceremonies), socio-economic activities and agriculture activities. The observation method was employed to observe use of bed nets for other purposes like chicken houses construction and fishing.

3.9.1 Bed Net Use

The data related to bed net use were collected considering the frequencies of household using the LLINs and their availability in Ngoma district and describing why some household were not using the LLINs in that district. Monthly observation visit of bed net use was conducted for a period of six months to observe use of bed nets for other purposes like chicken houses construction and fishing and some information were collected from questionnaire.

3.9.2 Night Out-Door Activities

The human night out-doors activities considered were all activities done outside the house during the night such wedding ceremonies, animal keeping, fishing, etc. Questionnaire was employed to identify different variables relating to the night out-door activities in Ngoma district.

3.9.3 Traditional Customs

The data relating to traditional customs were collected by using the questionnaire.

3.10 Strategy for Control of Malaria Transmission

Rwanda has scaled up key malaria control interventions based on scientific evidence and supported by an exemplary organization and management of the health system. The main current measures are focused on reduction of the contact between mosquitoes and humans, the destruction of larvae by environmental management and the use of larvicides or mosquito larvae predators, and destruction of adult mosquitoes by indoor residual spraying and insecticide-treated bed nets.

In order to design an epidemiological model for control of malaria transmission in the study area, new malaria control model was designed basing on the results from assessing the existing malaria control methods and examine their effectiveness and applicability. Mean ranking was used accompanied by Participatory Epidemiology (PE) and Focused Group Discussion (FGD) to rank the existing control strategies and correlation analysis was employed to explain the relationship between malaria and strategy.

3.11 Data Analysis

The data collected on malaria cases and meteorological parameters (i.e. rainfall and temperature) over the five years was managed and analysed using SPSS (statistical package for social sciences) version 20. Spearman correlation coefficient was used to quantify the strength of linear relationships between meteorological variables and malaria cases and future prediction of malaria was done.

The frequencies test, the mean ranking and Chi-Square test were used to describe variables relating to the topic such as human behaviour activities, ecological factors influencing malaria transmission, and distributions of different variables about bed net use, human behaviour activities collected through questionnaire.

All those tests were used to determine whether there is significant different between seasonal transmission and malaria outbreak and direct monthly prospective longitudinal study was carried out for a period of 12 months at household level with parallel to hospital records for understanding malaria prevalence and seasonality.

3.12 Ethical Considerations

During the whole process of collecting data, the following ethical issues were considered:

(i) Rights and confidentiality of respondents in all phases of study

(ii) Ensure informed verbal consent from men and women taken before data collection

(iii) Ensure confidentiality all findings be presented without ascribing names or identifiable personal description

(iv) For respondents not comfortable with being interviewed in English a

Translator was appointed to translate in a required language so as respondents to capture as much information as possible At institutional level, research permission (research clearance) was given to the research by The Open University of Tanzania under the statutes of the university. At the National level the mayor of the district gave the research clearance in collaboration with Rwanda Biomedical Centre (RBC), which is in control of health management information system (HMIS).

3.13 Summary

This chapter covered the methods and techniques, study design, study population, sample size, data analysis, ethical consideration of the study to be used for reaching the results and strategic model for reducing malaria transmission have been designed in this chapter.

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter presents the results of the research entitled "The influence of environmental and anthropogenic factors on malaria transmission in Ngoma District, Rwanda.

4.2 Socio-demographic Characteristics of the Respondents

Table 4.1 highlighted personal traits such as age, gender, education, occupation, marital status, and *ubudehe* and family size. (*Ubudehe* refers to the long-standing Rwandan practice and culture of collective action and mutual support to solve problems within a community) (MINALOC, 2000).

Gender of individuals who were involved in the study were identified. The findings showed that 41.7% were males while 58.3% of respondents were females. From this analysis, the females were dominant at the rate of 58.3% and the mean of 1.58 and Standard deviation of 0.495.

Age of the respondents was a crucial item that was investigated in this study. Identifying age group of respondents is important so as to have assurance that respondents are mature enough to understand the study topic and respond accordingly.

The results from Table 4.1 indicate that dominant age groups, the range of ages of 31 to 40 years were 41.7%, the range between51-60 were 12.6% and 18.9% were aged between 41-50 years old, and 4.7% of respondents were aged less than 20 years. The findings showed that the most interviewed respondents in Ngoma District were in the range of 31 to 40 (41.7%), mean of 3.22, Std: 1.147.

Education of the respondents was investigated in this study. The findings indicate that 6.3% of respondents studied primary, 73.2% of respondents studied secondary, 17.3% of respondents studied university and 3.1% of respondents attended other technical schools. The findings in Table 4.3 indicated that each interviewed person had attended school where the education of the respondents were dominated by secondary education at the rate of 73.2%, mean 3.17 and Std of 0.579.

About occupation of respondents, findings indicated that 31.5% were farmers, 9.4% were teachers, 9.4% businessmen, 28.3% were unemployed and 21.3% of respondents were occupied in other occupations, which were not indicated during the study. The findings indicated that the dominant occupation of interviewed persons were famers (31.5%) with the mean of 2.98 and Std of 1.584.

Ubudehe is the socio-economical categorization of citizens in Rwanda according to their income where category I stands for the poorer, category II for those who can survive for at least one meal per day, category III moderate income earners regardless of the salary and category, category IV is for the rich including all government officials. Findings indicated that 0.8% of respondents were in the category I, 20.5% in category II, 74% in category III and 4.7% of respondents were in category IV. The findings indicated that the majority of respondents were moderate income earners with at 74%.

The family size of the respondents was investigated and was the crucial factor to assess the local epidemiological factors affecting malaria transmission in Ngoma District- Rwanda. Findings indicate that 27.6% of the respondents had fewer than four members of family, 51.2% had 5-9 members of family and 21.3% of respondents had 10-15 members of family. The findings indicated that the majority of interviewed had family members of varying from 5 to 9 members (51.2%).

Table 4.1: Presentation of Socio-Demographic Characteristics of Ngoma District (N=127)

Gender	N	Percent	Mean	SEM	Std
Male	53	41.7			
Female	74	58.3	1.58	0.044	0.495
Age					
<=20	6	4.7			
21-30	27	21.3			
31-40	53	41.7	3.22	0.102	1.147
41-50	16	12.6			
51-60	24	18.9			
>=61	1	0.8			
Education					
Primary	8	6.3			
Secondary	93	73.2	3.17	0.051	0.579
University	22	17.3			
Others (specify)	4	3.1			
Occupation s					
Farmers	40	31.5	2.98	0.141	1.584
Teacher	12	9.4			
Businessman	12	9.4			
Unemployed	36	28.3			
Others (specify)	27	21.3			
Ubudehe categories					
Category I	1	0.8			
Category II	26	20.5			
Category III	94	74.0	2.83	0.045	0.505
Category IV	6	4.7			
Family size					
<=4	35	27.6			
5-9	65	51.2	1.94	0.062	0.699
10-15	27	21.3			

Source: Research data 2019

4.3 Malaria Hospital Admission Rates in Ngoma District

4.3.1 General Malaria Hospital Admission Rates in Ngoma District

Table 4.2 shows general malaria hospital admission rates in Ngoma district; the results revealed that malaria hospital admission rates increased from 24.2% in 2012 up to the peak 52.2% in 2014 and reduced considerable to 19.7% in 2017. In Ngoma district, 2014 experienced highest malaria hospital admission rates 52.2% due to change of temperatures and low rain.

Table 4.2: General Malaria Positivity Rate in Ngoma District from 2012 to 2017

Years	All people attended hospital and Health centres per year	Malaria positive after diagnosis per year (%)
2012	174959	42330 (24.2)
2013	318494	126182 (39.6)
2014	466758	243428 (52.2)
2015	509489	205331 (40.3)
2016	295754	52905 (17.9)
2017	370471	73155 (19.7)

Research data 2019

4.3.2 Malaria Positive Rin adults in Ngoma District from 2012 to 2017

Table 4.3 shows malaria positive rates in Ngoma district from 2012 to 2017, malaria hospital admission rates have decreased from 23.5% in 2012 to 21.5% in 2017. But before decreasing it was increase to highest peak 51.0% in 2014. From 2014 malaria hospital admission rate in Ngoma district has shown reasonably decline.

Table 4.3: Malaria Positivity Rate in Adults in Ngoma District from 2012 to 2017

Years	All people attended hospital and Health centres per year	Malaria positive after diagnosis per year (%)
2012	161505	38018 (23.5)
2013	290785	114283 (39.3)
2014	427671	218169 (51.0)
2015	472713	184378 (39.0)
2016	257909	47586 (18.5)
2017	292498	62870 (21.5)

Source: Research data 2019

4.3.3 Malaria Positivity rate in Children under Five Years of Age in Ngoma District from 2012 to 2017

Table 4.4 shows malaria hospital admission rates in children under five years of age. The results revealed that malaria hospital admission rates in children under five years of age in Ngoma district has declined from 32.0% in 2012 to 13.2% in 2017. But in 2014 Ngoma district experienced highest malaria hospital admission rates of 64.6% in children under years of age.

Table 4.4: Malaria Positivity Rate in Children under Five Years of Age in Ngoma District from 2012 to 2017

Years	All U5Y attended hospital and Health centres per year	Malaria positive after diagnosis per year (%)
2012	13454	4312 (32.0)
2013	27709	11899 (42.9)
2014	39087	25259 (64.6)
2015	36776	20953 (57.0)
2016	37845	5319 (14.1)
2017	77973	10285 (13.2)

Source: Research data 2019
(Hospital admission cases)
Source: (HMIS 2016/2017)

4.3.4 Malaria Positivity Rate at House Hold Level

Malaria information from field on house hold level. 127 families represented by head of house hold were visited by researcher, it was found out that these families had 792 family members which were grouped into two groups of under five years (U5Y) and adults.

Table 4.5 summaries the information obtained from field. It was found out that out of 147 children under five years old 59 had suffered from malaria in past 12 months prior research was conducted in the area that means malaria hospital admission rates were 40.1% for U5Y. While out of 645 adults in the study 181 had suffered from malaria in past 12 months prior the study was conducted in the area, which means that malaria hospital admission rates were 28.1% for adults.

Table 4.5: Malaria Positivity Rate at Level of Household

Family size (HH members)	Household N (%)	Frequency			Malaria prevalence	
		Adults	U5Y	S/Total	Adults	U5Y
0-4	35(27.5)	78	19	97	35(44.9)	10(52.6)
5-9	65(51.2)	331	75	406	98(29.6)	28(37.3)
10-14	27(21.3)	236	53	289	48(20.3)	21(39.6)
Total	**127**	**645**	**147**	**792**	**181(28.1)**	**59(40.1)**

Source: Field data, 2019

4.3.5 Malaria Information at House Hold Level

Table 4.6 revealed that malaria hospital admission rates were observed at household level with a mean of 1.30 and standard deviation of 0.460 and malaria was dominant in women with a mean of 1.39 and standard deviation of 0.491 and rainy season was major dominant season for the outbreak of malaria with a mean of 1.36 and standard deviation of 0.483. With January –April as the appreciated months of high malaria with a mean of 1.79 and standard deviation of 0.793

Table 4.6: Malaria Information at Household Level

Variables	N (%)	MEAN	Std Dev.
Malaria detection			
YES	89(70)	1.30	0.460
NO	38(29)		
Gender with Malaria			
FEMALE	77(60.6)	1.39	0.491
MALE	50(39.4)		
Season of malaria			
Rainy season (September to May)	81(63.8)	1.36	0.483
Dry season (June to August)	46(36.2)		
Months with malaria			
January-April	56(44.1)	1.79	0.793
May-August	42(33.1)		
September-December	29(22.8)		

4.3.6 Malaria Positivity Rate by Deasons in Ngoma District

The results revealed that malaria hospital admission rates in adults in Ngoma district is seasonal with highest peaks in October through December and April to June every year as shown in Figure 4.1 and Figure 4.2 shows monthly malaria hospital admission rates in under five years of age in Ngoma district from 2012 to 2017. In children under five years of age, the highest peaks were in months of May to June except in 2014 where October through December was highest. In other words 2014 in Ngoma district it was year of malaria.

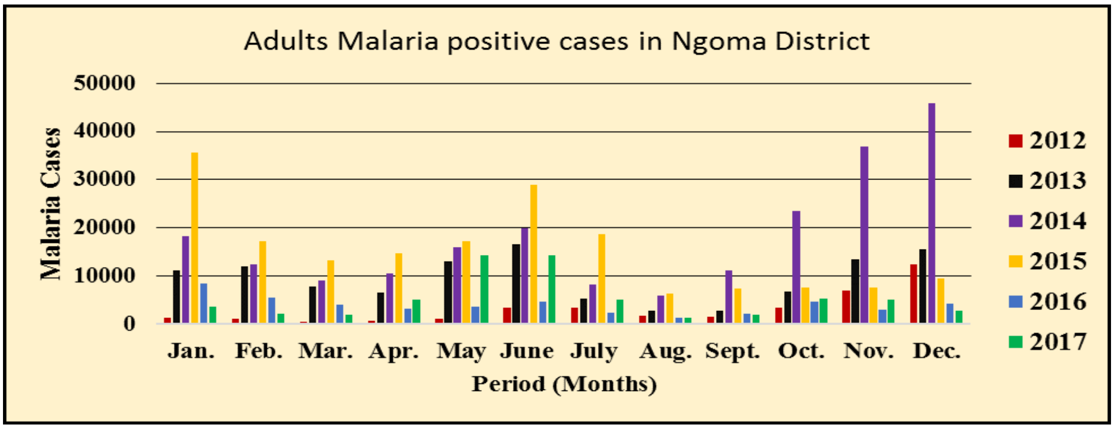

Figure 4.1: Monthly Malaria Positive Case in Adults in Ngoma District from 2012 to 2017

Source: Field data 2019

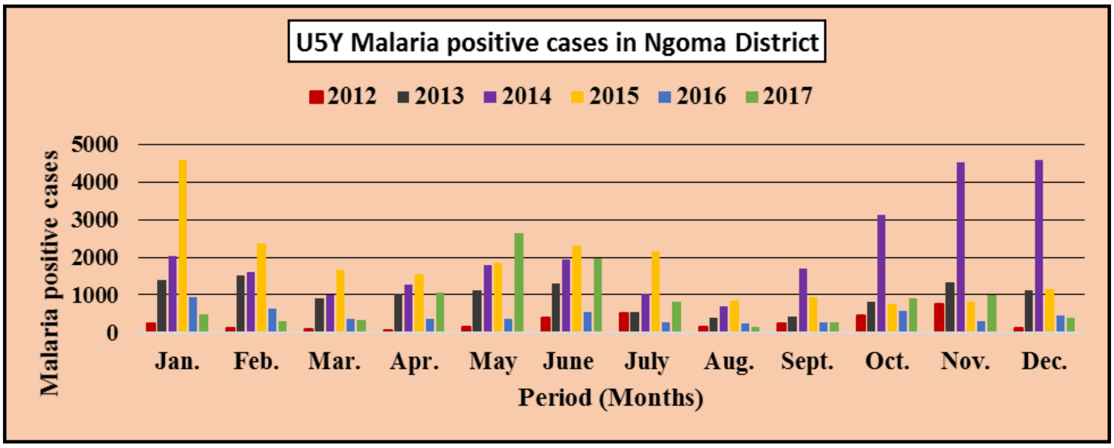

Figure 4.2: Monthly Positive Malaria Cases among Children Under Five Years of Age in Ngoma District from 2012 to 2017

Source: Field data 2019

4.3.7 Monthly Minimum Mean Temperatures from 2012 to 2017 in Ngoma District

Figure 4.3 shows the monthly minimum mean temperature in degrees Celsius and February has the lowest minimum mean temperature in general.

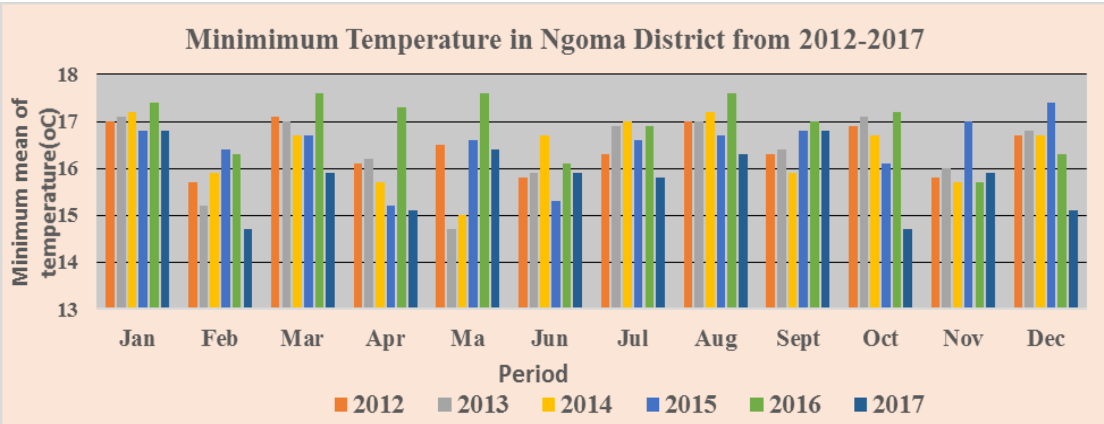

Figure 4.3: Monthly Minimum Mean Temperatures from 2012 to 2017 in Ngoma District

4.3.8 Monthly Maximum Mean Temperatures from 2012 to 2017 in Ngoma District

Figure 4.4 shows the monthly maximum mean temperature in degrees Celsius and 2015, 2016 and 2017 had highest maximum mean temperature in general.

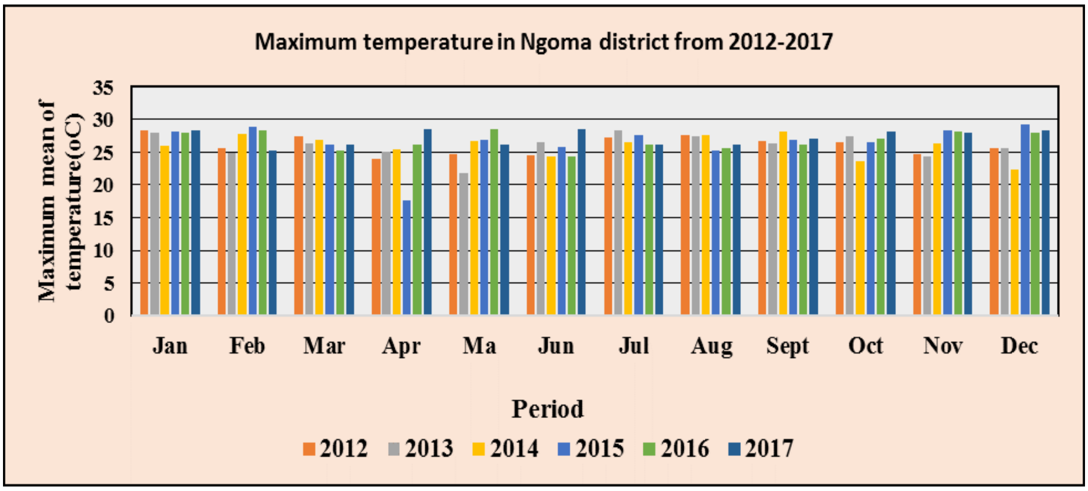

Figure 4.4: Monthly Maximum Mean Temperatures from 2012 to 2017 in Ngoma District

4.3.9 Monthly Mean Rainfall from 2012 to 2017 in Ngoma District

Figure 4.5 shows the monthly mean rainfall in Ngoma district, where March April has heavy rainfall and again heavy rainfall comes back in September through November and December the rain starts decreasing and this has resulted in high malaria positive rate in the study area. Because as heavy rain stops as short dry season is coming there was a lot of mosquitoes hence more bites and increase in malaria positivity rate.

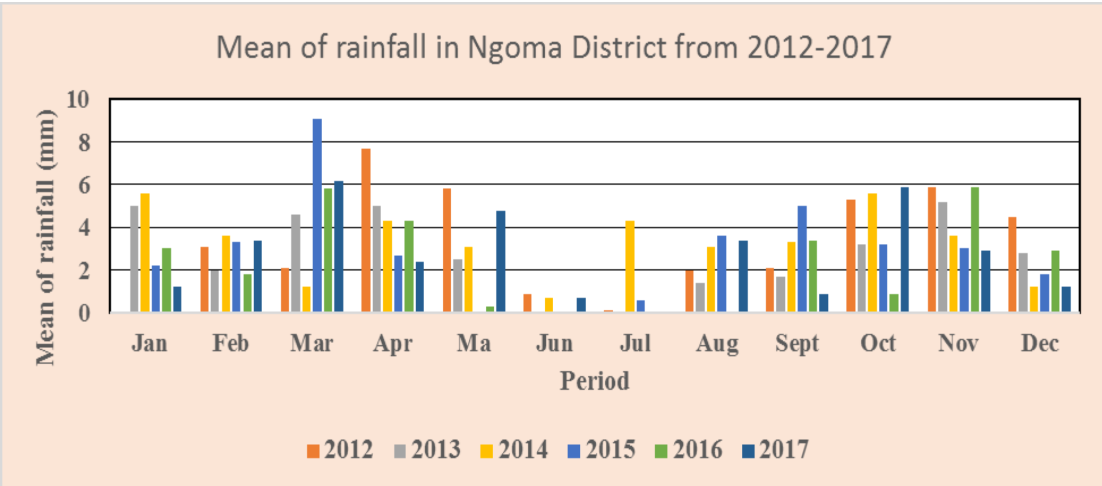

Figure 4.5: Monthly Mean Rainfall from 2012 to 2017 in Ngoma District

Source: Field data 2019

4.4 Awareness of Night-Time Outdoor Activities that Contribute to the Risk of Malaria Infection

Table 4.7 highlights the night-time outdoor activities that contribute to the risk of malaria infection. This analysis employed Friedman Test and was done through the use of a 10 points Liker scale ranging from 1 very important through 10-least important and according to this scale the lower the mean the higher the importance attached by respondents to a given night-time outdoor activities.

A non-parametric test (Friedman's Test) was used to rank the different night-time outdoor activities involving respondents as regards the most common night-time outdoor activities that contributed to the risk of malaria infection. The most appreciated night-time outdoor activities were evening parties (Chi-squared value 184.068, p=0.000) where it is ranked by 3.57.

Table 4.7: Human Night-time Outdoor Activities Leading to the Risk of Malaria Infection

Variables	Mean Rank	Std	Chi(X^2)	Df	P	(N=127)
Evening parties and out sleeping,	3.57	0.492	184.068	9	0.000	
Wedding	5.85	0.350				
Ceremony after harvesting season	5.78	0.366				
Sports watching	5.66	0.387				
Hunting,	5.46	0.416				
Guarding property	5.26	0.440				
Funerals	6.41	0.175				
Small business	6.01	0.314				
Cooking outside at night hours	4.99	0.466				
Others (Fishing)	6.01	0.314				

Friedman test

Source: Research data (2019)

4.5 Mosquito Avoidance Behaviour

The use of malaria vectors preventive measures and ownership of bed net in Ngoma District. Table 4.8 presents the use of preventive measures to reduce transmission of malaria in Ngoma District. This analysis was done using Friedman Test through the use of a different points Liker scale ranging from 1 very important through least important and according to this scale the lower the mean the higher the importance attached by respondents to the use of available preventive measures that affect malaria transmission. A non-parametric test (Friedman's Test) was used to rank the different parameters regarding the use of available preventive measures that affect malaria transmission. Table 4.8 shows that the most common available preventive measure was IRS (In door residue spraying) (Chi-squared value 132.704, p=0.000) where it is ranked by 1.70±0.373.

Table 4.8: Malaria Vectors Preventive Measures

Variables	Mean Rank	Std.Dev	Chi(X2)	Df	P (N=127)
Bed net use	2.54	0.466			
Treated net use	1.76	0.449			
IRS	1.70	0.373	132.704	2	0.000

Friedman Test

Source: Research data (2019)

The next Figure 4.6 highlighted the frequencies of respondents presenting the use of bed net. The results indicated that 81% of respondents use bed nets in Ngoma District while 19% of respondents did not use bed nets in Ngoma District. Which is contrary to direct observation where 72% of the visited households had bed nets but in different modes (some were torn other in good conditions) and only 28% had no bed net in any mode. But out of 72% who had bed nets some of the bed nets were used in making chickens houses and others in making green gardens.

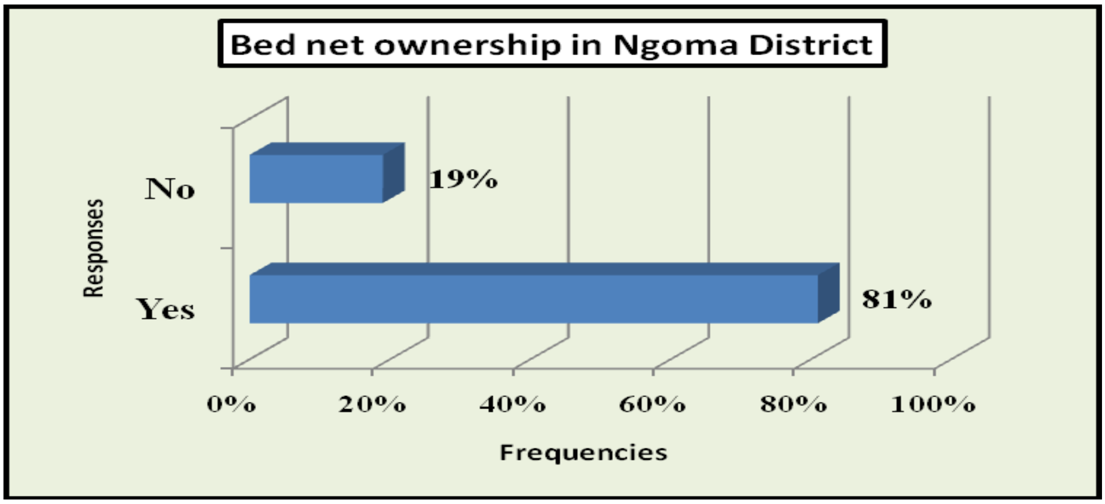

Figure 4.6: Bed net use in Ngoma District

According to Table 4.9, bed nets are insufficient in the study area where bed net per at least two persons is at 25% and families have more than four members sleeping under one mosquito net is 36%, which increases risks for mosquito bites to persons at the end of the bed hence increasing malaria in the area.

Table 4.9: Observation of Distributed Bed Net use in Ngoma District

Bed net	1 person (%)	2 persons (%)	3 persons (%)	4 and above persons (%)
1 Bed net	7 (6)	23 (19)	47 (39)	43 (36)
Family size	0 (0)	13 (11)	31(26)	76 (63)

Source: Observation Field data 2019

Reasons for not owning the Bed nets and LLINs

The findings from the Table 4.10 indicated the reason for not having LLINs. 41.7% of respondents said that they were not available, 19.7% of respondents said that they were unaffordable, 7.9% of respondents said that unavailability of mosquitoes and 19% of respondents said that they are used for other purposes such as fishing (6.3%) of respondents and other reasons such as making chicken house or green garden 24.4% of respondents. The main reason for not owning the LLINs shown in the findings is that the LLINs were not available as noted by 41.7% of the respondents in Ngoma District.

Table 4.10: Reason for not Owning LLIN in Ngoma District

Variables	N	%	Mean	Ch-X^2	SEM	Std	Df	P
Not available	53 (127)	41.7	3.15	22.965[a]	0.039	0.440	5	0.000
Unaffordable to buy	25(127)	19.7	3.50		0.031	0.350		
Old; then thrown away	10(127)	7.9	3.69		0.024	0.270		
Used for fishing	8(127)	6.3	3.74		0.022	0.244		
Making chicken house or green garden	31(127)	24.4	3.43		0.033	0.373		

Friedman Test

Source: Research data (2019)

Perception (attitude) of respondents about bed net use in Ngoma District

The findings presented in the Table 4.11, indicated the reason for not using the bed net in Ngoma District. The findings regarding the reasons for not using LLINs shown in Table 4.11 indicate that 29.9% of the respondents agreed that the housing types and structures affects bed net use, while 7.1% said that LLINs were absent. 57.5% of respondents said that they afraid of it toxicity. 3.1% of respondents said that weather was not conductive, and 0.8% of respondents said bed nets did not prevent malaria. 1.6% of respondents gave other reasons. The main reason for not using available LLINs as shown in the findings was fear of toxicity (40.2%) with Chi-square of 140.626 and $p<0.001$

Table 4.11: Reasons for not using the available LLINs

Variables	N	%	ChX^2	Std	Df	P
Housing type and structure affects the net use	38 (127)	29.9		0.416		
Absence of beds	9(127)	7.1		0.258		
Afraid of its toxicity	73(127)	57.5	140.626	0.492	5	0.000
Weather not conducive	4(127)	3.1		0.175		
Nets do not prevent malaria	1(127)	0.8		0.089		
Mosquito nets are hot	2(127)	1.6		0.125		

Source: Research data (2019)

4.6 Agricultural Patterns

In this study, the agricultural patterns considered were irrigation, rice field and distance from the farms.

4.6.1 Perception (Attitude) of Respondents about Irrigation and use of Water for Agriculture in Ngoma District

The most irrigated land in Ngoma district is not large because there are two main irrigation schemes in Rukira and Murama sectors.

Photo 4.1: Rice Growing in Rukira Sector with Dam for Irrigation

Photo 4.2: Rice Farming in Murama Sector

Table 4.12 indicates the attitude of respondents about irrigation and use of water for agriculture as a factor of malaria transmission in Ngoma District. Those factors were dam construction (13.4%), living near dams (8.7%), field for rice (55.9%), micro-dams (5.5%) and rainfall collection ditches (16.5%). The dominated factor of malaria transmission is rice farming and river Akagera tributaries (55.9%).

Table 4.12: Attitude of Respondents about Irrigation and use of Water for Agriculture and Malaria Transmission

Variables	(N=127)	%	Ch-X^2	Df	P
Dams construction	17	13.4			
Living near dams	11	8.7			
Rice field and water of river Akagera tributaries	71	55.9	46.977	4	0.000
Micro-dams	7	5.5			
Rainfall collection ditches	21	16.5			

Source: Research data (2019)

4.6.2 Distance from Homesteads to Mosquitoes Breeding Sites

The distance from breeding site to homesteads varies from home to home. Some are near breeding sites and others are far away.

Photo 4.3: Residents around Rice Farming in Rukira where First House is found in 2Km and 125 Meters from Rice Fields

Photo 4. 4: Residents around Rice Farming in Rukira Sector where the First House is found at 317 Meters from Rice Fields

Photo 4.5: Settlement around Rice Farming in Murama Sector where the First House Is found in 427 Meters from the Rice Farming

Table 4.13 highlights the distance from homesteads to mosquitoes breeding sites in Ngoma district. The findings indicated that 53.5% of the respondents lived over 3 km from the sites, 12.6% of the respondents lived exactly 3 km from the site, 20.5%

of respondents lived less than 3 Km and 13.4 % of respondents lived far away from breeding site (Rice farming). The results indicated that the distance from living areas was over three km (53.5% of the respondents) to mosquitoes breeding sites. But 20.5% of the respondents live less than 3Km and this may cause more mosquito bite hence increasing malaria in the area.

Table 4.13: Distance from the Rice Fields (as Breeding Sites)

Variables	N	Percent	Mean	Std	SEM	Variance
>3 Km	68	53.5	1.94	1.132	0.100	1.282
Exactly 3 Km	16	12.6				
< 3 Km	26	20.5				
Far away	17	13.4				
Total	**127**	**100.0**				

Source: Research data (2019)

4.7 Relationship between Housing Construction and Malaria Transmission in Ngoma District

Table 4.14 highlights the attitude and perception of the respondents about housing construction in relation to malaria transmission in Ngoma District. The poor roofing materials was reported by 4.7% of respondents, poor housing walls materials by 16.5%, closed eaves by 11%, non-windows screening by 62.2% and over hanging roof by 5.6% of respondents. The findings indicated that malaria transmission was significantly associated with non-windows screening 62.2% of respondents in Ngoma District (p = 0.0).

Table 4.14 shows that out of 120 houses visited during this research, 87 houses were good representing 73% and 33 houses were poor (27%). A cemented house was considered as good and non-cemented was considered as poor in this study.

Table 4.14: Observed Housing Construction in Ngoma District

Variables	N	%	Ch-X^2	Df	P
Poor housing roof materials	6	4.7			
Poor housing walls materials	21	16.5			
Closed eaves	14	11			
Non windows screening	79	62.2	271.342	4	0.000
Over hanging roof	7	5.6			

Source: Research data (2019)

Photo 4.6: Non-cemented Poor House in the Study Area

Photo 4.7: Cemented Good House in the Study Area

Table 4.15 shows visited houses for observation of window screening and open eaves. According to the observed housing conditions in Ngoma district, 95% of the visited houses had no window screening, 93% had no ventilation screening and 92% of the houses visited had open eaves. All these contribute to mosquito increase in the house hence increasing mosquito bite and malaria.

Table 4.15: Visited Houses in the Study Area with Respect to their Conditions

House features	Number of house with (%) N=120	Number of houses without (%)
Window screening	6 (5)	114 (95)
Ventilation screening	8 (7)	112 (93)
Open eaves	110 (92)	5 (8)

Source: Field Observation data (2019)

4.8 Perception and Attitude about General Sanitation for Malaria Transmission in Ngoma District

The Table 4.16 highlights the different views about general sanitation as the factor of malaria transmission in Ngoma District. The findings indicated that cleaning bushes surrounding the houses was reported by 55.9% of respondents, draining and filling ditches by 30.7% and indoor residual spraying by 13.4% of respondents. The results indicated that to clean the bushes surrounding the living houses 55.9% of respondents, have an impact of reducing malaria transmission in the study area.

Table 4.16: Perception and Attitude of Respondents about General Sanitation in Ngoma District

Variables	N	%	Ch-X^2	Df	P
Cleaning surrounding	71(127)	55.9	19.500	2	0.000
Draining & filling ditches	39(127)	30.7			
Indoor residual spraying	17 (127)	13.4			

Source: Research data (2019)

4.9 Perception and Attitude of Respondents about land use Patterns as a Factor of Malaria Transmission in Ngoma District

The Table 4.17 indicated that agriculture activities 59.1% of respondents such as some plant planted near the houses attract mosquitoes. 25.2% of respondents attached their responses to swamps created and afforestation, 15.7% of respondents. Those variables indicated as the factors for malaria transmission. The findings indicated that agriculture activities (59.1%) is the main factor of land use in Ngoma district that influence the malaria transmission due to swamps created for agriculture mainly rice growing in the district.

Table 4.17: Perception and Attitude of Respondents about Land use Patterns in Ngoma District

Variables	N=127	%	Ch-X^2	Df	P
Agriculture activities	75(127)	59.1	51.941	2	0.000
Swamps created	32(127)	25.2			
Afforestation	20(127)	15.7			

Source: Research data (2019)

4.10 Livestock Keeping Practices Influencing Malaria Transmission in Ngoma District

In this section the results included the types of animals kept, the number of animals kept per house, where those animals are kept (kept indoors or outdoors) and the distance of outdoors animals sheds.

The Table 4.18 indicated the overview of livestock practice influencing malaria transmission in Ngoma District. The most kept animals in the district are cows representing 63.8% and 19.7% of the reared animals are goats, sheep were 7.1% and

Poultry was 9.4%. The findings have shown that in Ngoma District, all types of animals were kept and significantly dominated by the cows 63.8% (Chi-square: 81.506, Std. Dev.=0.489 and p:0.000). About the number of animals kept per house in Ngoma District. From this study, the respondents said that 42.5% had less than 2 animals at their homes, 37.8% of respondents had between three to five animals at their houses and 19.7% of respondents had over six animals at their houses.

About how the animals were kept in Ngoma District. From this study, the respondents said that 23.6% keep the animals outdoor, 45.7% of respondents keep the animals indoor and 30.7% of respondents keep the animals in both outdoor and indoor.

Table 4.18: Livestock and Malaria Transmission in Ngoma District

Variable	% (N)	Chi-X^2	Std Dev.	Df	P
Type of animal kept					
Cows	63.8 (81)	81.506	0.489	3	0.000
Goats	19.7(25)		0.342		
Sheep	7.1(9)		0.213		
Chicken/Poultry	9.4(12)		0.333		
Animal kept per house					
< 2 animals	42.5	NA	0.758	NA	NA
3-5 animals	37.8				
Over 5 animals	19.7				
Kept indoors or outdoors					
Kept outdoor	23.6	NA	0.737	NA	NA
Kept indoor	45.7				
Both	30.7				
Distance of outdoors animal sheds					
< 50 M	48.8	NA	0.737	NA	NA
50-100 M	35.5				
> 100 M	15.7				

NA: Not Applicable

Source: Research data (2019)

And the distance of animals' shed in Ngoma District according to the study, 48.8% of the respondents said distance was less than 50 meters, 35.5% of respondents, said that distance was between 50 to 100 meters and 15.7% of the respondents said that distance was over 100 meters.

4.11 Demographic Characteristics and Malaria Prevalence

4.11.1 Age and Bed Net Use

The Table 4.19 shows the relationship between the age and bed net use in Ngoma district regarding to the malaria transmission. It is highly noted that the people of the range of age from 31 to 50 years old use bed net during sleeping. The findings show that the children are at risk of being infected with malaria.

Table 4.19: Cross Tabulation of Age and Bed Net use in Ngoma District

		Bed net use		**Total**
	Years of households	**YES**	**NO**	
Age	<=20	0	6	6
	21-30	1	26	27
	31-40	9	44	53
	41-50	9	7	16
	51-60	1	23	24
	>=61	1	0	1
Total		**21**	**106**	**127**

Chi-Square Tests

	Value	**Df**	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	30.411[a]	5	0.000
Likelihood Ratio	26.814	5	0.000
Linear-by-Linear Association	3.037	1	0.081
N of Valid Cases	127		

a. 6 cells (50.0%) have expected count less than 5. The minimum expected count is .17.

4.11.2 Education and Bed Net Use

The Table 4.20 shows the relationship between the education and bed net use in Ngoma district regarding to the malaria transmission. It is highly noted that the majority of interviewed people which have attended secondary school did not use bed net during night time. Therefore, education has no influence on the use of bed net in Ngoma district.

Table 4.20: Education and Bed Net use Cross tabulation

		bed net use		Total
		YES	NO	
Education	Primary	1	7	8
	Secondary	12	81	93
	University	7	15	22
	Others (specify)	1	3	4
Total		**21**	**106**	**127**

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.914[a]	3	0.178
Likelihood Ratio	4.331	3	0.228
Linear-by-Linear Association	3.242	1	0.072
N of Valid Cases	127		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .66.

4.11.3 Sex and bed net use

The Table 4.21 shows the relationship between the gender and bed net use in Ngoma district regarding to the malaria transmission.

It is highly noted that the majority of interviewed people are females which did not use bed net during night time. The number of interviewed were using bed net were still few, that should result to the increasing of malaria prevalence. Therefore, gender has no influence on the use of bed net in Ngoma district.

Table 4.21: Gender and bed net use Cross tabulation

Gender	**Bed net use**		
	Yes	**No**	**Total**
Male	10	43	53
Female	11	63	74
Total	**21**	**106**	**127**

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.359[a]	1	.549
Likelihood Ratio	.355	1	.551
Linear-by-Linear Association	.356	1	.551
N of Valid Cases[b]	127		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.76.

4.11.4 Family Size and Bed Net Use

The table 4.22 shows the association of family size and bed net use in Ngoma district.

The findings show that the families with 5 to 9 members did not try to use bed net during night. The non-use of bed net during night has influences on high prevalence of malaria in Ngoma district during the period of the study.

Table 4.22: Family Size and Bed net use Cross Tabulation

		bed net use		
		Yes	**No**	**Total**
Family size	<=4	4	31	35
	5-9	13	52	65
	10-15	4	23	27
Total		**21**	**106**	**127**

Chi-Square Tests

	Value	**Df**	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	1.285[a]	2	.526
Likelihood Ratio	1.323	2	.516
Linear-by-Linear Association	.205	1	.651
N of Valid Cases	127		

a. 1 cells (16.7%) have expected count less than 5. The minimum expected count is 4.46.

4.11.5 Socio-economic Status and Bed Net Use

The Table 4.23 indicated that relationship between the ubudehe category and bed net use in Ngoma district. As the ubudehe category is based on the income of the population, two first category did not use the bed net. Although, third category included many people in Ngoma district, the majority of this category also did not use the bed net properly during night period which increase the prevalence of malaria in Ngoma district as suggested by chi-square test were significantly ($P<0.05$ at 5% level of significance).

Table 4.23: Cross Tabulation of Ubudehe Category and Bed Net use in Ngoma District

	bed net use		
Ubudehe category	**Yes**	**No**	**Total**
Category I	1	0	1
Category II	1	25	26
Category III	19	75	94
Category IV	0	6	6
Total	**21**	**106**	**127**

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.191[a]	3	.017
Likelihood Ratio	10.800	3	.013
Linear-by-Linear Association	.091	1	.763
N of Valid Cases	127		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .17.

4.12 Waste Disposal Management and Malaria transmission

The Table 4.24 presents the findings relating to the management of the waste disposal in Ngoma District and malaria transmission.

The findings show that the waste is deposited near the living house at the rate of 52.8%, the waste is collected in sacs (63.8%), the type of waste commonly available in Ngoma District is un used basins (28.3%) and the frequency of waste collection is described as every day at the rate of 44.1%.

Table 4.24: Description of Waste and Malaria Transmission in Ngoma District

Variables	N (%)	Ch-X2	Std Dev.	Df	P
Where the waste is deposited					
Near the living house	67 (52.8)	0.386	0.501	1	0.535
Far the living house	60 (47.2)				
Waste is collected in					
Polythene bags	23 (18.1)				
Cut jerry cans	18 (14.2)				
Sacs	81 (63.8)	107.299	0.834	3	0.000
Others	5 (3.9)				
Type of waste commonly available					
Broken glasses	32 (25.2)				
Broken pots	22 (17.3)				
Unused basins	36 (28.3)	19.024	1.253	4	0.001
Cut jerry cans	29 (22.8)				
Others (specify)	8 (6.4)				
Frequency of waste collection					
Daily	56 (44.2)	35.677	1.098	3	0.000
Weekly	38 (29.9)				
Monthly	12 (9.4)				
Never	21 (16.5)				

4.12.1 Consideration of Waste Disposal as Breeding Site of Mosquitoes

The respondents considered this as: strongly disagree (3.1%), disagree (11.8%), agree (14.2%) and strongly agree (70.9%).

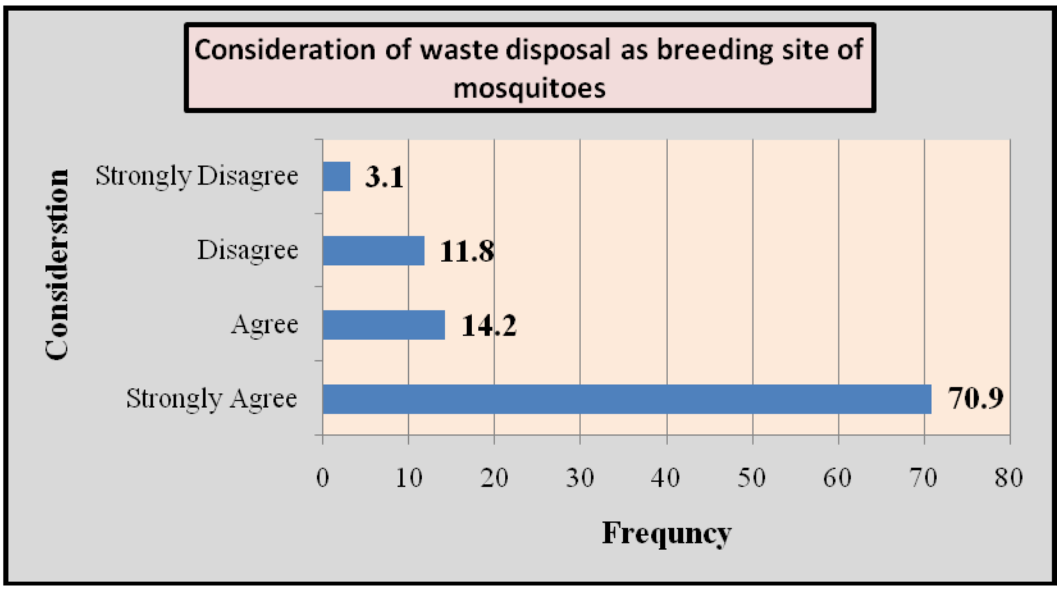

Figure 4.7: Consideration of Waste Disposal as Breeding Site of the Mosquitoes

4.13 Strategy for Control of Malaria Transmission

Direct logistic regression was performed to assess the impact of a number of factors on the likelihood of reducing malaria burden.

Table 4.25: Table Presenting the Strategy Control for Malaria Transmission Reduction

							95.0% C.I.for EXP(B)	
	B	S.E.	Wald	df	P	Odds Ratio	Lower	Upper
Bed net use	.21	1.4	.02	1	.88	1.23	.08	19.67
Agriculture activities	-.96	.10	.92	1	.34	.38	.05	2.72
Distance from breeding sites	-2.75	.77	12.90	1	.00	.06	.01	.29
Housing construction	-.02	.61	.00	1	.97	.98	.30	3.25
Livestock Keeping	2.92	1.28	5.26	1	.02	18.62	1.53	226.55
Night time Outdoor behaviour	.18	.43	.18	1	.67	1.20	.52	2.75
Constant	.02	1.32	.00	1	.99	1.02		

Logistic Regression predicting likelihood of reducing malaria burden

Further analysis shows

Table 4.26 shows the full model being tested as it is shown below

$$ln\left(\frac{P}{1-P}\right) = -0.601 - 2.739D + 2.586L$$

Where P= Probability of occurrence

D= Distance from breeding site

L= Livestock keeping

Table 4.26: Variables in the Equation with Significant Contribution

								95.0% C.I. for EXP(B)	
		B	S.E.	Wald	df	P	Odds Ratio	Lower	Upper
Step 1[a]	Livestock Keeping	2.586	.688	14.118	1	.000	13.281	3.446	51.187
	Distance from breeding sites	-2.739	.597	21.028	1	.000	.065	.020	.208
	Constant	-.601	.896	.450	1	.502	.548		

a. Variable(s) entered on step 1: livestock keeping and

The strategy contained six variables (bed net use, agriculture activities, and distance from breeding sites, housing construction, livestock keeping and night time outdoor behaviour). The full model containing all factors was statistically significant, Chi-square (6, N=127) = 32.178, $p < 0.001$, indicating that the strategy was able to distinguish between factors that may reduce malaria burden and those that may not reduce malaria burden. The strategy's ability of reducing malaria burden was explained between 22.4 % (Cox & Snell R Squared) and 30.1% (Nagelkerke R Squared) of the variance and correctly classified 74.0% of cases.

As shown in the Table 4.25 only two factors statistically contribute much to the model (Distance from breeding sites and Livestock Keeping). The strongest contributing factor was livestock keeping with an odd ration of 18.62. This indicated that keeping away livestock from houses was almost 19 times more likely to reduce malaria burden controlling other factors in the strategy. The odds ratio of .06 for distance from breeding sites was less than 1, indicating the .06 times less likely to reduce malaria burden making other factors constant.

The implementation and management of malaria prevention measures by combining various parameters such as distance from breeding sites and livestock keeping at the high rate and enforcing bed net use and house window screening should properly lead to reduction of malaria burden in Rwanda.

Sustainable Malaria control strategy

From this study bellow malaria strategy was adopted due to more influential factor that were shown by the study. Venn-diagram below shows four factors which are more influential in the study area and how this can be control.

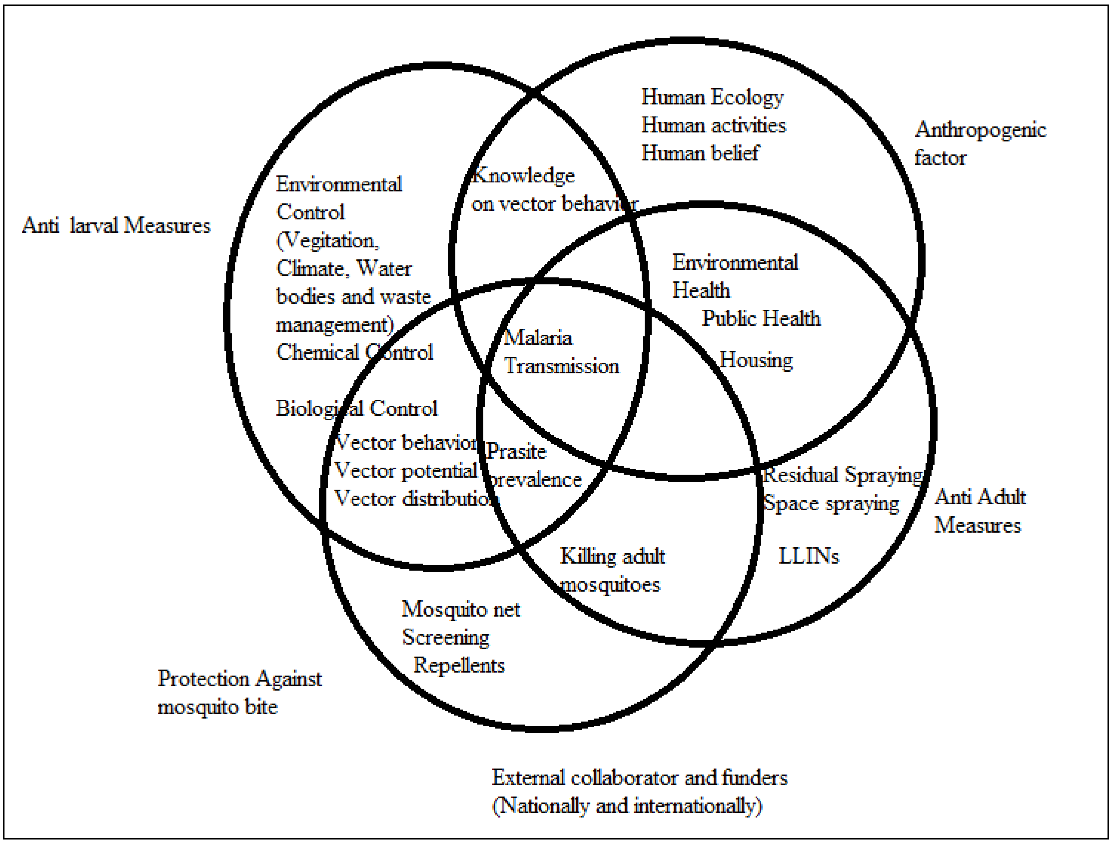

Figure 4.8: Sustainable Malaria Control Strategy

Source: Field data 2019

The best way of combating malaria is the control of the following four parameters protection against mosquito bite, anti-adult measures, anti-larval measures and anthropogenic factors control and effectively monitoring of these factors affect the control strategies and their implementation at both local level and national level.

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the discussions of the results of the study titled "Assessment of local epidemiological factors affecting malaria transmission in Ngoma District-Rwanda. The discussion is based on the results and other similar researches done on the topic in different countries. Finally, this led to the conclusion and recommendations.

5.2 Discussion

5.2.1 Malaria Prevalence in Adults and Children under Five Years from 2012 to 2017 in Ngoma District

The findings of the current study showed that, the malaria prevalence for adults continued to decrease from 23.5% in 2012 to 21.5% in 2017 with sharp decline in 2016 at 18.5%, and increased for children from 32.0% in 2012 to 64.6% in 2014. But it decreased sharply to 13.2% in 2017. This increase in malaria prevalence in adults was due to the fact that more emphasis was being put for children under five years of age (President's malaria initiative, Rwanda, 2017). And this can be explained by the results in 2017 where prevalence in adults was 18.5% and 13.2% for children under five years lowest in 2017. These results are similar to various reports studies on malaria in Rwanda (President's malaria initiative, Rwanda, 2017) as reported from RBC that say that from 2009 to 2011, there was a steep decline in total malaria cases reported at 45% decline in the number of malaria deaths, and a 75% decrease in the test positivity rates and this declining was due to different application of taken measure by community health workers (CHWs) such as testing malaria regularly at the village level and distribute the medicine at the same level. Since 2011, the number of cases has increased 11 fold (President's malaria initiative, Rwanda, 2017). This increase in malaria prevalence from 2011 to the present could be explained by the increase in numbers of malaria cases treated through health facilities and home-based management by community health workers (CHWs) for all age groups. A total of 3,324,678 (71%) cases were treated in health facilities, while 1,345,009 (29%) were treated through CHWs. Treatment of adults at community level was extended in all 30 districts in October 2016 (Rwanda Ministry of Health, 2016).

Reports from Burundi, a neighbouring country with almost similar transmission characteristics, indicate that 3.9 million people were infected by malaria during the same period (Keiser *et al.,* 2016). Furthermore, WHO (2016) observed that malaria remains an acute threat to public health, particularly in sub-Saharan Africa, home to 90% of the world's malaria cases.

According to a retrospective studies done in Tubu village of Botswana in 2016 showed that malaria prevalence was high in >5 years (adults) for five consecutive years and this was similar to results from Ngamiland district, Botswana where malaria was higher in old age (>5Years) (Chirebvu *et al.,* 2016). And this evidence that the area has low transmission rate because where there is high transmission rate malaria prevalence is high in young of <5years (Ndenga *et al.,* 2016). This is similar to the results of last two years where under five years of age prevalence is lower than adults' prevalence in the study area. Contrary with the results from HMIS that showed that malaria hospital admission rates of U5Y is higher than that of adults and it is high in Ngoma district.

5.2.1.1 Relationships between Malaria Prevalence and Rainfall

Again, the increase in malaria prevalence reported above could be explained by the conducive rainfall patterns observed. Results of the present study shows that there is a significant relationship between malaria prevalence and the annual rainfall patterns as observed from 2012 to 2017. This means that mosquito density rises soon after the start of the sunny season, because the rains provide good breeding sites for mosquito vectors. According to the results of the present study, it is clear that when rainfall decreases, malaria cases increases for adults and children of less than 5 years of age. Similarly to the results a study done by Odongo *et al.,* (2005) on the relationship between malaria infection intensity and rainfall pattern in Entebbe Peninsula, concluded and confirmed that rainfall patterns influence parasite density and present study, revealed that 2015 malaria peaks were observed in January-February and then May-June which was similar to study done by Lameck *et al.,* 2018 in Kigali Rwanda, where malaria occurs during when rainfall was low. That is to say the brief short dry/low rain period that follows heavy rains in October-December and March-April respectively.

A previous study done in Rwanda by Asingizwe *et al.,* 2015 reported that the rainfall can flush away breeding habitats temporarily, but mosquitoes start to breed as soon as the rains stop. In most cases, flushing has a bigger impact on vector breeding habitats in the highlands and hilly areas than in the lowland plains. Not all water collections are suitable for the mosquito life cycle. In Rwanda, rain water bodies are the most important breeding grounds, as the anopheline mosquitoes prefer to breed in fresh water collections created after the rainy season. Such water bodies may be clear or muddy but they are not polluted (Asingizwe *et al.,* 2015).

Therefore, there are also places where the rainfall is not abundant and drought can favour mosquito breeding and malaria transmission. Such places are usually covered by vegetation throughout the year and where streams and rivers often flow rapidly. When the rains fail or are delayed, the flow of streams is interrupted and pooling occurs along the streams. Pooling creates favourable environment for mosquito breeding. Malaria vectors mainly breed in stagnant water collections, rarely in slightly moving waters and never in rapidly flowing rivers and streams (Chirebvu *et al.,* 2016).

Other studies done elsewhere, observe that rainfall can also affect malaria transmission indirectly through its effect on humidity. Generally, vegetation covers add moisture in the air by transpiration and help in lowering temperature, thus increasing precipitation. The moist environment and breeding sites created by rainfall increase vector population, their longevity and hence increase malaria transmission (Van Geertruyden *et al.,* 2005; Walker *et al.,* 2013).

5.2.1.2 Relationship between Malaria Prevalence with Temperature

The findings indicate that there were no significant temperature variations during the period from 2012 to 2017. The average temperature in 2012 varied from 20.1 ^{o}C to 21.3 ^{o}C in 2014 while in 2015 the average temperature was 19.4 and in 2016 increased to 22.0 while in 2017 the average temperature was 17.9 ^{o} C. Previously published scientific studies put the optimal temperature for malaria transmission from mosquitoes to humans at 31 °C. However, according to a new mathematical model, the temperature for peak transmission of the parasite, *Plasmodium falciparum*, is much lower at temperatures less than 28 °C (Erin et *al.,* 2012). The present study reports high malaria prevalence at temperatures between 17.9 °C to 22.0°C. Therefore the present, further provide new knowledge on the continuing decreasing optimum temperature for malaria transmission.

Stive (2006) reported that temperature changes can affect the risk of malaria in populations living 1,200 metres above sea level. Many millions of people in the tropics live at higher altitudes because they have been historically at lower risk of malaria and other tropical diseases. For instance, 43 per cent of Ethiopia's population live in the Debre Zeit region, at an elevation of between 1,600 metres and 2,410 metres (Stive 2006). The Present study was conducted in Ngoma district, Rwanda which has an altitude which ranges from 1,400 to 1,700 m above sea level and still experiences malaria outbreaks with low temperatures below optimal for malaria transmission. Given that hundreds of millions of cases of malaria are reported in the tropics and subtropics each year, new control strategies that can effectively combat malaria in high altitude areas such as Ngoma district in Rwanda.

Caminade *et al.,* 2014 identified temperature, rainfall and humidity as the major climatic factors greatly influence the pattern and level of malaria transmission in Rwanda. However, In Rwanda, malaria transmission cannot be attributed to one factor; many factors play a role in the distribution and reoccurrence of malaria epidemics (Bizimana, 2014b). Apart from climatic factors, agricultural (irrigation) and land use patterns, have also been considered the major causes of increased malaria in the area (Van Geertruyden *et al.,* 2005).

Most countries in Sub-Saharan Africa have annual mean temperatures between 20 and 28°*C*. It is likely that, regions with temperatures below 18°*C*, as is typical for the highland areas of East and Southern Africa, which are too cold for malaria transmission, might experience more malaria if their temperatures increase. However, malaria transmission depends on many other factors such as human, behaviour, agriculture activities, mode of housing construction, educational level, and access to medical care, host immunity and malaria control measures (Lunde *et al.,* 2013).

According to Rajini *et al*., 2017, noted that the environmental factor is also another contributing factor; after rainfall once there is water accumulation in buckets, old tires, or containers, there is a likelihood of creating suitable breeding sights for mosquitoes. Weeds, overgrown grasses and bushes can also contribute to breeding sites hence increasing malaria possibilities and is a major issue in Guyana.

5.2.1.3 Relation between Land use Patterns and Malaria Transmission in Ngoma District

The present study has indicated that land use factors favourable for malaria transmission in Ngoma District were the agricultural activities (rice farming). The findings of this study are similar to the studies done in Kenya by Afrane *et al*., (2011) who observed that survivorship rate of mosquito in farmland habitats was significantly greater than those in swamps and forests. Their study recommended that deforestation and cultivation of natural swamps in the western Kenyan highland create favourable conditions for the survival of *An. Gambiae* larvae, and consequently increase the risks of malaria transmission to the human population (Afrane *et al.,* 2011).

Other land cover changes such as swamp reclamation have been shown to have similar effects as deforestation on malaria vectors development. This has the potential to increase the population of mosquitoes and to which could also potentially cause an increase in malaria transmission if infected humans are available (Kovats *et al.,* 2016). The present study has found that cultivation of natural swamps for rice growing has created favourable conditions for larvae survival and consequently increasing malaria transmission. On the other hand, irrigation agriculture keeps more challenges to community as far as the malaria is concerned worldwide and Africa in particular as a result of agriculture promotion. For malaria control in the irrigated areas need to drain out dams every month especially during dry months (Keiser *et al.,* 2005: Wielgosz *et al.*, 2012). An estimated 40,000 large dams and 800,000 small dams have been built, and 272 million hectares of land are presently under irrigation worldwide. The creation and operation of water projects has had a history of enabling modification in the occurrence and transmission dynamics of malaria, but analyses of these environmental risk factors are thin. Several studies have revealed that the development of irrigation schemes in sub-Saharan resulted in the increase of malaria risk through creating favourable breeding sites for malaria vectors (Kibret *et al.,* 2014).

In Rwanda, studies about malaria targeted particularly malaria control policies and programmes. The focus was on the contribution of anti-malaria drugs, mosquito and residual sprays, the prevalence of malaria in pregnant HIV positive women and the resistance of *Plasmodium falciparum* to antimalarial drugs (Karema *et al.*, 2013). However, the present study revealed that more studies are needed for assessing irrigation and its impact on malaria transmission. It was understanding also how water management could be applied for malaria vector control in different irrigation practices.

Regarding to livestock practice in influencing malaria transmission in Ngoma district, the results indicated the dominant animals kept were the cattle and about 45.7% of respondents kept the animals indoor and the distance of outdoors animal sheds were less than 50 meters (48.8%). Franco *et al.,* (2006), in the study of Effects of Livestock Ownership on the Risk of Human Malaria, reported that the presence of one or more sheep/goats, cows, ox/bulls, calves, or chickens within the household compound was associated with an increased risk of clinical malaria.

The current study concurs with similar studies elsewhere that reported negative association between livestock keeping and malaria transmission (Mayagaya *et al.*, 2018). Raising domestic animals near the households may provide alternate sources of blood meals for Anopheles mosquitoes and thus decreasing human exposure (Verhulst *et al.,* 2010). In addition, carbon dioxide is prone to mosquito activation and attraction more than any other compounds Mweresa *et al.*, 2016). Keeping other animals that produce carbon dioxide like cows can reduce malaria mosquito bites to humans thus reducing malaria transmission but due to feeding habit of mosquitoes, current study showed that keeping animals near households increases malaria which is similar to study done by Franco and his colleagues in 2006 in the study entitled Effects of Livestock Ownership on the Risk of Human Malaria (Franco *et al.,* 2006). The study showed that malaria and agriculture more especially rice growing has positive relationship which is similar to study that was done in Peru on malaria control study (Chang, 2007).

5.2.2 Relationship between Housing Construction and Malaria Transmission

The present study revealed that malaria transmission significantly associated with poor housing construction. Most houses reported have no window screening and had open eaves. It has been reported that in sub-Saharan Africa where up to 80-100 % of malaria transmission occurs indoors at night, the home can be a place of high risk for malaria transmission (Tusting *et al.,* 2015).

About the potential of improved housing that reduce house entry by mosquitoes can help to reduce human exposure to infectious bites. Such features may include closed eaves (the gap between the top of the wall and bottom of the roof), screened doors, and windows and the presence of a ceiling (Njie *et al*., 2009). Recent studies indicate that well-built, modern housing can be protective in many tropical countries and that simple features, including closed eaves (the gap between the top of the wall and the over-hanging roof), brick walls, tiled or metal roofs, or ceilings can reduce mosquito house entry (Kigadye, 2006: Tusting *et al.,* 2015). In additional, poorly constructed houses, such as houses with open eaves and with limited space becomes a hindrance to appropriate bed net use (Tusting *et al.,* 2015). Other features are poorly maintained water supply systems, poor sanitation, and poor drainage systems.

Irrigated farming contribute to the transmission of malaria by providing potential breeding sites for mosquitoes (DFID, 2010) and (Boelee, 2003) within are close to human dwellings (Wielgosz *et al.,* 2012b).

Therefore, mode of housing construction is among the factors that may be contributing to the high malaria burden in Rwanda and other resource-limited countries in sub-Saharan Africa. Several studies have identified particular household characteristics as risk factors for an increased burden of malaria. An increase in the presence of household openings, such as windows and open eaves, has been associated with increases in mosquito entry into the home and parasite prevalence. (Lwetoijera *et al.,* 2013; Bradley *et al.,* 2013). Poor-quality household construction materials have also been associated with increased mosquito entry, malaria incidence, and parasite prevalence (Haque *et al.,* 2014: Temu *et al.,* 2012).

The present study also has also observed poor house quality to be associated with greater presence of mosquitoes in the home and higher malaria incidence which is similar to the results of the present study where the observed housing conditions in Ngoma district, 89% of the visited houses had no window screening, 93% had no ventilation screening and 96% of the houses visited had open eaves. All these contribute to mosquito increase in the house hence increasing mosquito bite and malaria. However, there are very few efforts on promotion of housing improvements - traditionally a key pillar of public health, remain underexploited in malaria control.

5.2.3 Relationship between Human Behaviour and Malaria Transmission

The present explored peoples' understanding of malaria transmission in Ngoma district, focusing on knowledge of outdoor malaria transmission. Human practices that increase vulnerability to outdoor transmission, and protective practices that people presently use to avoid being bitten when outdoors were investigated. Human night time outdoor activities such as evening parties, funerals, sports watching etc. were among the major factors contributing to malaria transmission that were reported by respondents.

There are concerns that many people are still contracting malaria despite the wide use of LLINs and that people are more often bitten outdoors than indoors imply on-going outdoor malaria transmissions in the study area. The present study findings concur with other studies where minimal protection against malaria was apparent even under full coverage with LLINs and IRS) (Matowo *et al*., 2013). Night-time outdoor activities, in a setting where the malaria vectors exhibit at least some exophagic and exophilic behaviour, increase the risk of outdoor biting and malaria transmission (Gryseels, *et al.,* 2015).

These activities are habitual, thus indicating long-standing risk of exposure to outdoor mosquito bites and malaria transmission in the area, more so because nearly 99% of the local vector population is comprised of *Anopheles arabiensis* which is strongly exophagic and exophilic. Molecular identification of *An. gambiae* s.l. in Rwanda has shown that *An. arabiensis* to be the dominant species (Hakizimana, 2018). *An. arabiensis* are opportunistic indoor or outdoor feeders and can thus better survive indoor-based interventions than *An. gambiae s.s*. The night time activities comparable to those observed in this study have been described elsewhere (Harvey *et al.,* 2014; Gryseels, *et al.,* 2015).

Outdoor control interventions need to be prioritized due to the increased outdoor biting and the close proximity of households to breeding areas. Furthermore, people in the study areas rely primarily on the use of bed nets indoors to prevent malaria and so remain unprotected before going to bed and/or when outdoors.

5.2.4 Bed Net Utilization and Malaria Transmission

The results on bed net use indicated that bed nets are not widely used by people in the study area as means of protection against malaria transmission despite the wide distribution through malaria control programmes. Similar studies conducted in Equatorial Guinean by Reddy *et al*., (2011) reported that, even where the distribution of free mosquitoes net program are expanded many household do not use them. In Kenya, approximately 30 percent of the nets were unused. Mboera *et al*. (2011) reported that community members in Northern Tanzania resisted their house to be sprayed with Indoor Residual Spray (IRS). The reasons for rejecting IRS were mainly bad smell of the insecticides and the fear that insecticides might kill their domestic animals (Greenwood & Targett, 2009). It has been also stated by Kisinza *et al.*, (2008) and Kovats *et al*., (2016) that, although LLINs have significantly decreased malaria in Sub-Saharan Africa, some unforeseen consequences of distribution of nets have been reported. LLINs have been used for constructing chicken pens and fences around vegetable gardens; improvise as wedding veils, drying fish and for fishing rather than malaria prevention.

According to Breman (2009), important components, for reducing new cases of malaria and death include more sensitive diagnostic tools, effective use of antimalarial drugs and improved personal protection by LLINs. Consequently

(Yadav *et al.,* 2007) revealed that cultural and social economic factors have positive and significant effect to the risk of malaria morbidity and mortality and that poverty rates are directly associated with social economic status, peoples believes about causes of malaria transmission.

Rwanda achieved universal coverage of Insecticide-Treated mosquito Nets (ITNs) in 2011 for all age groups. Since then, President's Malaria Initiative (PMI) has collaborated with the Malaria and Other Parasitic Disease Department (MOPDD) and the Global Fund (GF) to continue the procurement and distribution of ITNs. PMI procures ITNs for routine distribution. These ITNs are distributed through antenatal clinics (ANCs), expanded program for immunization clinics (EPI) and boarding schools. In 2015, PMI procured 1,000,000 ITNs to support a rolling mass distribution campaign planned for 2016. It was expected that in 2016 over six million ITNs would be distributed as part of a planned mass campaign with Global Fund and PMI support (President's Malaria Initiative-RWANDA, 2017). However, the present study revealed that about 27% of household members never slept under an insecticide treated mosquito net.

On the other hand, almost half of the respondents (46%), never checked for holes or never repaired mosquito nets even though they slept under mosquito nets. There are concerns that many people are still contracting malaria despite the wide use of Long Lasting Insecticide mosquitoes Nets and that people are more often bitten outdoors than indoors imply on-going outdoor malaria transmissions in the study area. This is in line with other studies where minimal protection against malaria was apparent even under full coverage with LLINs and IRS) (Matowo *et al*., 2013). The distribution of insecticide sprayed bed nets has become a key malaria control strategy in endemic regions. However, the gap lies between availability and use of the nets.

This study has showed that the majority of the respondents had access to bed nets (81%), but a little 27% do not use bed net for malaria control. Previous study has been found that bed net should vary with seasons of the year and the acceptability of the nets in terms of size, colour, and shape. Demographic characteristics like age, education, size of household, and ethnicity influenced the use of bed nets (Binka *et al*., 1998). Hence, it should be the same reason including selection of people to use the bed net in household, bet net are not available as indicated in Table 4.10.

According to the study conducted in Mali revealed that the most common reasons for not using bed nets were cost, availability, and lack of knowledge regarding the effectiveness of bed net in preventing malaria (Rhee *et al*., 2005).

Contrary, a similarly study conducted in Nigeria on Insecticide-treated bed net ownership and utilization in Rivers State, showed that although 552 (68.1%) of the households owned bed nets, only 245 (30.2%, 95% CI=27.1–33.5) of them owned long-lasting insecticide nets (LLINs and only 37.2% of those who owned ITNs slept under them at night (Tobin *et al.,* 2011).

For the case of Ngoma district housing also affects the use of mosquitoes nets, for example a family with 12 members had a house of three rooms this means that four members should sleep under one bed net and this mosquitoes out of bed net bite them easily. This was direct observation.

5.2.5 Relation between Distance from Mosquito Breeding Site and Malaria Transmission

The results indicated that the distance from living area were over three Km (53.5%) from breeding site of mosquitoes. Maximum flight distances of *An. gambiae* is between 9-12 km (Kaufmann and Briegel, 2004), the observed distance from breeding habitats in Ngoma district is therefore within the flight range of malaria vectors. Previous studies (Lindsay *et al.,* 2000; Staedke *et al.,* 2003) showed a strong relationship between the risk of malaria infection and the distance from the anopheles breeding sites to the houses. They noted also that the closer residents live to anopheles breeding sites, the higher the risk of malaria infection becomes, due to the higher density of anopheles. The breeding of Anopheles mosquitoes occur in various habitats which can either be manmade or natural, sunny or shaded, permanent or temporal (Machault *et al*., 2009) cited by Nyirakamana *et al.,* 2017.

The current study indicated that the distance from breeding site to homesteads varies from home to home. Some are near breeding sites and others are far away. Effects of rice farming (agriculture) depend on distance from breeding sites which intensifies mosquitoes and increase human vector interaction hence malaria outbreak. Malaria and rice farming has shown positive relationship(Chang, 2007).

This study reports that general sanitation measures practices in the study area include cleaning bushes around the living houses (55.9%), and indoor residual spraying (53.5%). These are being enforced by the Rwanda's strategy of reducing malaria transmission. In 2014, two spray rounds (February/March and September/October) were conducted and protected approximately 1 million residents in three districts bordering malaria-endemic zones. The coverage rate was more than 98% of the 242,589 targeted population. A spray round in February to April 2015, which was implemented in collaboration with the Global Fund, protected 99% of the targeted population and covered 250,000 structures. A spray round occurred in September to October 2015 using a carbamate insecticide and a second round began in February 2016 (MOH_RWANDA, 2017).

5.2.6 Demographic Characteristics and Malaria Transmission

The current study considered the following socio demographic data age, gender, educational level and family size and ubudehe (socio economic status).

5.2.6.1 Malaria and Gender

The current study revealed that females were dominant, in Ngoma district females do activities outside their houses which expose them to mosquito bite. This is similar to study done by brief in 2017 on malaria, gender and human rights indicating that activities outside may influence malaria transmission through mosquito bites (Brief, 2017). But malaria is not gender based because mosquitoes do not distinguish who to bite but women's household tasks, including cooking the evening meal outdoors or waking up before sunrise to prepare the household for the day, may put them at greater risk of malaria than men (United Nations Development Programme, 2015).

5.2.6.2 Malaria and Age

The present study revealed that in adults, age has no significant influence on malaria transmission in Ngoma district. Malaria was dominant in children under five years of age compared to adults. Similarly to different studies and noted that generally, children are mostly affected by malaria especially in endemic regions of Africa, where in poverty stricken areas impregnated bed nets are not provided nor can lifesaving treatment be afforded or even accessed; millions of children succumb to this disease globally. This disease also causes severe infections in pregnant women resulting in anemia leading to increased rates of infant mortality (Zurovac *et al*., 2006) cited by Rajini *et al.*, 2017.

With focus on the most affected age group being 15-49, it is evident that this age group consists of persons that are more active within the regions as it relates to school, travelling from various villages. This working class of people has led to increase in the transmission of the disease as these persons are not only more exposed to the environment but also to other persons that may be carrying different stages of malaria (UN-2013) cited by Rajini *et al.,* 2017.

In Kenya, ITNs use by children aged less than five significantly increased from 7% in 2004 to 23.5% in the next year and to 67% in 2006 (Hu *et al*., 2016 & Fegan *et al*., 2017), Even though the number of INT users in Africa increased every year still the distribution and transmission of the disease is continued, why it so? Resistance of the vector to the pyrethriod (pyrethriod insecticides used 40% for IRS and 100% as ITNs by WHO) is the main challenge in many Africa countries such as Kenya, Ghana, Tanzania, Mozambique, Benin, etc (Jones *et al*., 2012, Kawada *et al*., 2011, Awola *et al*., 2009 & Nicolas *et al*., 2012).

5.2.6.3 Ubudehe (Socio-economic status)

The present study has revealed that ubudehe has an influence to this high prevalence of malaria observed in Ngoma during the period of study and findings indicated that

0.8% of respondents were in the category I, 20.5% of respondents are in category II, 74% of respondents are in category III which considered as a group or category of people with low annual income. However, socio-economic status has to go with other factors such as housing patterns, which also affect human vulnerability to vector-borne diseases. Similarly, the study conducted in Mannar and Trincomalee districts of Sri Lanka Malaria about demographic, epidemiological, and socio-economic determinants and their potential impact on malaria transmission, where noted that malaria is considered as a disease associated low income communities with poor socio-economic status because, poor communities have comparatively less access to anti-malarial and anti-mosquito measures, since they cannot afford personal protection measures, a clean environment free of mosquito breeding sites, vulnerable to ineffective diagnosis and treatment due to financial and cultural implications (Ayele *et al.,* 2012 and Ajayi *et al.,* 2013) quoted by Gondaliya *et al*., 2015. Therefore, a better understanding of the relationships between malaria and socioeconomic variables is needed to enable design effective policies and tools to tackle the problem.

5.2.6.4 Education Level and Malaria

The present study has shown that education level has no influence on high malaria prevalence in Ngoma district with is contradictory to the study done on the importance of education to increase the use of bed nets in villages outside of Kinshasa, Democratic Republic of the Congo noted Education about malaria transmission and the benefits and proper use of bed nets should eliminate the misconceptions about bed nets usage. Results reported here demonstrate that the education level of the family head of household was linked with bed net use amongst family members in the surveyed villages.

A study in Kinshasa by Minakawa & Ndjinga (2010) also reported that women who had secondary school or higher education were 3.4 times more likely to own and 2.8 times more likely to use a bed net compared with women with less education. This study also found a lower prevalence of net use among children less than 5 years of age and among adults, and a greater prevalence of use among school children 5 to 15 years old (Pettifor *et al.,* 2009) quoted by Minakawa & Ndjinga 2010.

5.2.6.5 Malaria and Family Size

The current study revealed that family size in Ngoma district influence malaria prevalence due to economic factors. Many of the families are in category I, category II and category III whose economic status is low and having many children and this leads to cause problems of not getting sufficient bed net for all children, hence increasing malaria prevalence in Ngoma district. This is similar to study conducted by Xu *et al*., (2008) average household size and the eradication of malaria where. Again present study is similar to a study done on family size housing conditions and malaria by Huldén *et al*., (2014) where the study revealed when family size exceeds four member there is high risk of mosquito bite hence increase in malaria prevalence due to many children sleeping under one mosquitoes nets (Huldén *et al*., 2014).

5.2.6.6 Occupation and Malaria

The findings indicated that the dominant occupation of interviewed persons were famers (31.5%) with the mean of 2.98 and Std of 1.584 and this influence malaria prevalence in such way that they wake up early morning for going to their farms hence contacting mosquitoes and increase risk of biting hence increase in malaria transmission. Similarly, study done in updated by Burkina Faso by documentation of malaria program implementation in Burkina Faso has shown that may is dependent on occupation (Reiter, 2001). Occupation continue to contribute to high malaria prevalence as discussed in high health risk (Wielgosz *et al*., 2012b).

5.2.7 Strategy for Control of Malaria Transmission in the Ngoma District

Human efforts at controlling malaria date back many years ago, since then a lot has taken place. In the 1970s measures to immunize humans against *P. falciparum* and *P. vivax* were introduced. At the moment there is massive renewed interest in malaria activities following the declaration on the control of malaria by the Ministerial conference held in Amsterdam in October 1992 (WHO, 2010).

Strategies for malaria transmission control from various countries are based on the situation of malaria of a given period of study. Like a study done on outdoor mosquito control is situational control (Okumu *et al*., 2013). Reduction of human-vector interaction strategy was discussed in malaria transmission during irrigation construction was also situational control measure (Panigrahi & Mahapatra, 2013). Referring to the findings of the current study, malaria is still a threat to the people while different measures for fighting malaria have been suggested (Nuwaha *et al*., 2013).

In order to prevent and control Malaria, it is important to combine measures aimed at breaking the “human-vector” contact cycle of transmission to cure the infected population. The control of malaria therefore involves education, vector control and control of malaria parasites. The most effective control strategies however is the one that breaks the “human-vector” contact cycle of transmission. An effective vector control method should be able to reduce the vectorial capacity of mosquitoes as it was mentioned in study done (Baeza *et al*., 2013). Educational campaigns for malaria eradicating strategies at the household level should be a strategy for sustainable preventive method (Wirth & Alonso, 2016). Breaking vector-human contact has reduced malaria in Southeast Asia it was discussed (Lim & Vythilingam, 2013). Housing construction is paramount in malaria transmission increase since window screening, open eaves and ventilation screening all may increase mosquitoes in the house hence increased mosquito bite and increase in malaria.

Due to assessment of possible existing malaria control strategy, the present study designed the combination of anti-larval measures (environmental control, chemical control and biological control), protection against mosquitoes (use of mosquito nets, house screening and use of repellents), anti- adult measures (residual spraying, space spraying and use of LLINs) and anthropogenic factors measures (human ecology, human activities, human beliefs, environmental health and housing) should reduce the rate of malaria prevalence in Rwanda, referring to the findings of the study conducted in Ngoma district that is the sustainable malaria control strategy.

Direct logistic regression was performed to assess the impact of a number of factors on the likelihood of reducing malaria burden. The strategy contained six variables (bed net use, agriculture activities, distance from breeding sites, housing construction, livestock keeping and night time outdoor behaviour). The full strategy containing all factors was statistically significant, Chi-square (6, N=127) = 32.178, p

< 0.001, indicating that the model was able to distinguish between factors that may reduce malaria burden and those that may not reduce may burden. The strategy was as a whole explained between 22.4 % (Cox & Snell R Squared) and 30.1% (Nagelkerke R Squared) of the variance in reducing malaria burden and correctly classified 74.0% of cases. As shown in Table 4.25 only two factors statistically contribute much to the strategy (Distance from breeding sites and Livestock Keeping). The strongest contributing factor was livestock keeping with an odd ration of 18.62. This indicated that keeping away livestock from houses was almost 19 times more likely to reduce malaria burden controlling other factors in the model. The odds ratio of .06 for distance from breeding sites was less than 1, indicating the .06 times less likely to reduce malaria burden making other factors constant.

The implementation and management of malaria prevention measures by combining various parameters such distance from breeding sites and livestock keeping at the high rate and enforcing bed net use and house screening should properly lead to reduction of malaria burden in Rwanda.

In order to reduce malaria burden to Rwanda, policy makers and planners should organise eradication and awareness campaigns that reach community to grass root levels in prone districts such that community should be aware of most contributors factors of malaria such as night movements and stop it if possible or alternative measure may be taken like providing long sleeved shirts with mosquito pyrethrum repellent. For the case of intervention measures, policy makers and planners should put more emphasis on community education and early treatment rather than community health worker without medicine, where in some sectors you find some community health workers without malaria medicine up to three weeks. This should be addressed by policy makers and planners.

5.3 Conclusions

This study focused on the “influence of environmental and anthropogenic factors on malaria transmission in Ngoma district Rwanda. The study was based on the general and specific objectives. It was a cross-sectional prospective study conducted in Ngoma district, of Easter Province where 127 households were interviewed during the period of the study. The data were collected by using questionnaires, reading hospital records, observation and participatory epidemiology and analysed by using SPSS version 21 program and finally making conclusion and recommendations.

The findings of this study showed that 41.7% of the respondents were males and 58.3% were females. The age of the respondents ranged from less or equal to 20 to over 61 years old. The family size ranged from 1 to 15 members. Each respondent had attended school. Majority were employed and majority of those households are in third category of Ubudehe (78.4%). The present study revealed that malaria prevalence was 51.0% for adults in 2014 and 64.6% for children under five years old in 2014. The findings showed that malaria is seasonal dependent.

Specific objective one assessed malaria status in the study area

The results showed that hospital admission rates for malaria in adults and children was highest in 2014 at 51.0% and 64.6%, respectively and increase in malaria prevalence in adults was due to the fact that more emphasis was being put for children under five years of age (President’s malaria initiative, Rwanda, 2017). The present study reports high malaria prevalence at temperatures between 17.9 °C to 22.0°C. Therefore the present study, further provide new knowledge on the continuing decreasing optimum temperature for malaria transmission.

Specific objective two environmental factors affecting malaria transmission in the study area

The present study revealed that malaria transmission significantly associated with poor housing construction. Most houses reported have no window screening and had open eaves in Ngoma district.

The present study has found that cultivation of natural swamps for rice growing has created favourable conditions for larvae survival and consequently increasing malaria transmission in Ngoma district. The results of present study indicated that the distance from living area were over three Km (53.5%) from breeding site of mosquitoes which led to the maximum of malaria transmission because the observed distance from breeding habitats in Ngoma district is therefore within the flight range of malaria vectors.

Therefore, referring to the findings of the present study, people are still dying from malaria despite measures for fighting malaria having been suggested and practiced in the study area and in various sub Saharan countries. Therefore, the problem is the implementation of malaria eradication strategies at the household level which were not well conceived and practiced. Other environmental factors that were showed by the present research are rice farming, housing and housing conditions water for irrigation and improper waste management.

Specific objective three anthropogenic behaviours activities influencing malaria transmission in the study

Human night time outdoor activities such as evening parties, bar attending, and sports watching were among the major factors contributing to malaria transmission that were reported by respondents. The results on bed net use indicated that bed nets are not properly widely used by people in the study area as means of protection against malaria transmission despite the wide distribution through malaria control programmes. Inappropriate use of bed nets, protection against mosquitoes (use of mosquito nets, house screening and use of repellents) were missing in the study area as reported by the respondents.

Specific objective four suggested the Interventions strategy for malaria control

The designed malaria intervention strategy was a combination of anti-larval measures (environmental control, chemical control and biological control), anti-adult measures (residual spraying, space spraying and use of LLIN) and anthropogenic factors measures (human ecology, human activities, human beliefs, environmental health and housing).

5.4 Recommendations

Based on the results of the current study and the conclusions made, the study recommends the following:

5.4.1 Recommendations to Stakeholders

About the potential of improved housing that reduce house entry by mosquitoes can help to reduce human exposure to infectious bites. Such features may include closed eaves (the gap between the top of the wall and bottom of the roof), screened doors, and windows and the presence of a ceiling.

Outdoor control interventions need to be prioritized due to the increased outdoor biting and the close proximity of households to breeding areas.

Introduction of repellent as a tool for preventing human-vector interaction while doing outdoor activities as protective measure to community.

5.4.2 Recommendations to Study Area

Awareness campaigns for the people in the study area on the proper use of long lasting insecticide treated bed nets.

Awareness campaigns for the citizens on constructing houses with window screening and closed eaves and roofing.

5.4.3 Recommendations to Ministry of Health

The distribution of the long lasting insecticide treated bed nets should be followed up to insure the better implementation and use.

The people should stay away from swampy areas under the guidance of ministry of health while people constructing their houses.

5.4.4 Recommendations to General Public

(i) The people should use the plant named Cyprus because their smelling is toxic for insects.

(ii) The people should improve their houses to be suitable against mosquitoes. Considering window screening as important.

(iii) The windows of their houses should be screened by mosquito gauze.

(iv) The people should wear long sleeve clothes during night outdoor activities.

(v) The people should clear the bushes around their houses and drain water filled ditches.

(vi) The people should use the available bed nets every night.

5.4.5 Area for Further Research

The present study have highlighted on contribution of irrigation to malaria transmission but deep analysis is needed for assessing irrigation and its impact on malaria transmission and understanding of how water management could be applied for malaria vector control in different irrigation practices.

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APPENDICES

Appendix I: Questionnaires

INTRODUCTION AND CONSENT

Hello. My name is James Kant Kamuhanda. I am PhD student in The Open University of Tanzania. We are conducting a survey about" Assessment of the influence of environmental and anthropogenic factors on malaria transmission in Ngoma District, Rwanda. The information we collect will help the government to plan health services and other researchers who should be interested with this topic. Your household was selected for the survey. I would like to ask you some questions about your household. The questions usually take about 15 to 20 minutes. All of the answers you give will be confidential and will not be shared with anyone other than members of our survey team. We hope you will agree to answer the questions since your views are important. If I ask you any question you don't want to answer, just let me know and I will go on to the next question or you can stop the interview at any time.

SIGNATURE OF INTERVIEWER _______________Date________________

RESPONDENT AGREES TO BE INTERVIEWER: 1 (continue the conversation)

RESPONDENT DOES NOT AGREE TO BE INTERVIEWED: 2 (End the conversation)

RECORD THE TIME: STARTED AT ……..…… AND ENDED AT …………….

Please fill this information before answering the questions below

Name of the head of House hold……………

Name of village/Umudugudu……………………

Family size

Q1. Number of children under five

Q2. Number of HH members above five years

Q3. Have you had any person who suffered from malaria in the past 12 months in your family?

Yes No

If yes,

b) What was the gender of that person?

Female Male

Q4. Which season do most of your family or neighbours suffer from malaria?

Rainy season Dry season

Q5. Which months of the year do malaria goes up in your area?

January-April May-August September-December

SECTION A: SOCIO- DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

1. What is your Age? /_______/

2. What is your Gender?

   1) Male
   2) Female

3. Please indicate the highest level of education completed

   1) Informal Educated
   2) Primary
   3) Secondary
   4) University
   5) Others

4. Occupation

   1) Farmer
   2) Teacher
   3) Businessman
   4) Unemployed

   Other (specify)………………………….

5. Ubudehe category

   1) Category I
   2) Category II
   3) Category III
   4) Category IV

6. How many persons who usually live in your household including the head of the household? (number) /_______/

7. Preventive methods (circle)

    1) Use of insecticide treated nets
    2) Cleaning of bushes around your home
    3) Draining stagnant water
    4) House spray with insecticide

8. Malaria elimination practices

Question	Never	Sometimes	Always
How often do you sleep in an insecticide treated net?			
How often do other members of the household sleep in insecticide treated net?			
How often do you check for holes/repair of insecticide treated net?			
How often do you clean/cut bushes around your house?			
How often do you clean stagnant water near your house?			
How often do you close the windows before 6 pm?			
How often do you visit the health centre when you fall sick?			

9. When do most of the vectors prefer humans? ____________________

10. Where does human vector contact take place? _____________________

11. Are the people outdoors at night mosquitoes bite them most? ______________

SECTION C: RELATIONSHIP BETWEEN PREVALENCE OF MALARIA AND CLIMATIC FACTORS

12. Do you think that rainfall and temperature have an influence on the prevalence of malaria?
    1) Yes
    2) No
13. If yes, how?

    …………………………………………………………………………………

Since rain fall has started raining how often you are suffer from malaria?

1) Always
2) Sometimes
3) Never

14. During dry season how often you are suffer from malaria?
    1) Always
    2) Sometimes
    3) Never
15. In which period do you suffer from malaria most?
    1) During rainy season
    2) During dry season
    3) Both rain and dry seasons

SECTION E: ECOLOGICAL FACTORS

16. How far is here from rice growing places?

    1) >3Km

    2) Far away

    3) Exactly 3Km

    4) <3Km

17. How do you keep water for building if someone is building?

    1) Deep holes

    2) Jerry-cans

    3) Half cut drums

18. Do you harvest rain water in water tanks?

    1) Yes

    2) No

19. If yes, are those water tanks closed or opened?

    1) Closed

    2) Opened

20. Do you think that irrigation has an influence on the prevalence of malaria?

    3) Yes

    4) No

21. If yes, how?

    ………………………………………………………………………………………

22. Do you think that housing have an influence on the prevalence of malaria?

    5) Yes

    6) No

23. If yes, how?

……………………………………………………………………………………

……………………………………………………………………………………

24. Which type of house do you have?

1) Burnt bricks houses/ Modern house
2) Unburnt bricks houses
3) Mud Houses

Part Two: HUMAN BEHAVIOUR ACTIVITIES INFLUENCING MALARIA TRANSMISSION

1. How is Malaria transmitted?

a) Through female anopheles mosquito bite

b) Contact with a malaria patient

c) Exposure to rain

d) Eating maize stalk

e) Other________________________

2. Where do the mosquito's breeding sites found around your home?

a) Less than 100 meters from dwelling house

b) 100-500 meters away from dwelling house

c) 500-1000 meters away from dwelling house

d) 1000-3000 meters away from dwelling house

e) More than 3000 meters

3. What type of breeding site is close to your house?

   a) Ponds, river bed, swampy areas drain and ditches
   b) Man-made pits, holes and agriculture rice field activities
   c) Pit latrines, septic-tanks and soakage-pits
   d) Others___________________

4. Are the breeding sites available throughout the year?

   a) Rainy season
   b) Dry season
   c) Both wet and dry seasons
   d) Don't know

5. Does your house have open eaves?

   a) Yes
   b) No
   c) Other _____________________

6. Are the windows screened with the mosquito wire gauze?

   a) Yes
   b) No
   c) Others____________________

7. Has your house been sprayed with IRS?

   a) Yes
   b) No

c) If No, explain why____

8. How can you prevent mosquitoes from breeding in various sites?

a) Cleaning the surrounding
b) Draining and filling ditches
c) Residual indoor spraying
d) Use of treated mosquitoes net
e) Case management by ursin of Anti-malaria's/ALU
f) Treated mosquitoes net and one or more of the above interventions
g) Residual indoor spraying and one or more of the above interventions
h) Don't know

9. What type of the following night-time outdoor activities that contribute to malaria infection in this area?

a) Evening parties
b) Wedding
c) Ceremony after harvesting season
d) Sports watching
e) Hunting
f) Guarding property
g) Funerals
h) Small business
i) Cooking outside at night hours,
j) Others ____________________________

10. What kind of individual protection do you use against Mosquito's while conducting/performing the night-time outdoor activities?

   a) ____________________________________

   b) ____________________________________

   c) ____________________________________

11. Have you ever heard of mosquito nets treated with insecticide?

   a) Yes
   b) No
   c) Don't know

12. Do you own one?

   a) Yes
   b) No,

If No then answer 13 if yes leave 13 unanswered

13. Reason for not owning the LLINs:

   a) Not available
   b) Unaffordable to buy
   c) Old; then thrown away
   d) Unavailability of mosquitoes
   e) Used for other purposes
   f) Others (Specify)_______________

15. How many LLINs do you have in your house?

   a) One

b) Two

c) Three and above

d) None

16. Can you mention how many members sleep on the bed?

a) Under-five children

b) Head of the family

c) Pregnant mother

d) The whole family

17. The current situation of the available.

a) LLINs: in good order

b) Torn

c) Don‘t know

18. Is your LLINs treated with insecticide?

a) Yes

b) No

c) Don‘t know

19. Are you using bed net every day?

a) Yes

b) No if No, please answer the question number 20

20. Reasons for not using the available LLINs:

a) Housing type and structure affects the net use

b) Absence of bed

c) Afraid of its toxicity

d) Weather not conducive

e) Nets do not prevent malaria

f) other (specify)__________

21. Did you use mosquito net last night?

a) Yes

b) No

22. Frequency of mosquito net use;

a) Always

b) Not always

23. How did you get them?

a) Free from the government source

b) Voucher system

c) School net distribution program

d) Others/specify

24. When were LLINs supplied to you?

a) < 6 months

b) > 6 months

c) > 1 years

d) 2- 3 years

e) Others_________________

25. In case you did not receive LLINs from the hospital or school program, can you afford to purchase one?

a) Yes

b) No if No Explain why_______________________________

26. What do you think are the advantages of sleeping in the Mosquito nets?

a) Reduce the burden of malaria

b) Reduce mosquitoes bite nuisance

c) People sleeps better

d) Luxury

e) Don't know

27. How many rooms in this household are used for sleeping? __________________

a) 1-2 rooms

b) 3-4 rooms

c) 4-6 rooms

d) More than 6

28. What kind of malaria vector bite protection do you use?

a) Use intact mosquitoes net at night

b) Sleep in a screened room, or in air condition room using a mosquito spray to kill any mosquitoes that entering in during the day

c) Wear long sleeves and long trousers outdoors after sunset? Are those clothes impregnated with permethrin

d) Use repellants (e.g. DEET) on exposed skin and garments

29. What time do adults sleep and get up? ______________________________

30. What kind of malaria treatment do you use? _________________________

31. Do people delay in seeking treatment? _____________________________

32. How, why and what kinds of traditional methods are used?

33. Do you own any livestock (animals) in your house? ___________________

Part 3: Ecological and environmental factors

1. Arrange the following human behaviour activities that affect malaria transmission in their descending order.
    a) bed net use
    b) outdoor activities
    c) traditional customs

2. Arrange these ecological factors that affect malaria transmission in their ascending order
    a) Housing
    b) Agricultural activities and river Akagera tributaries
    c) Irrigation
    d) Land use

3. Do you own any livestock, other farm animals, or poultry?
    1) Yes
    2) No

4. If yes which of the following animals do own?

    2) Cows

    3) Goats

    4) Sheep

    5) Chicken/Poultry

5. Which land use below do you consider as a factor of malaria transmission?

    a. Agriculture activities

    b. Swamps

    c. Afforestation

Any other comment____________________________________

Thank you for your cooperation

James Kant Kamuhanda

Appendix II: Interview Guide

1. Do night – time outdoor activities influence malaria transmission in your area? _

____

____

2. What are human night-time outdoor activities contributing to malaria transmission in your area?

____

____

3. What behaviours put them at risk of exposure to malaria to vectors?

____

____

4. Are the night-time movements and habits of people likely to affect exposure to vectors, including time they go to bed?

____

____

5. What kind of individual protection do they use against Mosquito's while conducting/performing the night-time outdoor activities?

____

____

6. Which agriculture and irrigation activities shown below you consider to be a factor of malaria transmission and rank them?

a. Dams constructions

b. Living near dams

c. Rice field

d. Micro-dams

e. Rainfall collection dams

7. General sanitation is a factor of malaria transmission in your area do you agree with the following?

a. Non-cleaning of house surrounding

b. Draining & filling ditches

c. Residual indoor spraying

QUESTION RELATED TO THE DOMESTIC WASTE MANAGAMENT

1. Do think that waste disposal has influence on malaria?

a) Yes b) No

2. What is the current situation of waste disposal?

a. Permanent
b. Non permanent
c. Waste additional

3. Who is responsible to collect the waste? a. Man b. Women

4. Do you separate liquid and solid waste before taking them to waste disposal?

a. Yes b. No

5. How do you consider waste influence as mosquitoes breeding site?

a. Strongly Agree
b. Agree
c. Disagree
d. Strongly Disagree

6. Where the waste is deposited from your living house?

a. Near the waste
b. Far the waste

7. Waste is collected before collectors take them to dumpsite in:

a. polythene bags

b. cut jerry cans

c. Sacs

d. Others (specify)……………

8. Which waste are common in your area?

a. broken glasses

b. broken pots

c. unused basin

d. cut jerry cans

e. Others (specify)…………………..

9. How frequently do waste collectors collect wastes in your area?

a. weekly

b. Daily

c. Monthly

Any other comment___________________________________

Thank you for your cooperation

James Kant Kamuhanda

COMMUNITY HEALTH WORKERS GUIDE QUESTIONS

Q1. What kind of individual protection do you use against mosquitoes while conducting/performing the night-time outdoor activities?

Q2. Do you think protection against mosquitoes during night-time outdoor activities is needed?

Q3. Do people use personal protection as needed? What kind of protection do they use while outdoors?

Q4. As CHWs do you think that people use mosquito net properly? If not what other services do they use mosquito net for?

Q5. What do you think that is the main cause of increase in malaria in the district?

Thank you for your cooperation

James Kant Kamuhanda

Appendix III: Research Clearance Letter

THE OPEN UNIVERSITY OF TANZANIA
DIRECTORATE OF RESEARCH, PUBLICATIONS, AND POSTGRADUATE STUDIES

P.O. Box 23409 Fax: 255-22-2668759
Dar es Salaam, Tanzania,
http://www.out.ac.tz

Tel: 255-22-2666752/2668445 ext.2101
Fax: 255-22-2668759,
E-mail: drpc@out.ac.tz

06/09/2017

Hon. Mayor,
Ngoma District,
Eastern Province,
RWANDA.

RE: RESEARCH CLEARANCE

The Open University of Tanzania was established by an act of Parliament no. 17 of 1992. The act became operational on the 1st March 1993 by public notes No. 55 in the official Gazette. Act number 7 of 1992 has now been replaced by the Open University of Tanzania charter which is in line with the university act of 2005. The charter became operational on 1st January 2007. One of the mission objectives of the university is to generate and apply knowledge through research. For this reason staff and students undertake research activities from time to time.

To facilitate the research function, the vice chancellor of the Open University of Tanzania was empowered to issue a research clearance to both staff and students of the university on behalf of the government of Tanzania and the Tanzania Commission of Science and Technology.

The purpose of this letter is to introduce to you **James Kant Kamuhanda; Reg.No. PG201610668** who is a **PhD** student at the Open University of Tanzania. By this letter **James K. Kamuhanda** has been granted clearance to conduct research in the country. The title of his research is "**Assessment of Local epidemiological factors affecting Malaria Transmission in Ngoma District - RWANDA.**"

The period which this permission has been granted is from 7/09/2017 to 8/11/2017.

In case you need any further information, please contact:
The Deputy Vice Chancellor (Academic);
The Open University of Tanzania;
P.O. Box 23409;
Dar Es Salaam.
Tel: 022-2-2668820

We thank you in advance for your cooperation and facilitation of this research activity.
Yours sincerely,

Prof Hossea Rwegoshora
For: VICE CHANCELLOR
THE OPEN UNIVERSITY OF TANZANIA

Appendix IV: Acceptance Letter

REPUBULIC OF RWANDA

EASTERN PROVINCE
NGOMA DISTRICT

Ngoma on .6../.6../2017
Ref:..1201/07.05.06

To: James Kant KAMUHANDA
Student at OUT

Re: Acceptance

Dear James,

Reference is made to your letter dated May 18th, 2017 requesting for data collection on the field in our District, I am pleased to inform you that you are allowed to gather the information related on **Effect of land use patterns, human behavior and climatic factors on Malaria transmission Ngoma District - Rwanda** in the provided timeframe as mentioned in the research clearance issued by the Vice Chancellor of the Open University of Tanzania.

I wish you success in your study.

Best regards,

NAMBAJE Aphrodise
Mayor of NGOMA District
C.I:
- Vice /Mayor (all)
- Executif Secretary of Ngoma District
  NGOMA

Website: www.ngoma.gov.rw / E-mail: ngomadistrict@ngoma.gov.rw / P.O.Box: 01 Kibungo

Appendix V: Published Papers

Imperial Journal of Interdisciplinary Research (IJIR)
Vol-2, Issue-9, 2016
ISSN: 2454-1362, http://www.onlinejournal.in

Review of Malaria Epidemiology in Rwanda

James Kant KAMUHANDA
Environmental Studies, the Open University of Tanzania
Kigali, Rwanda

Abstract *: Malaria in Rwanda is one of the major health issues to be tackled diligently by both researchers and government officials. In Rwanda malaria is seasonal disease and environmental related. Where eastern province is more epidemic-prone than the rest of the provinces of Rwanda.*

Keywords*: Malaria, environmental changes Rwanda*

Introduction

Rwanda is a small (26,338 km^2), land-locked country in the Great Lakes region of Eastern Africa, bordered by Uganda, Burundi, the Democratic Republic of the Congo, and Tanzania. It has a population of approximately 12 million people (projection from 2012 census results), making it the most densely populated country in continental Africa. Administratively, the country is made up of 30 districts, which are divided into sectors, cells (cellules), and 14,953 umudugudus (villages of 50–100 households). The entire population is at risk for malaria, including an estimated 1.8 million children under five years of age (14.6% of the population) and 443,000 pregnant women/year (30.2% standardized birth rate; projections based on 2012 census results).(1)

Malaria parasite was discovered in 1880 by Alphonse Laveran (2). Africa had no malaria before and according to Nandi elders, malaria was introduced into Africa by African soldiers who participated in First World War in 1918 and 1919 and after coming back, 25% of the indigenous population got the disease. (3). In Rwanda, malaria was not health problem since its introduction in 1918 (3). The risk of getting Malaria disease in Rwanda can be partially explained by social conditions of Rwandan population (4) and environmental changes (climatic change).

In Rwanda, malaria presence is associated with climatic changes, as the climate was changing since first world war led to changing of malaria prevalence in Rwanda (5). Study in Rwanda found that recent increases in temperature and rainfall were associated with a steep rise in malaria cases (3). DDT was used to treat mosquito nets in Rwanda but now it has gone out of its use, it cannot be used because it has health effects. DDT elimination in Rwanda it was as a result of Stockholm Convention negotiations which helped lives to be saved and diseases prevented as a consequence using an alternative measure (6). Even though all those were done in Rwanda but malaria is still health threat that bit used to be during its introduction to Africa.

Rwanda experienced an upsurge in malaria cases with 1.7 times more cases than in 2013. The NMCP, PMI, and other malaria stakeholders are currently investigating the drivers of this increase to respond appropriately. Data from early 2015 reveal that the NMCP responses are having an effect as malaria cases have decreased compared to the same time period in 2014, but analysis is ongoing.(7)

Malaria situation in Rwanda

According to NMCP's health management information system (HMIS) data from June 2015, the NMCP has classified 19 (63%) of the country's 30 districts as epidemic-prone and the remaining 11 as endemic including Bugesera, Gatsibo, Kabutare, Kamonyi, Kayonza, Kirehe,Muhanga, Ngoma, Nyanza, Ruhango, and Rwamagana. Of these 11 high burden districts Ruhango, Kirehe, Kayonza, Gatsabo, and Ngoma are supported by PMI and Global Fund supports the remainder and most are of eastern province. The NMCP has also targeted eight districts for pre-elimination activities: Burera, Gakenke, Gisagara, Musanze, Ngororero, Nyabihu, Nyagatare, and Rubavu. According to the HMIS data, the 11 endemic districts accounted for 76% of all malaria cases reported. Malaria transmission occurs year-round with two peaks from May to June and from November to December in the endemic zones following distinct rainy seasons.(7) In addition to climate and altitude, other factors that influence malaria in the country include high human concentration near vector habitat (e.g., boarding schools in proximity to marshlands); population movement (especially from areas of low to high transmission); irrigation schemes (especially in the eastern and southern parts of the country); and cross-border movement of people (especially in the eastern and southeastern parts of the country).(7)

In recent years Rwanda has seen an increase in reported malaria cases, from an estimated 225,176 cases in 2011 to 1,598,055 in 2014 and more in 2015. (1) as malaria parasites are difficult to handle and they ability to develop is complex (8)

Malaria and Environment in Rwanda

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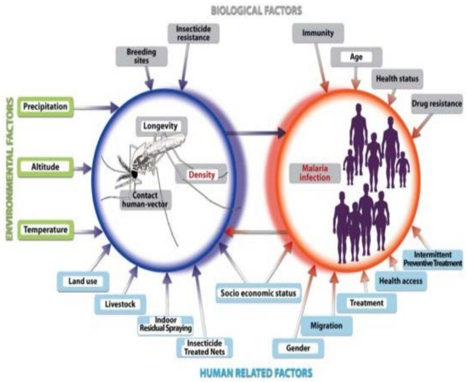
Interventions to fight against Malaria in Rwanda have resulted in small decline of malaria incidence. But this achievement is slow as for local malaria transmissions remain and the risk of getting malaria infection is explained by social and environmental factors (9). Due to temperature and rain fall change in Rwanda malaria reoccurs even though, the government has put control mechanisms such
use of Long-lasting insecticidal nets (LLIN), indoor residual spraying (IRS) and malaria case treatment with artemisinin-based combination therapy (ACT) and have been proven to reduce malaria incident, but may not lead to malaria eradication.(10)
As malaria is both sensitive to environmental and socio-economic factors, and malaria is the interplay of climate variability and interventions in Rwanda highlands. Malaria and interventions related data from Rwandan Ministry of Health show that malaria depends on both environment and socio-economic factors.(11)

Climatic Factors and Malaria

Rainfall plays an important role in malaria epidemiology because water not only provides the medium for the aquatic stages of the mosquito's life cycle but also increases the relative humidity (12)
For example, in Gambia, malaria transmission is restricted largely to the rainy season.(13)
However, rain may prove beneficial to mosquito breeding if moderate, but it may destroy breeding sites and flush out the mosquito larvae when it is excessive. And in the intermediate rainfall zone of Sri Lanka both the correlation and regression analyses suggest that temperatures and rainfall act on malaria with a lag of one month. Because most of the malaria cases in Shuchen County were associated with Plasmodium *vivax,* such delays are consistent with the estimated minimum temperature generation time of a case of Plasmodium *vivax* (12)

Is the Warming associated with increased incidence of Malaria?

Global environmental change is expected to increase the incidence of vector-borne diseases, especially malaria. (14) in Rwanda due to malaria increase in its neighboring countries such as DRC Congo, Burundi because of monthly rainfall and minimum temperatures which were the top environmental predictors for malaria risk(1), Uganda, Kenya and Tanzania, malaria increased due to El Niño (15) . Malaria has increased dramatically and this is due climate change and temperature raise. (16)
In Rwanda malaria is influenced by three risk factors which are Environmental factors, Biological and Humana related factors as it is summarized in the figure below.



Source (17)
Figure 1. Conceptual model of important risk factors affecting malaria prevalence in the African Highlands. Factors are regrouped in 3 main classes (environmental factors: green label, biological factors: grey label and human related factors: blue label). Dependent variables included in the CART analysis are displayed in red and predictor variables are highlighted in white (17)

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Assessment of Local Community Awareness on Health Effects of Improper Electronic Waste Disposal in Rwanda: A Case of Gasabo District Kigali City

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Abstract*: Electronic waste improper disposal in Rwanda particularly in Gasabo district is major health threat due to the fact that there is no laws governing its disposal and local community is not aware of the effect of e-waste on human health and the study was done on 207 informants in Gasabo district and 36 participants from district authorities, 33 participants from sector authorities and 138 participants from local community level*

Keywords: e-waste, health effects, Rwanda

INTRODUCTION

Gasabo is one of the three districts of the most beautiful city of Kigali, it boards with Kicukiro, Rwamagana and
In technological era many electronic equipments and gadgets have been invented, this technological innovation makes life easy, comfortable and simple for people around the globe The electronics products have evolved since the 1950s where electronics were only limited to radio and television, today the world has turned into a virtual, ranging from automotive engines to automated equipment in production settings: travel with ease, pay bills instantly, getting clothes washed, office now can do away with loads of files which data are stored in discs or sticks instead of cupboards saving office space, factories produces items by the thousands in very little time, bank deposit and withdraw in an automatic cash distributor machine, electronic trade, various kind of communications, telemedicine and entertainment. Electronic industry is experiencing the planned obsolescence strategy where the production of uneconomically short lives products such that customers will have to repurchase more often became a policy.
Electronic waste (e-waste) is one of the fastest-growing pollution problems worldwide given the presence of a variety of toxic substances which can contaminate the environment and human health (1), if disposal protocols are not meticulously managed and the lifespan of many electronic goods has been substantially shortened due to advancements in electronics. All these factors have contributed to the current phenomenon of continuous increasing of e-waste as emerging environmental health issues. These kinds of problems occur in exchange for the simple and easy lifestyle that people get with the use of electronics. It is urgent to find a balance on how to use electronics and maintain the environment and health safe otherwise we are all at risk while using electronics in our daily lives.(2)

Electronic-waste is much more dangerous than many other municipal wastes because electronic gadgets contain thousands of components made of deadly chemicals and metals like lead, cadmium, chromium, mercury, polyvinyl chlorides (PVC), brominates flame retardants, beryllium, antimony and phthalates (3). Long-term exposure to these substances damages the nervous systems, kidney, and bones, reproductive and endocrine systems. Some of them are carcinogenic and neurotoxin. (4)

Generally, e-waste can be defined as all secondary electronic equipment including computers, entertainment devices, mobile phones, television sets, refrigerators, etc. whether sold, donated or discarded by their original owners.
According to the Australian Bureau of Statistics, Electronic waste are the electronic appliances such as computers, laptops, TVs, radios, DVD players, printers, mobile phones, MP3 players etc. including their assembly, sub-assembly, components and consumables, which have reached end-of-life through being obsolete, broken or used. Sometimes the term e-waste also includes electrical waste such as refrigerators, washing machines, dryers, air conditioners, vacuum cleaners, coffee machines, toasters, irons, etc. The US Environmental Protection Agency (EPA) defines e-waste by categorization (5).
EPA policy states that obsolete electronics are not considered waste until a specialized decision is made stating their continuous usability hence the use of

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non-waste as indicated in the definition above(6). In Rwanda, E-waste means any electrical or electronic equipment which the holder discards or intends or is required to discard. In Rwanda (7), the legal framework for waste management is documented in the Organic Law N° 04/2005 of 08/04/2005 determining the modalities of protection, conservation and promotion of environment in Rwanda. The Law N° 39/2001 of 13th September 2001 establishing Rwanda Utilities Regulatory Agency (RURA) giving responsibility of handling the removal of waste products from residential or business premises among others. The Law N° 16/2006 of 03/04/2006 determining the organisation, functioning and responsibilities of Rwanda Environment Management Authority (REMA) provides details of its responsibility, among many others responsibility we can list: to implement the Environmental Policy, to assess and approve EIAs for development projects, and to prepare action plans for prevention of environmental risks and hazards (8). The Law Nº 43/2010 of 07/12/2010 establishing Energy, Water and Sanitation Authority (EWSA) determining its responsibilities, organization and functioning establishes and defines its responsibilities, among others to establish ways of transporting and treating of waste. However, these Laws do not specifically address E-waste and there are currently no specific legislations regulating the management and safe disposal of Electronic Wastes (9) that is imply that the lower administrative levels which are closer to communities are managing the e-waste issue without any specific legal and regulatory framework (10)

By 2013, the number of active mobile cell phones subscribers was 63.5% of the population which represent 6,689,158 subscribers, the internet penetration was at 20% by December 2013 with 2,068,178 subscriptions, 2.4 % of Household had a computer, 7.8% of Household had a TV set and 64% of household had radio set. Although Rwanda is a signatory to the Basel Convention on the Control of Trans-boundary Movements of hazardous wastes and their disposal, at this stage, nothing has been done about e-waste.

EFFECTS TO HEALTH AND ENVIRONMENT

E-waste consists of a large variety of materials, some of which contain a range of toxic substances that can contaminate the environment and threaten human health if not appropriately managed. E-waste disposal methods include landfill and incineration, both of which pose considerable contamination risks (11). Landfill leachates can potentially transport toxic substances into groundwater whilst combustion in an incinerator can emit toxic gases into the atmosphere.

Recycling of e-waste can also distribute hazardous substances into the environment particularly when the recycling industry is marginally profitable at best and often cannot afford to take the necessary precautions to protect the environment and workers health.

While there are more than 1000 toxic substances (11) Associated with e-waste, the more commonly reported substances include: toxic metals, persistent organic pollutants (POPs) and polyvinyl chloride (PVC) (12). These are persistent, mobile, and bioaccumulative toxins that remain in the environment (13) But their forms are changed and are carcinogens, mutagens and teratogens. Human beings and other biodiversity face fatal diseases, such as cancer, reproductive disorders, neural damages, endocrine disruptions, asthmatic bronchitis, and brain retardation (14)

COMMON TOXIC SUBSTANCES ASSOCIATED WITH E-WASTE AND THEIR HEALTH IMPACTS.

Substance and location in e-waste	Health impact
Antimony (Sb) a melting agent in CRT glass, plastic computer housings and a solder alloy in cabling	Antimony has been classified as a carcinogen. It can cause stomach pain, vomiting, diarrhea and stomach ulcers through inhalation of high antimony levels over a long time period
Arsenic (As) Gallium arsenide is used in light emitting diodes	It has chronic effects that cause skin disease and lung cancer and impaired nerve signalling
Barium (Ba) Sparkplugs, fluorescent lamps and CRT gutters in vacuum tubes	Causes brain swelling, muscle weakness, damage to the heart, liver and spleen though short-term exposure
Beryllium (Be) Power supply boxes, motherboards, relays and finger clips	Exposure to beryllium can lead to beryllicosis, lung cancer and skin disease. Beryllium is a carcinogen
Brominated flame retardants (BFRs): (polybrominated biphenyls (PBBs), polybrominated diphenyl ethers (PBDEs) and tetrabromobisphenol (TBBPA) BFRs are used to reduce flammability in printed circuit boards and plastic housings,	During combustion printed circuit boards and plastic housings emit toxic vapours known to cause hormonal disorders

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Substance and location in e-waste	Health impact
keyboards and cable insulation	
Cadmium (Cd) Rechargeable NiCd batteries, semiconductor chips, infrared detectors, printer inks and toners	Cadmium compounds pose a risk of irreversible impacts on human health, particularly the kidneys
Chlorofluorocarbons (CFCs) Cooling units and insulation foam	These substances impact on the ozone layer which can lead to greater incidence of skin cancer.
Hexavalent chromium/chromium VI (Cr VI) Plastic computer housing, cabling, hard discs and as a colourant in pigments	Is extremely toxic in the environment, causing DNA damage and permanent eye impairment
Lead (Pb) Solder, lead-acid batteries, cathode ray tubes, cabling, printed circuit boards and fluorescent tubes	Can damage the brain, nervous system, kidney and reproductive system and cause blood disorders. Low concentrations of lead can damage the brain and nervous system in foetuses and young children. The accumulation of lead in the environment results in both acute and chronic effects on human health
Mercury (Hg) Batteries, backlight bulbs or lamps, flat panel displays, switches and thermostats	Mercury can damage the brain, kidneys and foetuses
Nickel (Ni) Batteries, computer housing, cathode ray tube and printed circuit boards	Can cause allergic reaction, bronchitis and reduced lung function and lung cancers
Polychlorinated biphenyls (PCBs) Condensers, transformers and heat transfer fluids.	PCBs cause cancer in animals and can lead to liver damage in humans
Polyvinyl chloride (PVC) Monitors, keyboards, cabling and plastic computer housing	PVC has the potential for hazardous substances and toxic air contaminants. The incomplete combustion of PVC release huge amounts of hydrogen chloride gas which form hydrochloric acid after combination with moisture. Hydrochloric acid can cause respiratory problems
Selenium (Se) Older photocopy machines	High concentrations cause selenosis

Source: (15)

METHODS

This study was purposive and all participants were 207 and were distributed as follows: 36 participants from district level stratum, 33 participants from sector level stratum and 138 participants from community level to determine the target population, two methods of sampling was employed: stratified random sampling and quota sampling. Stratified random sampling was applied to determine the primary stakeholders in the electronic waste management in Gasabo district which are (i) the district councilors, (ii) the district executive committee members, (iii) the district staff, (iv) the Sectors staff, (v) contracted waste collectors companies and workers in selected Sectors and Nduba dumping site management company and workers.

RESULTS AND DISCUSSION

AWARENESS OF THE EFFECTS OF E-WASTE ON THE HUMAN HEALTH AND ENVIRONMENT

Findings showed that, the awareness of the respondents about the environmental pollution/threat by the electronic waste is serious and complex, therefore, there is need to have a special treatment for electronic wastes, and the effects of its improper disposal has potential risks to both human health and environment.

ENVIRONMENTAL POLLUTION

Results indicated that the participant who know that improper e-waste disposal has negative consequences on the environment pollution is 64.5% of district level respondents, 62% at sector level and 54.3% at the waste collection company workers.

Pathways of Electronic and Electrical discarded equipment

When participants from the district and sector level were asked if they are aware of what happen to the discarded electronic and electrical equipment, the study revealed that 60% of respondents said that they are refurbished by local repairs, 36.6% said that they are scavenged then smelted to make new materials and 3.3% said that they are sent to land fill.

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EFFECTS OF THE IMPROPER E-WASTE DISPOSAL ON ENVIRONMENT

Regarding the risks associated with the improper disposal of e-waste, the study showed that the majority do not know the effects of the improper disposal of the e-waste.

At the district level 77% of respondents indicated that they are not aware of the effects of improper e-waste disposal on the environment while 29% indicated to be aware. At the sector level 89% of respondents indicated not to be aware of the effects. At the waste collection company workers level 89% of respondents indicated to be not aware of the effects of improper e-waste disposal on the environment.

AWARENESS OF THE EFFECTS OF THE IMPROPER E-WASTE DISPOSAL ON HUMAN HEALTH

The results, showed that 74% of the respondents are not aware of the effects of improper e-waste disposal on the human life while only 26% are aware. For sector level 79% are not aware of the effects of improper e-waste disposal and 21% are aware while the waste collection workers 89% are not aware of the effects of improper e-waste disposal. This showed that people in Gasabo district are not aware of effects of improper e-waste disposal on human health. And among the respondents who claimed to be aware of the effects of the improper e-waste disposal on human health 92.3% indicated that they do not know exactly the effects on human health while 7.7% of them indicated the improper disposal of e-waste has high risk of cancer and skin problems and this is due to heavy metals (4).

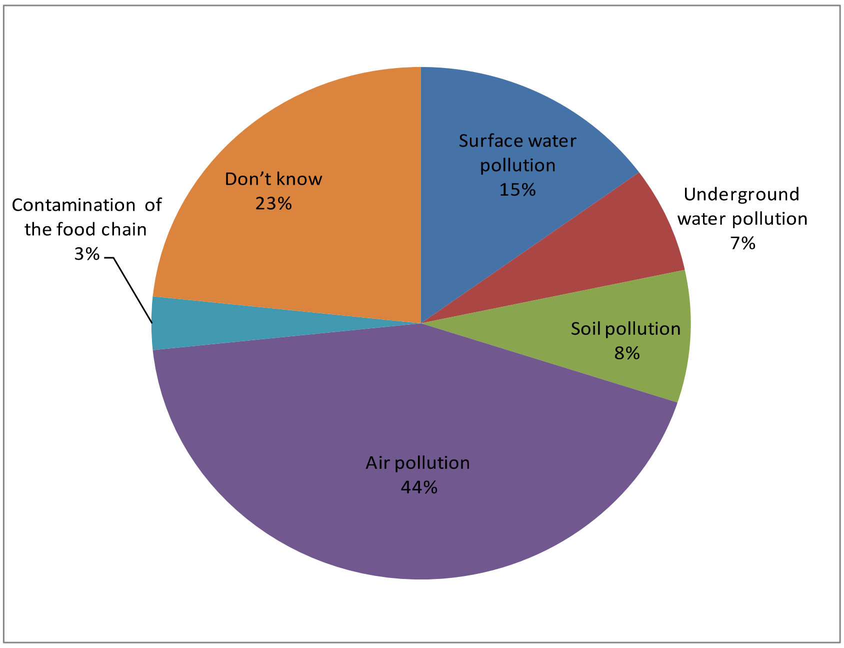
WASTE COLLECTION WORKERS AWARENESS ON IMPROPER HANDLING OF E-WASTE AND LOCAL COMMUNITY

Among the respondents belonging to the waste collection companies and dump site workers' 56.7% confirmed to be aware that improper handling or being exposed to electronic waste may have a negative impact on their health and environment when those e-wastes are liquid or powder while 43.3% said the electronic waste as hazardous than as other wastes.

AWARENESS OF E-WASTE AS ENVIRONMENTAL CONTAMINATION

Results revealed that 44% of respondents are aware that e-waste causes air pollution, 23% don not know the mechanisms through which the e-waste enters into the environment therefore, it does not contaminate the environment, 15% are aware that the e-waste pollutes the surface water, 8% are aware that it pollutes soil, 7% are aware that it pollutes the underground water while 3% are aware that it enters into the food chain. As shown in the figure below

Awareness and local community awareness on electronic wastes and environmental impact



The above pie-chart shows awareness of e-waste as environmental contamination

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INCREASE OF E-WASTE

72% of the respondents from waste collection company management and workers indicated that they have noticed an increase of discarded electronic and electrical equipments in the client's waste bins and the dumpsite, 28% indicated to have not noticed any change.

SPECIAL TREATMENT FOR SOME HAZARDOUS FRACTIONS BEFORE DISPOSAL

Within the respondents from the district and sector level, 37% are aware that some hazardous materials need a special treatment before disposal while 63% are not aware.

The research showed that 100% of respondents from waste collection

Company management and workers are aware that e-waste may be entirely valuable which can be sold to repairs or in valuable in parts like metals which are sold to smelters.

The waste are taken from the entrance of every compound by waste workers to the waste truck. The workers have to transport waste a long distance. The waste truck is loaded manually and unloaded manually in Nduba sector while the Kacyiru waste trucks are manually loaded but automatically unloaded. The manual loading and unloading require some workers to operate inside the waste trucks which puts their health in danger (16). In Nduba sector waste workers are equipped with an apron only, while in Kacyiru waste workers are equipped with overalls, boots and gloves. For Kacyiru waste company, the workers operating inside the waste truck are equipped with extra pants covering the overalls and boots which covers them from high risk (8)

HEALTH AND SAFETY CONSIDERATIONS

Waste are not segregated from the waste generator, are stored in inappropriate containers as used and damaged bags previously used to pack rice, sugar or flavor, that bags may leak when they contain wet or liquid substances. Other households use old and often damaged basins and buckets. The collection day the containers are displaced to the street, discharged and returned back to its owner to be reused and some of these westes are non-recycled (17). The waste trucks are loaded or unloaded manually by workers without adequately equipped for such special tasks. Those practices are not safe and healthy to the waste work and even to the environment. Local authorities and waste collection companies leaders should put in place good and health mechanisms to load and offload these waste collection trucks such that they workers are safe.

Again awareness campaigns on the health effects of these heavy metals that are found in these e-wastes should be put in consideration (18)

The government should emphasize on household proper separation of e-waste and put in place policies and regulations that governs e-waste collection transportation and disposal.

In fighting these chronic disease and increasingly observed disease even toxic environment and environmental alterations, the effects of these heavy metals such as Arsenic (As), Mercury (Hg), Nickel (Ni), Selenium (Se) etc should be looked at.

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