INTEGRATING INDIGENOUS AND SCIENTIFIC KNOWLEDGE IN COMMUNITY-BASED EARLY WARNING SYSTEM DEVELOPMENT FOR CLIMATE-RELATED MALARIA RISK REDUCTION IN MOPANI DISTRICT OF SOUTH AFRICA.

by

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DECLARATION

I, **BRENDA NYEVERWAI RUMUTSA**, declare that the research report

INTEGRATING INDIGENOUS AND SCIENTIFIC KNOWLEDGE IN COMMUNITY-BASED EARLY WARNING SYSTEM DEVELOPMENT FOR CLIMATE-RELATED MALARIA RISK REDUCTION IN MOPANI DISTRICT OF SOUTH AFRICA.

is my own work and has not been previously submitted in any form whatsoever, by myself or anyone else to University of Venda or any other educational institution for any degree or examination purposes. All resources that I have used or quoted have been indicated and duly acknowledged by means of complete references.

8 September 2020

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BRENDA NYEVERWAI RUMUTSA **DATE**

Abstract

Malaria is a climate-change concatenated biological hazard that may, like any other natural hazard, can lead to a disaster if there is a failure in handling emergencies or risks. A holistic solution for malaria mitigation can be provided when indigenous knowledge is complemented with scientific knowledge. Malaria remains a challenge in South Africa and Limpopo province is the highest burdened malaria-endemic region. Specifically, Vhembe District is the highest burdened followed by Mopani District (Raman *et al.*, 2016). This research sought to mitigate malaria transmissions in Mopani District through the integration of indigenous and scientific knowledge. The study was carried out in Mopani District of South Africa and 4 municipalities were involved. These are Ba-Phalaborwa, Greater Tzaneen, Greater Letaba, and Maruleng. A pragmatism philosophy was adopted hence the study took a mixed approach (sequential multiphase design). Data was collected from 381 selected participants through in-depth interviews, a survey and a focus group discussion. Participants for the in-depth interviews were obtained through snowballing and selected randomly for the survey, while for the focus group discussion purposive sampling was used. The study applied constructivist grounded theory to analyze qualitative data and to generate theory. Statistical Package for Social Sciences version 23.0 was used for quantitative data. Based on empirical findings, it was concluded that temperature and rainfall among other various factors exacerbate malaria transmission in the study area. Results of the study also show that people in Mopani District predict the malaria season onset by forecasting rainfall using various indigenous knowledge based indicators. The rainfall indicators mentioned by participants in the study were used in the developed early warning system. An Early warning system is an essential tool that builds the capacities of communities so that they can reduce their vulnerability to hazards or disasters. In the design of the system, Apache Cordova, JDK 1.8, Node JS, and XAMPP software were used. The study recommends malaria management and control key stakeholders to adopt the developed early warning system as a further mitigation strategy to the problem of malaria transmission in Mopani District.

Keywords: Malaria, Indigenous knowledge, scientific knowledge, climate, climate change, disaster, disaster risk reduction, early warning system.

Dedication

I would like to dedicate this study to my late father Felix Muchapondwa, my mother Davidzo Muchapondwa, my husband Maxwell as well as my children Michelle, Maxwell and Brendan.

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The completion of this thesis would not have been possible without the support and encouragement of several people hence, I would like to show my gratitude to those who assisted me in a myriad of ways.

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List of Acronyms

CC –	Climate Change
CCA -	Climate Change Adaptation
DoH -	Department of Health
DRR –	Disaster Risk Reduction
EIR -	Entomological inoculation rate
EWS –	Early Warning System
FGD –	Focus Group Discussion
GIS –	Geographical Information System
GPS –	Global Positioning System
HFA –	Hyogo Framework of Action
ICT-	Information and Communication Technologies
IK –	Indigenous Knowledge
IFCR –	International Federation of Red Cross and Red Crescent Societies
IPCC –	Intergovernmental Panel on Climate Change
ISDR –	International Strategy for Disaster Reduction
MEWS –	Malaria Early Warning System
MRR –	Malaria Risk Reduction
NAPAs-	National Adaptation Programs of Action
NGOs –	Non-Governmental Organizations
SADC –	Southern African Development Community
SWS -	South African Weather Service
SDGs –	Sustainable development goals
SFDRR –	Sendai Framework for Disaster Risk Reduction
SK -	Scientific knowledge
SSA –	Statistics South Africa
SPSS –	Statistical Package for the Social Sciences

SQL – Standard Query Language

UN – United Nations

UNESCO – United Nations Educational, Scientific and Cultural Organization

UNISDR – United Nations International Strategy for Disaster Reduction

VB – Visual Basic

WHO – World health Organization.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

The integration of indigenous and scientific knowledge is vastly gaining credible attention in contemporary disaster management initiatives. It was noted that indigenous knowledge (IK) can complement scientific knowledge (SK) and this can provide holistic solutions to problems (Kolawole 2015, Macherera and Chimbari 2016b). Integration of the two forms of knowledge in malaria risk reduction (MRR) is at a nascent stage as it was recognized that indigenous knowledge(IK) based forecasts have a potential to generate accurate warnings particularly when scientific data is insufficient (Cools *et al.,* 2016). This is partly influenced by continued malaria outbreaks that are being experienced in some parts of the world as control measures that are in place are failing. Unlike geophysical or hydro-meteorological hazards, malaria is not given adequate attention in Disaster Risk Reduction (DRR). To further elaborate on this, Macherera and Chimbari (2016) states that, the malaria hazard is not considered a natural hazard that also requires an early warning system (EWS) for disaster mitigation. Malaria happens to be a climate-change (CC) concatenated biological hazard that can, like any other natural hazard, lead to a disaster if there is failure in handling emergencies or risks. It is anticipated that malaria is related to climate change (CC) as more cases recur in areas that used to be at low-risk (Komen *et al.,* 2015; Ngarakana-Gwasira *et al.,* 2016). Changes in temperature and rainfall may affect malaria vector distribution (Aboda 2012) hence it is a climate-related hazard transmitted by female anopheles mosquitoes.

Globally, more than a million people die each year because of malaria (Newby *et al*., 2016). According to the World Health Organization (WHO), an estimate of three-quarters of the Southern African Development Community (SADC) populace is at risk of contracting the biological hazard (Newby *et al*., 2016). In South Africa, malaria prevention has been principally through controlling the malaria vector (mosquitoes) and parasites (Maharaj *et al.*, 2012). Malaria remains a challenge in South Africa and Limpopo province is the highest burdened malaria-endemic region. Specifically, Vhembe District is the highest burdened district in Limpopo, followed by Mopani (Raman *et al.*, 2016). Active malaria transmission is usually in summer months between November and April (ibid). The emergence of the development of drug-resistant Plasmodium species and insecticide-resistant mosquitoes has necessitated the move to controlling the vector and avoiding mosquito bites (Kumar *et al.,* 2014; Christian *et al.,* 2018).

The Department of Health (DoH) of Mopani District which is the study area of this research acknowledged that it is failing at the prevention stage in malaria risk reduction (MRR) (Online News 24, 23 May 2017 article). The area is constantly experiencing malaria outbreaks and in April 2017 only, 1200 cases were recorded and 76 lives were lost due to the hazard (ibid). There is a need to make an effort in the advancement of MRR interventions in the district. MRR strategies should be achieved by coming up with a complete conceptual framework of elements that are well-thought-out and capable of reducing vulnerabilities to disaster risks. An Early Warning System (EWS) can assist as it is a safety critical-system that helps for such hazards. It encompasses a set of capacities required to generate and disseminate meaningful warnings when there is still ample time for those being threatened by the hazard to prepare or take action to minimize the possibility of harm or loss (IFRC*.,* 2012). EWS assist in predicting a hazard in advance and assist in generating sound epidemic alerts and a contingency plan for preventive actions (Grover-Kopec *et al.,* 2005).

An EWS is more than just prediction as it prevents hazards from turning into disasters. According to Adeola *et al.,* (2015) an effective EWS should predict and issue warnings of an epidemic several months in advance. Advance prediction is the best as it gives enough time for preventive actions. A period of one-month prediction serves for confirmatory alerts (ibid). To be effective, an EWS has to be community-centered (Gaillard and Mercer 2013; Macherera and Chimbari 2016; Twigg 2015). It should also integrate four elements, which are - (i) *knowledge of the risks faced; (ii) technical monitoring and warning service; (iii) dissemination of meaningful warnings to those at risk; and (iv) public awareness and preparedness for action* (ISDR 2006:2). These elements should be organized in such a way that specific objectives are attained through the control and distribution of material resources, energy, and information (Simonovic 2010). Failure in any one of the elements can result in the failure of the whole system (Macherera and Chimbari 2016; Karanath and Dashora 2014; Twigg 2015; Simonovic 2010). Karanath and Dashora (2014) also mention that to enhance its effectiveness, technical agencies that generate warning information, DRR experts as well as vulnerable communities are supposed to be connected. Contemporarily EWS are focusing on sophisticated data and modelling that do not formally prescribe IK as a solution yet MSK on its own is proving to be inadequate in helping communities single-handedly evidenced by continuous malaria outbreaks. This, therefore, calls for the complementation of MSK with IK through the integration of both forms of knowledge in MRR.

1.2 Gaps in malaria risk reduction

Climate-related malaria risk reduction (MRR) is proving to be a challenge even though presently there are measures to control the disease. The continued transmissions in malaria-prone areas such as in Mopani District call for an urgent need to scale up the current malaria risk reduction interventions. Currently, the existing malaria risk reduction initiatives are focusing on sophisticated scientific data and modelling disregarding IK. Most computerized early warning systems that have been designed only use sophisticated scientific data, however, integrating IK and MSK in early warning systems is vital in DRR (Gaillard and Mercer, 2013). It is an essential tool that builds the capacities of communities so that they can reduce their vulnerability to hazards or disasters. The best solution for the recurring problem of malaria transmissions could be through applying an integrated form of IK and MSK. This can as well be enhanced by incorporating Information and Communication Technology (ICT) as this can further improve current MRR efforts.

South Africa meets the pre-elimination criteria and is earmarked for malaria eradication (Maharaj *et al.*, 2012). This research might help in fulfilling the malaria elimination agenda by complimenting scientific knowledge with IK. This is in line with the World Health Organizations' malaria rollback plan (to eliminate malaria) and the South African malaria elimination strategic plan (to achieve zero local malaria transmission). It also falls in line with the local Mopani District Municipal Integrated Development Plan which seeks to mitigate and prevent hazards that affect the Districts` economic growth and the livelihoods of its communities. Top-down command and control strategies that are dominating malaria risk reduction (MRR) still dismiss communities' contributions (Gaillard and Mercer, 2013; Lunga, 2015). There is a need to bridge the gap to allow communities to participate in malaria risk reduction (MRR) with their IK and practices. This research could also be a platform to raise the need for local policies to consider affected communities to participate with their IK and practices in DRR instead of relying on frameworks that emphasize the use of scientific knowledge in EWS. Little research has been done on the integration of scientific and IK specifically in malaria early warning systems. There is no documentation or record of any malaria early warning system (MEWS) that uses information and communication technology (ICT) as a platform for integrating scientific and indigenous knowledge for climate-related malaria risk reduction. This is because little is known on how and indigenous knowledge can be integrated into an ICT based malaria early warning system (MEWS) as the translation of IK into DRR action engaging communities to participate in malaria control programs.

More-so, currently, there is no evidenced practice of communities participating with their IK and practices in MEWS as little is known on how the IK can be translated into MRR actions that involve communities. This research, therefore, seeks to fill that knowledge gap as well as to make an original contribution in developing an innovation that could be a solution for MRR in Mopani District. A functional ICT-based EWS that integrates scientific and IK based indicators was developed and this could help in seasonal malaria prediction and its subsequent elimination. The innovation might enable communities to participate in MRR using their IK and practices. It might end up being adopted for use by other local or international communities in similar situations.

1.3 Statement of the problem

Climate-related malaria risk reduction remains a challenge as malaria transmissions continue to persist in Mopani District of Limpopo Province, even though South Africa has been implementing malaria control interventions since the 1930s (Khosa *et al.*, 2013). Contemporary malaria control initiatives are denigrating IK more-so, malaria is not regarded as a hazard that needs an EWS for communities to prepare and act in sufficient time to reduce the possibility of harm or loss. This, therefore, calls for the consideration of complementing the existing science knowledge-based malaria risk reduction interventions with indigenous knowledge in the development of an integrated early warning system.

1.4 Study purpose and aim

The purpose of this study was to come up with an effective mitigation measure for malaria transmissions in Mopani District, hence the aim was to develop an EWS that integrates indigenous and scientific knowledge for climate-related malaria risk reduction in Mopani District.

1.5 Research objectives

1. To identify the factors that influence malaria transmission in the Mopani District.

2. To examine the nature of the existing malaria early warning system of Mopani District.

3. To investigate the existing indigenous knowledge-based prediction indicators and prevention measures against climate-related malaria among the Mopani District communities.

4. To develop an integrated scientific and indigenous knowledge-based early warning system for climate-related malaria risk reduction for Mopani District.

These objectives are the driving force of the research and precursors for the formulation of the research questions. Since the research questions should drive design decisions, the researcher ensured that the questions are aligned for a mixed method-grounded theory (MMGT) approach. The questions are as follows;

1.6 Research questions

1. What are the factors that are influencing malaria transmission in Mopani District?

2. How is the nature of the existing malaria early warning system of Mopani District?

3. What are the existing indigenous knowledge-based prediction indicators and prevention measures against climate-related malaria among the Mopani District communities?

4. Can an integrated scientific and indigenous knowledge-based early warning system for climate-related malaria risk reduction be developed for Mopani District?

1.7 Significance of the study

In all its subject policies disaster risk reduction frameworks are calling for the valuing of the integration of indigenous knowledge as it is acknowledged as a fundamental resource for building community resiliency in a cheap and sustainable way. The study was considered significant to various stakeholders that included, Department of health workers, disaster risk reduction experts, and the community members in Mopani District. It was expected that the Department of health and Disaster management centers realize the necessity to consider communities to participate with their indigenous knowledge and practices as well as to use their local resources in disaster risk reduction. This might empower them and strengthen their coping capacities so that they remain resilient in case the existing science-based initiatives fail. In other words, this will assist the building of local capacities by the activation of IK in support of current scientific efforts for effective DRR. It is therefore hoped that this research informs and gives recommendations on fostering tailor-made early warning systems that match different South African community setups and hazards considering each community`s unique IK.

1.8 Assumptions of the study

Firstly the researcher assumed that Mopani District communities are aware of the malaria hazard in the area and they have prediction indicators as well as malaria risk reduction measures against the climate-related hazard. The researcher also anticipated that the elderly people (50 years and above) were the custodian of indigenous knowledge. Lastly, it was also assumed that malaria transmissions in Mopani District are as a result of complex dynamic processes that involve many interlinked factors.

1.9 Scope of the study

This research emphasized on integrating scientific and IK in an EWS for climate change-related malaria risk reduction in Mopani District, Limpopo Province, South Africa. It focuses on malaria which is a biological hazard. Other categories of hazards such as hydro-meteorological and geophysical hazards are not of any concern in this study. The research excludes reactionary measures such as malaria early detection, containment and treatment as it emphasizes on proactive measures. In the study malaria treatment measures are not regarded as part of MRR measures. The researcher believes that treatment is sought when people have already been affected, hence, this is not part of prevention since it is a reactive measure.

The study was being carried out in, 4 municipalities of Mopani District, in Limpopo Province of South Africa. The municipalities involved in the study are Ba-Phalaborwa, Greater Tzaneen, Greater Letaba, and Maruleng. These municipalities are predisposed to seasonal malaria outbreaks (Ikeda *et al.*, 2017) due to warm conditions (Komen *et al.,* 2015). Limpopo Province is situated in the northeastern part of South Africa (Approximately 22–25ºS, 27–32ºE) and lies in the low-altitude area in the most northerly part bordering Botswana, Mozambique, and Zimbabwe. In the south, it is bordered by Ehlanzeni District Municipality and on the west by Capricorn and Sekhukhune District Municipalities. According to Tshiala (2011)**,** Limpopo Province where Mopani District is located experiences extreme weather events and is particularly vulnerable to climate change impacts. There are three distinct climate regions in the province thus the high veld, middle veld, and low veld. The low veld is characterized by a semi-arid climate, the middle and high veld is considered semi-arid and some escarpments experience sub-humid climates (Rankoana and Chen 2016). Mopani District has a wide range of topography with an elevation between 600 and 900 meters above the sea level. Its geology is characterized by a variety of landscapes which include lowlands, plains, undulating landscapes and moderate relief (Mopani District Development Plan 2016).

During summer Limpopo Province experiences hot and dry weather conditions in most days. Rankoana and Chen (2016) observe that, in this season, warm days are usually interrupted by short-lived thunderstorms. The bulk of rainfall is received in summer and ranges from 400-600mm over most of the Province. Limpopo Province lies in the great curve of the Limpopo River and is characterized by mixed grassland and trees known as bush-veld, majestic mountains, gallery forests and patchwork of farmland. The average annual temperature is about 22ºC, with the highest temperatures, about 25ºC, recorded between December and January, while the lowest is felt in July, about 15ºC (Tshiala *et al.,* 2011). The following figure 1.1 shows a map of the study area.

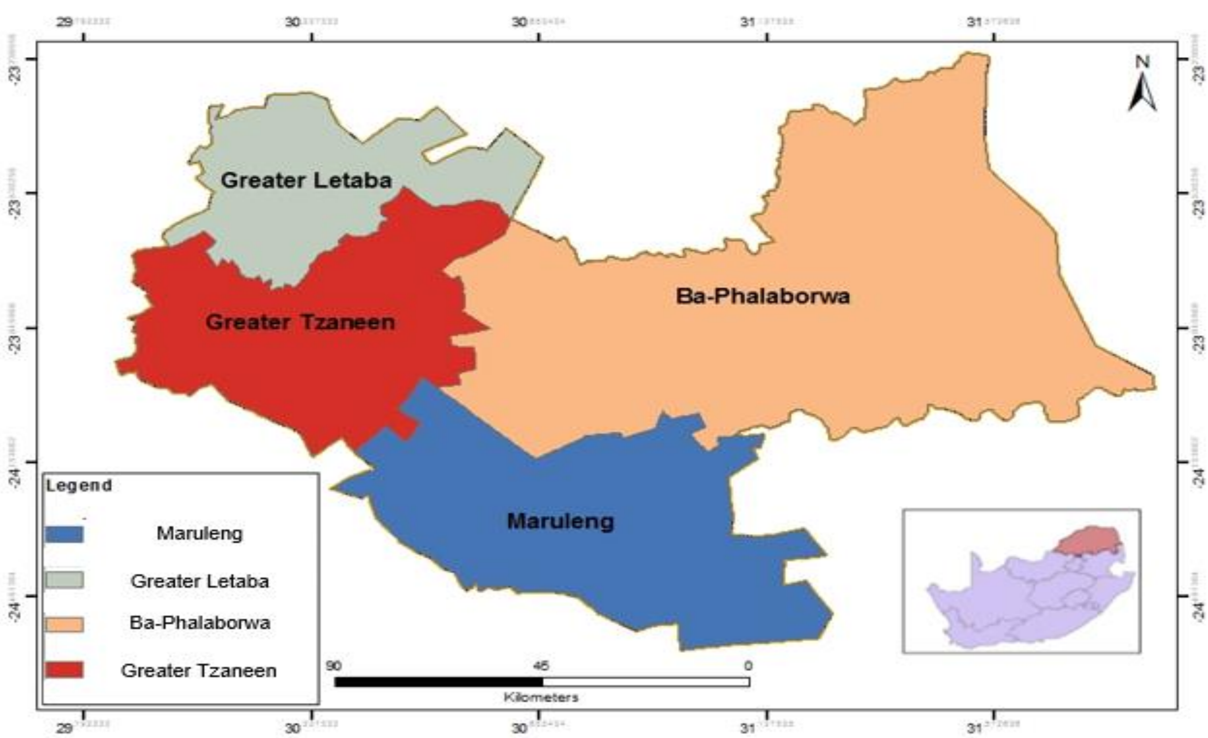


Figure 1.1 Map of the study area in Mopani District

In Mopani District, biological hazards such as malaria and hydro-meteorological hazards e.g. floods, droughts, and cyclones are common as enunciated by the Mopani District Development Plan of 2016. These affect its economy, sustainable livelihoods and cultural welfare, to mention a few. The factors that could lead to greater risk to these hazards in Mopani District communities include overpopulation, inadequate planning, and poor building methods. According to Statistics South Africa, in 2011, Mopani District had a total population of approximately 1 092 507. 81% of the population resides in rural areas, 14% in urban areas and 5% in farms. On average there were about 23 people per hectare. The higher proportion (49.4%) of the residents were young aged thus between 0-19 years (Statistics South Africa, 2011). About 25.9% of the population in Mopani District Municipality is employed in the farming sector (Statistics South Africa 2011a). The percentage of the unemployed among the potentially employable in the district is only 9% out of 39% of the population. Most of the unemployed are women and these make 60% of the unemployed in the district (Statistics South Africa, 2011). Literacy levels in Mopani District are very low. 27.1% of the adult population which is above the age of 20 years has not received any form of schooling (Statistics South Africa, 2011). Only 13% of the population completed primary education, 12.7% have completed their matric and only 6.5% any form of tertiary education. More than 40% of the adult population is considered to be illiterate (Statistics South Africa 2011a).

1.10 Definition of key terms

This study fits into the disaster risk reduction (DRR) domain. Keywords were defined to assist and enable the establishment of their relationships. The keywords include climate, disaster risk reduction, early warning system, indigenous knowledge, integration. In relation to this study the most appropriate definitions of key terms befitting this study mean the following;

Climate - *in this context climate refers to the average weather of an area, most often variables such as temperature, rainfall and wind changes in weather patterns* (IPCC, 2014:3).

Climate change- *refers to a change in the state of the climate that can be Identified by changes in mean/or the variability of its properties, and that persists for an extended period, typically decades or longer* (IPCC, 2014:3).

Disaster Risk Reduction- to *the concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including lessened vulnerability of people and property by wise management of the land and environment by improved preparedness* (IFRC, 2012: 7).

Early warning system- *the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss* (IFRC, 2012:7).

Indigenous knowledge (IK)- *is considered to be the knowledge that exists in local people that is acquired over a long period of time through experiences, community practices, in connection with nature and is passed down through generations* (Fernando,2003:56).

Integration- refers to the bridges and connections between concepts in the domain of disaster risk reduction (DRR) (Banwell *et al*. 2018:2).

Malaria- *is an entirely preventable and treatable illness caused by a parasite of Plasmodium species and transmitted exclusively by the bites of anopheles mosquito* (Sukhthankar *et al.* 2014:1).

Scientific knowledge - *it is a set of statistically analyzed data or instrumental records with independent or dependent variables that can be empirically measured and that demonstrate acceptable levels of reliability and validity* (Alexander *et al.*, 2011:477).

1.11 Outline of the thesis

The first chapter outlines the background of the study**.** Chapter 2 unpacks the concepts of the research. A review of policies, theories and frameworks influencing the study are then discussed in chapter 3. This is followed by the research methodology in chapter 4. In chapter 5, 6 and 7 the results from collected data on the first 3 research objectives are presented, analysed, and interpreted in respectively in each chapter. Chapter 8 follows outlining steps on how the functional early warning system was developed. The study conclusion and recommendations are finally given in the last chapter (9).

1.12 Summary

This introductory chapter discussed issues that motivated the researcher to conduct this study. The issues and motivations are focused on the pressing need for malaria risk reduction (MRR) in Mopani District as it facing a challenge of malaria hazard. The research was motivated by a desire to come up with a solution to the problem of malaria being faced in Mopani District. The statement of the problem, research objectives and questions, were stated as the chapter unfolded. The following chapter unpacks the major concepts informing the development of an early warning system developed in this study.

CHAPTER TWO

CONCEPTUALIZATION OF KEY TERMS

2.1 Introduction

This chapter unpacks the major concepts[1] of the study. According to Rocco and Plakhotnik (2009), all empirical studies that adopt a mixed, quantitative or qualitative method should be connected to a body of literature and have a conceptual or theoretical framework that forms their foundation. This is inclusive of researches that are underpinned by grounded theory (GT) (Oktay 2012). Even though the grounded theory was adopted for the study the researcher reviewed relevant concepts and theories to increase theoretical sensitivity. Oktay (2012) states that ignoring existing theories, even in the use of grounded theory, does not help the researcher to eliminate bias but it reduces theoretical sensitivity. This made the researcher aware of the significant theoretical concepts that might arise in the study. However, this did not influence the merging of a theory from the collected data to avoid research bias as the researcher maintained an open mind consistent with Oktay (2012). According to Jonker (2010) concepts develop in the course of the research and are places of interest or road signs which guide the conduct of research. In this section, the major concepts of the research are explained as well as their relationships. Oktay (2012) reveals that it is very crucial to develop a map regarding important concepts even when using grounded theory in research. The identification or definition of concepts serves as an audit trail (ibid). The identification of major concepts helped the researcher to make constant reference as the research unfolded towards EWS development.

2.2 Malaria

Malaria is a curable vector-borne illness that is caused by Plasmodium species' parasite and transmitted exclusively by bites of a female anopheles mosquito (Sukhthankar *et al.,* 2014). It is a challenging biological hazard as its transmission is a complex process that involves many interlinked dynamic factors, especially in developing nations (Kumar *et al.,*

[1] Malaria, Indigenous knowledge, scientific knowledge, climate, climate change, disaster, disaster risk reduction, early warning system.

2014). Four common Plasmodium species affect human health. These are plasmodium, *P. falciparum, P. ovule, P. malariae and P. vivax* (Paaijmans, 2008; World Health Organization, 2013). Though malaria is fatal, it is a preventable disease and prevention can be through taking appropriate precautions. An explanation of how malaria (which is a natural biological hazard) can consequently result in causing a disaster, is prerequisite towards integration of scientific and IK in the development of an effective practical EWS for climate-related malaria. A malaria hazard may have disastrous effects at different levels for example, at an individual, household, community and regional level (Macherera and Chimbari 2016). Regrettably, in many communities, malaria is not recognized or considered a natural biological hazard (Macherera and Chimbari 2016) despite it being a killer disease affecting populations, especially those in Africa (Bizimana *et al.,* 2015).

Malaria epidemics, by their nature, are a hazard that could lead to disasters (Mayhorn and McLaughlin, 2014; Macherera and Chimbari 2016; Banwell *et al.*, 2018) because they may challenge normal routine approaches to control and treat the disease, hence the need for a holistic approach to EWS. The hazard has previously compromised the functioning of some communities, for example, Vhembe District, in Limpopo Province of South Africa, where serious socio-economic periodic disruptions have been reported (Komen 2016; Ikeda *et al.,* 2017; Christian *et al.,* 2018). In the province, malaria hazard is endemic (Raman *et al.*, 2016) and reduces productivity in the agricultural sector and social development areas. Specifically, the Mopani District Heath Department admits that it is failing to control malaria outbreaks at the prevention stage (Online News 24, 23 May 2017 article). Bearing all these factors in mind, it is convincing that malaria is a hazard that is capable of causing a disaster. Failure to effectively handle malaria emergencies may lead to a disaster at the community or regional level.

2.3 Disaster

A disaster is a result of negative occurrences from the impacts of a hazard that affect vulnerable populations (Adepoju 2017). According to Baudoin (2016), disasters are conceptualized in terms of social losses. Disasters may be acute or chronic in nature or they could be sudden shocks such as malaria disease outbreaks (Westen 2012). The moment affected societies lose lives and properties and fail to cope with their own resources to the extent of requiring external assistance, the situation is referred to as a disaster. Social impacts of disasters include mobility, morbidity, disruption of social services and economic losses. This includes the loss of livelihoods, capital such as households and livestock and the interruption of development programmes.

Biological disasters result in processes of organic origin or those conveyed by biological vectors. These include epidemics, exposure to pathogenic micro-organisms, toxins and bioactive substances (UNISDR 2009). Biological disasters caused by malaria outbreaks which are a major concern in this research are capable of causing serious disruptions in communities (Adepoju 2017). Sometimes affected communities fail to cope with their capacities, hence it cannot be a misnomer calling such an event a disaster. Westen (2012) supports this assertion and reveals that disasters are a result of the interaction between hazards and vulnerable societies. According to Kelman (2015), disasters happen as a consequence of a combination of exposure to a hazard, vulnerability and insufficient coping capacity. This results in potentially negative events. Choices in skills and resources for DRR varies according to the nature of the hazard threat, coping capacities and priority adjustments during the progression of a disaster (Twigg 2015).

Disasters are the main threat that jeopardizes sustainable development the world over Twigg (2015). Developing nations experience greater losses in comparison to developed countries when a disaster strikes, due to lower awareness, preparedness and the weaknesses in EWS (Westen 2012). According to the UN's International Strategy for Disaster Reduction (ISDR), for an event to be considered a disaster that can be entered into the ISDR database, at least one of the criteria below should be met: ·

- *A report of 10 or more people killed. ·*
- *A report of 100 people affected. ·*
- *A declaration of a state of emergency by the relevant government. ·*
- *A request by the national government for international assistance*.

However, the impacts of a disaster can be reduced by employing DRR measures. Through the identification of risks, the occurrence of disasters and negative outcomes may be reduced where feasible. DRR measures which include improved governance, preparedness, and EWS, can reduce the chance of natural hazards turning into disasters.

The effective delivery of DRR programs can reduce the enormous burdens associated with disasters (Baudoin *et al.*, 2016).

2.3.1 The disaster risk reduction concept

While several authors in the disaster management field use the term preparedness, DRR is used in this research. Baudoin (2016) points out that Disaster Risk Reduction (DRR) evolved from the response and recovery traditional approach to disaster management.

In this study, the definition of DRR refers to *"the concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including lessened vulnerability of people and property by wise management of the land and environment by improved preparedness"* (IFRC, 2012: 7). DRR is intended to minimize the adverse effects of hazards. This is done by reducing societal vulnerabilities, avoiding (preventing) and limiting (mitigating and preparing) consequences of disasters. DRR mainly increases the ability of households or communities to mitigate, prevent and cope with shocks of disasters (Pelling 2012; Twigg 2015).

DRR does not include just one component in dealing with a disaster, but several ways for the mitigation of a hazard and its concatenated effects. Regrettably, DRR is highly likely to be ostracized in favour of other priorities perceived to be of pressing need (Twigg, 2015). Interconnecting appropriate and important components for EWS can make DRR successful. Concentrating on a single element of the components of an effective EWS is not sufficient to cushion communities. Prioritizing one element of an EWS exposes people to the risks associated with the hazard (Macherera and Chimbari 2016; Karanath and Dashora 2014; Twigg 2015). In some cases, some of the elements that contribute to the effectiveness of DRR measures are compromised, depending on the nature of the hazard being encountered.

2.4 Climate

Climate refers to the average weather of an area, most often variables such as temperature, rainfall and wind changes in weather patterns (Yasuhara *et al.*, 2014).

Climatic factors have been used as prediction indicators for malaria seasons as they have a capacity to influence outbreaks.

2.4.1 Effects of climate variability on malaria vector

Variations of climatic factors such as temperature, rainfall and humidity directly or indirectly affect malaria parasites and vectors (Macherera, Chimbari, and Mukaratirwa 2015). This notion is supported by Alemu *et al.*, (2011) who reveals that the dynamics of malaria vector populations are associated by temperature, rainfall and humidity. The climate variables are key determinants of the geographical distribution and abundance of mosquitoes as these factors create conducive conditions for mosquito vector survival (Jemal and Al-Thukair 2016). Mosquitoes are sensitive to these factors as they have an influence on the adult and larvae is affected. Their distribution is dictated by variable climatic patterns notably temperature, rainfall and humidity (Tonnang *et al.*, 2014). They are important drivers which affect the dynamics of vector populations (Alemu *et al*. 2011). Changes in temperature and rainfall may affect malaria vector distribution (Aboda 2012) hence it is an extremely climate sensitive hazard. Climate variables also influence the development of Plasmodium parasite, female Anopheles as well as infection and life cycles of the mosquito (MacLeod *et al.*, 2015). MacLeod *et al.*, (2015) further mentions that there is potential to predict malaria epidemics based on climate drivers.

2.4.2 Climate change

UNFCC (1992:3) defines climate change as "a *change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods of time*". Climate change is anticipated to result in an increase in the frequency and severity of extreme weather related hazards such as malaria, heat waves, droughts and heavy rainfall (Alexander *et al.*, 2011).

2.5 Early warning system

Various definitions have been used to describe Early Warning Systems. In this study, it is crucial to understand what an EWS is about and what it should be composed of for the development of an effective practical malaria early warning system (MEWS). An early warning refers to "*a thing that tells you in advance that something serious or dangerous is going to happen*" (Oxford English Dictionary, 2015). UNISDR (2009:12) defines an EWS as a *set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss*. The issuance of early warning information on its own is not useful unless it is complemented by an integrated system with different components that enable people to deal with an impending danger. Ideally, an early warning event should be augmented by a system that enables people to take action as in consistent with the definition given by the IFCR (2012), which is considered the perfect description an EWS for this study.

It is important to take note that vulnerable people should be able to take action against hazards threatening them and should not be treated as passive elements in DRR. People should have room to make their own decisions when they are notified of a hazard instead of decisions being imposed on them. Lenton (2012) is of the idea that EWS potentially reduces the impact of hazards when they provoke the action of those that are at risk. Their designated functions are fulfilled when they can detect hazardous events timeously, transfer warning to people at risk to avoid losses (Sättele *et al.,* 2015; Anup *et al.,* 2014; Lenton 2013). An EWS is an effective operational model aimed at reducing the impacts of natural disasters on societies (Baudoin *et al.*, 2016). They enable communities to assess levels of risk so that they make informed decisions to safeguard themselves (Macherera and Chimbari 2016). EWS enable information to be generated before losses are incurred and they can be regarded as critical-safety systems that shield people from a hazardous event (Löwe *et al.*, 2013). It prevents hazards from turning into disasters as it is more than just prediction.

An early warning is comprised of a strongly linked chain of elements for its effectiveness. The failure of one element or component in the chain or any weak link in the elements of EWS may result in underperformance or failure of the whole system (Macherera and Chimbari 2016; Karanath and Dashora 2014; Twigg 2015). A system is comprised of subsystems which are smaller entities that make up the larger system (Simonovic 2010).

All components in them have interdependent relationships among them (ibid). An EWS is an open system that has inputs, processes and outputs. It is a useful tool and an essential component of DRR (Meissen and Voisard, 2010) that save lives. EWS must be viewed as a subsystem within the larger socio-economic, cultural and political system.

This study specifically sought to develop an EWS for malaria which is a biological hazard. Macherera (2015:50) defines a malaria early warning system (MEWS) as "*a series of approaches that refine the understanding of the geographical variation of malaria risk in a dynamic environment and usually comprises forecasting, early warning and early detection*". However, the definition of EWS by Macherera (2015) considers early malaria detection as part of early warning but the Oxford Dictionary defines early warning as something that tells people in advance that something serious or dangerous is going to happen. Regarding the definition by Macherera (2015), it can be deduced that the system is not merely proactive but also reactive as it includes detection. Detection is the action or process of identifying the presence of something hidden (Oxford English Dictionary 2015), hence the focus is concerned with that which has already been affected. Ideally, an effective EWS is supposed to be pro-active, preventing damages and loses before they occur. An effective and proactive EWS is supposed to prevent the people at risk from being affected by a hazard at all cost (malaria).

2.5.1 Benefits of early warning systems in disaster risk reduction

According to Sättele *et al.,* (2016) early warning is mainly classified as an alarm and forecasting systems. An EWS is important as it helps in the detection, forecasting and issuing alerts in the event of hazard risk (Siddhartha, 2017). Precursors for monitoring and predicting an event can be automated with the aid of human decisions. The alarm is raised when thresholds are reached and these are determined by human decision. Technically Leonard (2013) brings out that in an EWS there should be an assemblage of technological, telemetry and notification which should trigger a proactive reaction. A comprehensive evaluation of the EWS` reliability and its effectiveness is determined by human decisions and the nature of predictive models (Sättele *et al.,* 2015). Their reliability and effectiveness (a relative measure of achieved risk reduction) rely on components and the ability of the system to identify the intended hazard (Sättele *et al.,* 2015). Effectiveness of an EWS is defined as a relative measure of achieved risk reduction and it is deteriorated by false alarms. This causes warning fatigue, where continued false alarms over a number of years end up causing loss meaning of the alerts (Mayhorn and McLaughlin 2014). They are most effective for hazards that take long to culminate into a disaster.

EWS reduces exposure probability by providing the lead time that enables people to act before an emergency. In the case of malaria, issuing out supplies for malaria prevention, anti-malarial drugs and nets (which are some of the inputs in the early warning system) or raising awareness. Issuance of warnings (which is an example of an output of the early warning system) depends on the capacity of the EWS to determine the time lap between embryonic and mature stage of a hazard (Karanath and Dashora 2014). Banwell (2018), reveals that EWS in the resilience of health systems and populations is an essential aspect. They are a cost-effective risk mitigation measure as they provide timely information to prevent or palliate disasters. EWS have gone under rapid improvements technologically, however, guidelines and procedures to quantify their effectiveness are still wanting (Sättele *et al*. 2015). Evaluation of the EWS should reveal the benefits of risk reduction and consequences that could emerge due to false alarm propagation. False alarms compromise the effectiveness of the EWS and compliance of people intended to react by the system (Twigg 2015).

Regardless of how well an EWS is advanced technologically, it is more useful and effective when the communities are able to respond promptly to its messages. The possibility of their inclusion is when their IK is incorporated in tailored community EWS. This could possibly reduce implementation costs as it prevents losses through the reduction of relative costs associated with the aftermath of a disaster (Wilkinson *et al.*, 2017). The role of technical and disaster agencies as well as members of the community in EWS is critical depending on the hazard (Karanath and Dashora 2014). It is not only the technical capacity which guarantees its effectiveness but institutional capacity as well as DRR measures. Jørgen *et al.,* (2018) also reveal that it is safe to encourage communities to consider the collection of IK in a particular area, that enhances DRR at local levels. Generally, three variables interact to determine reaction by the public in impending danger, thus the attribute of a hazard; EWS components; and characteristics of the receiver (Mayhorn and McLaughlin 2014).

2.5.2 Types of early warning systems

EWS development mainly depends on the objectives of the system. Traditional indigenous knowledge early warning systems are based on indigenous observations of relevant factors (Basher 2006). Baudoin *et al*. (2016) reveal that traditional knowledge provides local people with relevant indicators for threatening natural hazards. In Simeulue Island (Indonesia), there were only 7 victims from 78,000 of the total population in the year 2000 (Syafwina 2014) affected by the Aceh–Andaman earthquake associated with the most devastating tsunami in human history which occurred in the Indian Ocean in, 2004 (Mayhorn and McLaughlin, 2014). The Simeulue tribe uses traditional based early warning systems. Through their traditional knowledge, sudden changes in the behaviour of animals and the sea in coastal is an indicator of a pending Tsunami disaster (Syafwina, 2014). After noticing the indicators, people move to safe grounds before this tsunami hits to minimize loss of lives. In Tanzania, the Maasai traditional knowledge custodians use their traditional observations of the behaviour of animals such as goats to forecast rainfall amounts for a season Villagrán de León and Pruessner (2013).

Conventional End to End EWS are typically top-down command and control in nature and uses a linear model (Basher 2006). The linear model that adopts a top-down approach from the scientific experts to the public. Traditional End to End EWS mainly uses an expert-driven approach. With this system, it is believed that technical expertise is considered more important and therefore are given a relatively high priority (Glantz *et al.*, 2014). Most disaster experts believe communities do not scientifically understand their risks and hence they consider the members as passive recipients (Twigg 2015). To a larger extent, therefore, communities are not involved or engaged in most of the activities (Basher, 2006).

Recently there has been a lot of changes in DRR as there are now different ICT based tools that can be used in predicting disasters before they occur (Siddhartha 2017). Technology has been used successfully in analysing and predicting hazards. It can be used as the basic foundation of networking arrangements that assist immensely in meeting the desired objectives of an EWS (Karanath *et al.,* 2014). Technology can be applied effectively in different stages of DRR to reduce the effects of disasters (Siddhartha 2017). This can be done where it suits depending on the requirements of the EWS to be developed. According to Kolawole (2015) recurring problems threatening people call for rethinking approaches to find solutions for the challenges that they are facing.

Integrated EWS emphasize on linkages and interactions among all the elements necessary for an effective response (Basher 2006). Humans are considered as elements of the system and their responsibility is to manage the risks (ibid). An integrated EWS requires a multi-sectorial approach (Atkinson *et al.*, 2010) as well as multiple interventions for hazards within the same community. However, not all systems fully constitute integrated EWSs. Most EWS prioritise certain elements and sectors in hazard mitigation.

Community- based EWS is also known as people-centred EWS. The system is initiated and driven at a local level by its beneficiaries (Baudoin *et al.*, 2016). In other words, it is developed, managed and maintained by the people likely to be affected by certain hazards. Individuals and communities are empowered to confront hazards and to act in sufficient time (Alessa *et al.*, 2016; Macherera and Chimbari 2016). However, according to Alessa *et al.,* (2016) only a few EWS that are driven by local communities exist. Community-based EWS was developed for 3 wards of Gwanda District in Zimbabwe. The CBEWS can predict droughts, floods and Malaria using traditional of local communities (Macherera and Chimbari 2016b). The CBEWS for Gwanda though, it is not technologically based and it involves only IK. However so far there are no community-based early warning systems for malaria that have been documented in the literature (Macherera and Chimbari 2016a).

2.6 Existing weaknesses of current Early Warning Systems

Even though scientific knowledge has developed malaria prediction and prevention measures, on the other hand, it is often far removed from the communities experiences since it rearranges and breaks down collected data (which could be qualitative or quantitative data) (Agrawal 1995). Where scientific knowledge is applied, usually the early warning systems are a theory since it does not match the local set up where it is adopted. Malaria early detection systems based on MSK are widely being used. Early detection and prevention are regarded as a key pillar in malaria control strategies (Sewe 2017). Alerts are being triggered when a high number of malaria cases are observed. Evidence indicates that unnecessary high mobility and morbidity due to malaria is attributed by inventions that are not timeous, with inadequate response strategies and failure by decision-makers to anticipate or identify epidemic events (Cox and Abeku 2007). Usually, there is a provision of information about the onset of a serious malaria epidemic and warnings are prompted only when an unusual transmission is underway. The observed rise in malaria cases cannot be referred to as a prediction measure since some people would have already been affected by the biological hazard. Evidently, this indicates a system that is reactive and not proactive. With an effective EWS in place contrary to early detection, there is an attempt to predict epidemics before unusual transmission begins (Teklehaimanot *et al.*, 2004; Macherera *et al.*, 2015).

2.7 Indigenous knowledge

IK is a broad range of knowledge which the indigenous people of a specified area hold (Armatas *et al.*, 2016). Indigenous Knowledge (IK) is a term that includes beliefs about indigenous people that are acquired through long-term association with a place (Goduka, 2012). According to Gope *et al.,* (2017), IK is a body of knowledge that is community-centered in nature and has a fixed territorial space for a considerably long period of time. IK is unique to a culture, community or society (ibid). This knowledge can be presented as local or traditional knowledge (Kiondo and Msuya, 2007; Cadag and Gaillard 2012). Kiondo and Msuya (2007) are of the notion that IK is scientific as it is obtained through practicing the same things over the years and can solve problems faced by communities. IK is mostly transmitted orally from one generation to the other (ibid).

IK has an advantage over science because it is tested in the context of survival (Mercer 2010). IK when complemented by scientific knowledge, can form a basis for sustainable development that is people-centered. It is one of the important components of DRR (Masipa 2016; Dube, *et al.,* 2018) as it encourages community participation and empowers them in reducing disaster risk (Masipa 2016). It has enabled communities to mitigate risks, prepare, respond and recover from disasters before the developments of high technology-based EWS (International Organization for Migration 2015). IK is an indispensable tool that can empower local communities and plays an important role in DRR in all stages (Dube, Munsaka and State, 2018). The Sendai Framework for Disaster Risk reduction (2015-2030) recognizes that indigenous people, through their experience and IK, contribute immensely in the development and implementation of developmental plans including those that encompass early warning systems, hence IK is a very important component of DRR (UNISDR 2015).

In the contemporary setting, IK is being threatened with virtual extinction by insensitive development over which the indigenous people have no participation (Lunga 2015). The knowledge of remote or sparsely populated areas especially rustic rural areas have traditional lifestyles that are being threatened by the growing environmental and social pressures (Lalonde 1991). IK is also facing a threat by formal education that mostly exposes students to scientific knowledge (Kiondo and Msuya, 2007). Scientific knowledge has taken over and people concentrate on IK that has direct financial benefits, for example, IK use in medicine, ignoring the knowledge that has no financial benefits (ibid). According to Cadag and Gaillard (2012), achieving a blending of the two sources of knowledge however proves difficult in DRR.

2.7.1 Indigenous knowledge-based malaria prediction indicators

IK can also be used by communities as bio-indicators for climate-related hazard predictions (Baudoin *et al.*, 2016). Given that local communities are able to predict weather conditions using IK, it is possible to utilize the knowledge for the development of a community inclusive MEWS (Macherera, *et al.,* 2017; Audefroy *et al.,* 2017; Ngarivhume *et al.,* 2014; Baudoin *et al.,* 2016). Communities` intimate knowledge of plant and animal cycles assist them to be able to associate nature events with particular climatic cycles, enabling the prediction of seasonal events (Chianese 2016). Unfortunately, people miss the indicators because observations are at individual basis (Macherera *et al.,* 2015). The following are some of the indicators that have been observed over the past years to predict climate-related hazard;

Macherera and Chimbari (2016) in a study that they carried out found out that meteorological indicators are reliable monitoring indicators for malaria. Plant phenology use in weather forecasting is widely practiced in Southern Africa and other parts of the world (Basdew *et al.,* 2017; Makwara 2013). Communities expressed that such indicators like plant phenology works for them especially for rainfall prediction. Macherera and Chimbari (2016) established that plant phenology was the most used rainfall indicator useful in predicting malaria in their study.

According to Makwara (2013), in a study done in Zimbabwe, significant flowering and good fruit-bearing of trees such as the *Uapaca kirkiana* and *Parinari curatellifolia* trees is an indicator of a poor rainfall season in the upcoming season. Zuma-Netshiukhwi *et al.,* (2013) reveals that in the South-Western Free State the *Faidherbia albida* tree is commonly used. It has unusual phenology and is unique in that it sheds its leaves with the rains and is green during the dry season. It is reported that an abundant yield of pods indicates a wet season to come and the other way around (ibid).

Seasonal forecasts and disaster prediction can be done by observing the breeding patterns of wild animals like the impala, kudus and bushbuck to mention a few (Makwara 2013). Giving birth of wild animals in large numbers signifies a good rainy season while the reverse is true. Croaking frogs also signify or indicate the approach of an imminent wet spell (Ibid). Zuma-Netshiukhwi *et al.,* (2013) also mention that an abundant movement of snakes and tortoises is an indication of good seasonal rainfall. According to (Chianese 2016), in the Philippines, the behaviour of various animals assists in predicting hazards. Fast movement of sea snakes and hermit crabs going inland or climbing up trees all foretell imminent storms or typhoons.

Insects such as armyworms, grasshoppers, termites, and butterflies also play an important role in predicting the onset and intensity of the rainy season (Okonya and Kroschel 2013). In Kaya and Koitsiwes`(2016)'s study that was conducted in the North West province of South Africa, some participants indicated that insects are sensitive to extreme weather conditions, especially temperatures. According to Kaya and Koitsiwe (2016), the appearance of red ants in large swarms around October or November and the appearance of a large number of moist anthills in August or September predict a wet season. The flying of bees from hills to lowlands in the North West province of South Africa also indicates a good rainfall season. A research conducted by Nkomwa *et al.,* (2014) reveals that termites indicate a good agricultural season and on the other hand occurrence of non-flying termites in a maize field predicts a prolonged dry spell. The appearance of edible insects in large numbers in spring, on the other hand, signifies shortage of rain in the next season (Rankoana and Chen 2016). Coming out of large numbers of crickets shows that a poor rainy season is expected (Makwara 2013).

Most birds are migratory species which are also regarded as important indicators of changing seasons. The behaviour of some birds is regarded as one of the best rainfall indicators (Makwara 2013). Migration of white and black stock indicates the approaching summer season (ibid). In Indonesia, they are a sign of impending heavy rains, storms or droughts (Chianese 2016). In Zimbabwe, the kingfisher also is associated with heavy rainfall downpours. Its appearance with the nature of its sound is said to resemble the clattering of heavy raindrops (Makwara 2013). Communities can predict weather conditions by observing the behaviour of birds (Lunga and Musarurwa 2016). Changes in the sounds of birds' indicate an onset of mating and reveal changes in seasons. The singing of such birds is regarded as a good omen as far as rainfall is concerned. Particularly the singing of the hornbill it is believed that the oncoming season will have good rains (Macherera *et al.,* 2015; Makwara 2013). Macherera (2015) also reveals that the hornbill usually makes noise around September to November.

When birds start to build their nests higher or nesting off the rivers this is an indication of an impending flood, the nests will be low and when floods are unlikely (Kaya and Koitsiwe 2016; Lunga and Musarurwa 2016; Makwara. 2013; Samardžija *et al.,* 2018). The appearance of black and white stork and swallows flying at a very high altitude predicts a good season and imminent rain (Macherera *et al.,* 2015; Makwara 2013; Lunga and Musarurwa 2016). Large numbers of swallows are usually observed in November, however, according to Macherera *et al.,* (2015) with this observation, the nature of the malaria season to be expected is unknown. Macherera *et al.,* (2015) also note that if guinea fowls lay many eggs it is a sign of a good rainy season and it implies that high malaria incidence would be observed.

Celestial bodies such as the moon, sun and stars can help communities to predict hydro-meteorological hazards (Hiwasaki *et al.*, 2014; Ayal 2017). They are important indicators that help in the prediction of weather. Observing the position and size of the moon can help to foretell the weather (Makwara 2013). If the moon is crescent-shaped and facing up, it is a traditional indicator of rainfall (Zuma-Netshiukhwi *et al.,* 2013). Zuma-Netshiukhwi *et al*. (2013) also reveal that the perspectives of the people in South-Western Free State are perceived as linked to the movements of rain-bearing winds in the area. Farmers in the same area believe that observing wind direction helps to predict the onset of rainfall and they believe that the new moon comes with a wet spell during the rainy season while the appearance of a new moon before receiving rainfall is an indicator of a prolonged dry spell (ibid).

The limitations of IK are that some knowledge in IKS cannot be explained empirically or scientifically (International Organisation for Migration 2015). IK is not researched like scientific knowledge but established through daily experiences. According to (Briggs 2013) there is a pervasive sense which results in dismissing IK as it cannot be trusted though valued unless its approval has been stamped by science. When it has been scientifically validated, that is, when it can be taken seriously otherwise devaluing IK as a knowledge system on its own has contributed to its dismissal in DRR and development (Briggs 2013). IK is relevant in particular contexts and taking it out of the context is a great challenge. It has also been noted that not all IK and practices have desirable effects. Some knowledge has proved to be unsustainable hence could be useful or harmful. Local IK is the science of people which can evolve with time, grow or diminish depending on the prevailing situation in the community (Iloka 2016). IK might not always be the right intervention for all hazards and disasters affecting communities, this means that in some cases it may exacerbate a community's vulnerability to disasters (Masipa 2016). Ayal (2017) mentions that the degree of accuracy of traditional weather forecasting depends on the quality of experts, the base of the forecasting, and the complexities caused by climate change. Some DRR experts are still doubtful about the relevance and effectiveness of IK in this contemporary era. More so, there is a lack of clarity on what IK constitutes (Dube *et al*. 2018).

2.7.2 Indigenous knowledge-based malaria prevention measures

The findings from reviewed literature show that generally there are more treatment measures than prevention measures for malaria. In countries such as Zimbabwe, some anti-malarial remedies are taken (Ngarivhume *et al.,* 2014). These remedies for preventing malaria include species such as the *Momordica* species which can be taken as relish during the rainy season (ibid). The roots of Adenia cisampeloides can also be taken as a hot or cold infusion and as well as Capsicum annum L. variety can be taken 3 times a day swallowing about 4 fruits per intake (Ngarivhume *et al*. 2014). Another study by Alebie *et al.,* (2017) done in Ethiopia identified anti-malarial plant species from 71 different plant families that can be used as anti-malaria's. Most of the anti-malarial plant species that were reported in Ethiopia were shrubs and herbs (ibid). The other common preventative measure is burning plant and animal material to make smoke that repels mosquitoes and other biting insects (Karunamoorthi *et al.*, 2013). Plant materials are commonly used since they are locally available, easily accessible and cost-free (Mavundza *et al.*, 2011). Specifically, in South Africa, the use of *L. javanica* was found to have repellent activity on mosquitoes in Mpumalanga (ibid).

2.8 Contribution of indigenous knowledge integration in early warning systems

IK and practices have reflected to be valuable for disaster risk reduction in the Hyogo framework of Action (2005-20015) which is a predecessor of the recent Sendai Framework for Disaster Risk Reduction (2015-2030). In the Sendai Framework for Disaster Risk reduction (SFDRR) IK is acknowledged as a fundamental resource for building community resiliency in a cheap and sustainable way. It is believed to be an important tool in solving rural community problems (Fernando, 2003; International Organisation for Migration, 2015). In Africa there are a number of indigenous cultural groups and much of the indigenous knowledge is remaining unexploited (Kiondo and Msuya, 2007: 4). Indigenous knowledge can offer security to communities threatened by hazards or disasters. According to Fernando (2003) IK is "*a body of knowledge associated with a fixed territorial space for a considerably long period of time*". Indigenous knowledge is unique to a culture, community or society. This knowledge can be presented as local or traditional knowledge (Kiondo and Msuya, 2007; Cadag and Gaillard, 2012). IK is not in written form and is transmitted from one generation to the other orally (Kiondo and Msuya, 2007).

Indigenous knowledge is valuable as it has helped most communities the world over to develop mitigation and adaptation strategies using their knowledge and practices to reduce vulnerability to malaria (Nyong *et al*, 2007: 788; Iloka *et al.*, 2015). Africa is the most vulnerable to effects of climate change as it is the least resourced (Iloka *et al.*, 2015). Such is believed because classification of vulnerability is usually based on financial capital as the ideal indicator, however adaptive capacity based on knowledge and not capital is the key to sustainable social and economic development (World Development Report 1998/99, 1998). Africa's adaptation capacity has been through indigenous knowledge because of its low technology. Communities have developed their mitigation and coping strategies in the past using their indigenous knowledge based on predicting weather and climate, and have survived as indicated by the population growth rate (Nyong *et al*, 2007). Humanity has always found ways to adapt to its constantly changing environment without the help of Disaster Risk Reduction (DRR) experts. The IK based strategies were used before technological advancement of early warning systems continuously adapting to environmental changes for their resilience in the face of disasters. According to the International Oganisation for Migration (2015) IK still plays an important role in DRR for communities even in this technological advancement era. Usually it is difficult for communities to develop advanced technologies as it requires expertise hence optionally they rely back on the knowledge and practices they have for survival.

Presently the focus of governments on western scientific knowledge forms for DRR has limited the confidence of communities to express (Iloka *et al.*, 2015) and develop their own adaptation strategies using their local capacities that have worked for them for generations. Time and seasonal indicators for environmental changes in local areas are soundly understood by indigenous knowledge (International Oganisation for Migration, 2015; Macherera *et al*, 2015). Improvement in coping strategies of local communities to environmental risks can be brought by the use of indigenous knowledge (Cadag and Gaillard, 2012). The knowledge is informal, experimental and its use has not been validated in comparison to western sciences. Kiondo and Msuya, (2007) are of the notion that IK is scientific as it is obtained through practicing the same things over the years and can solve problems faced by communities. Considering that some weather predictions for example require a long time to establish also basing on previous observations this is undeniable. However it should be validated by means of scientific criteria (Fernando, 2003).

According to Gaillard and Mercer (2013), solutions that are offered in DRR basing on scientific knowledge only may be unsuccessful since it does not fit within local wisdoms. Wisdom and skills within the traditional life styles are based on dynamic sophisticated understanding of the local surroundings. The change in indigenous knowledge is not random but predicted upon continuous conscious efforts by people to address threatening disaster risks and to come up with best solutions for the problem through local experiments (Lalonde, 1991). IK has helped communities such as Sambaa community in north east Tanzania to cure tropical diseases including malaria through the use of traditional medicine and other traditional means (Kiondo and Msuya, 2007). To a great extent the knowledge has also proved to be a helpful tool in predicting and forecasting weather patterns. It has enabled people to manage their vulnerabilities, however this was the case of farmers in Tanzania. Adaptive capacities need to be strengthened to reduce vulnerabilities of so that communities are able to cope with the impacts of climate change in their local areas (Nyong, *et al*, 2007).

Nyong *et. al* (2007) is of the assertion that incorporation of indigenous knowledge that is rich in local content adds value in the development of sustainable climate change coping strategies and build up community resilience. The value of IK also helps scientists and planners to improve conditions in communities (ibid).There is need to combine the most effective applicable indigenous and scientific knowledge. First the indigenous knowledge should be assessed for its applicability and effectiveness in mitigating disasters (Hiwasaki *et al.*, 2014) since some of the indigenous knowledge might no longer be viable as a result of changes experienced today. This could exacerbate vulnerability (Mercer *et al.*, 2007). On the same note in trying to tap IK in most cases there is a problem in the application of the knowledge by scientists since there are different values, perceptions and cultures between those interested in harnessing the knowledge and the IK custodians.

An understanding of the IK and customs can help the one who wants to apply the knowledge to establish a more flexible position to suggest effective alternatives and innovations for mitigation or adaption measures. UNISDR (2015) reveals a gap in the progress of knowledge based on science to deal with the frequently increasing disasters hence the need for complementing it with IK. Scientists however usually dismiss indigenous knowledge and view it as inferior and insignificant (Gaillard and Mercer, 2013) in comparison to scientific knowledge that is officially developed and verified. In the contemporary setting IK is being threatened with virtual extinction by insensitive development over which the indigenous people have no participation (Lunga, 2015).

The knowledge of remote or sparsely populated areas especially rustic rural areas have traditional lifestyles that are being threatened by the growing environmental and social pressures (Lalonde, 1991:191). IK is also threatened by formal education that exposes students to western scientific knowledge mostly (Kiondo and Msuya, 2007). Scientific knowledge has taken over and people concentrate on IK that has direct financial benefits (e.g. IK use in medicine) ignoring the knowledge that has no financial benefits (ibid). According to (Cadag and Gaillard, 2012) achieving a blending of the two sources of knowledge however proves difficult in DRR. The value of Indigenous knowledge is underestimated in fostering community action.

2.9 Scientific knowledge

Western science (scientific knowledge) is a system of knowledge that rests on certain laws established through the application of scientific methods on phenomena and is institutionally produced (Fernando 2003). It is defined *“as a set of statistically analysed data or instrumental records with independent or dependent variables that can be empirically measured and that demonstrate acceptable levels of reliability and validity”* (Alexander *et al.*, 2011)**.** The process of knowledge assembling is done through the formation of disciplinary societies, building instruments, standardization of techniques as well as writing articles (Le Grange 2005).

2.9.1 Science knowledge-based malaria prediction indicators

The prediction measures that are discussed in this section exclude malaria detection as it does not fall under prevention. Mosquito larva breeding sites can be mapped using GIS application (Jemal and Al-Thukair, 2016). GIS is an important tool for accessing spatial and non-spatial data and hence geographical modelling can be used to understand the spatial and temporal distribution and prediction of the disease (Baig and Sarfraz 2018). Malaria predictions based on seasonal climate forecasts have also been implemented in Botswana (Thomson *et al.,* 2006). Forecasting these climatic factors can assist in knowing mosquito vector abundance and distribution (Jemal and Al-Thukair 2016). According to Thomson and Connor (2001) weather can be indirectly used to predict the survival and density of mosquitos as well as parasite development rates. Sallam *et al*. (2017) also disclose that mosquito density can assist in knowing how people are exposed to mosquito biting risk and also the transmission potential as a function of biting rate. According to Sewe (2017), in malaria epidemiology, satellite-derived data has also been used. The most commonly used tool is remote sensing that determines land cover, a proxy for normalized difference vegetation index (ibid). Normalized difference vegetation index (NDVI) is referred to as "*a spectral measure of amount, relative greenness, phenological characteristics and productivity of vegetation*". It is defined as "*the difference between the visible (RED) and near-infrared (NIR) bands over their sum, (NIR−RED)/(NIR + RED)*" (Kipruto *et al.*, 2017:2). Vegetation has reflective characteristics in the near-infrared and on the other hand, is absorptive to the visible red (Sewe 2017).

2.9.2 Scientific based malaria prevention measures

Malaria prevention measures are comprised of dealing with both mosquito vectors and malaria parasites. Scientific based malaria prevention involves intensified utilization of a combination of primary vector control interventions. This can be through preventing mosquito bites as well as killing the vectors (mosquitoes and larva). Mosquito bites can be prevented by the use of a net that has been treated with a WHO-recommended insecticide. According to the World Health Organization (2013) to ensure the net`s continued insecticidal effect, its retreatment must be done after three washes, or at least once a year. On the other hand, with the long-lasting insecticidal net (LLIN) is factory treated with an insecticide. The insecticide is incorporated within or bound around the fibers of the net. Under recommended conditions of use, the LLIN must retain its effective biological activity against vector mosquitoes for at least three years. There is no need for regular insecticide treatment (WHO 2013).

Indoor residual spraying (IRS) is also another measure to prevent malaria. It involves the application of residual insecticides within a dwelling on its surfaces. If the anopheles mosquito rests on any of the surfaces sprayed then it is killed (WHO 2013). In most cases, DDT is being recommended as it has the longest residual efficacy when sprayed on walls and ceilings. Depending on dosage and nature of substrate, it lasts between 6–12 months (WHO 2013). According to Komen (2016), in recent years there has been a significant drop in malaria cases due to increased use of Dichloro-diphenyl-trichloroethane (DDT) for vector control. However, the adverse effects of synthetic pesticides on non-target plants, animals and human health has stirred up political and ecological protection pressure to reduce their usage. This is why it is now only being sprayed indoors. The Stockholm convention of 2001 on persistent organic pesticide reduction and elimination in the environment permitted South Africa to use DDT to control malaria specifically for indoor residual spraying (IRS) (Van Dyk *et al.*, 2010) because of the perception that it is a cheap, effective and long-lasting way of controlling malaria.

The use of mosquito repellents also reduces human-biting densities (WHO 2013). A repellent is a substance that is applied on the skin so that mosquito bites can be prevented. Repellents, therefore, prevent the transmission of vector-borne diseases through minimisation of humans and vector contact. The repellents are applied to clothes as well, they may protect people from mosquito bites outside their homes (Kazembe and Makusha 2012).

As an effort to prevent chances of being affected by malaria intermittent preventive treatment (IPTp) is mostly administered to infants, children and pregnant mothers (WHO, 2013). Even when one has been bitten by an anopheles mosquito the symptoms of the disease will not develop after being bitten by the mosquitoes. In the case of pregnant women, the WHO recommends the use of sulphadoxine-pyrimethamine (SP/Fansidar) in malaria-endemic areas. The prophylaxis is supposed to be administered to pregnant women at each routine antenatal clinic visit for protection against malaria during pregnancy. Breeding sites can be managed by draining water where it collects to eliminate stagnant waters. According to WHO, (2013), in order to control larva, the reduction of breeding areas is essential and this can be achieved through the use of larvivorous fish and larvicides. Other larvicide predators can as well be introduced into the waters and this will help in reducing adult density.

2.10 Integration

The most commonly referred terms which are used interchangeably with integration are coherence, synergy, collaboration, and coordination. Integration creates innovative ways of dealing with problems and this can as well be applied to mitigate disastrous situations. Review of literature on IK and MSK revealed the weaknesses of both methods and these can be overcome by integrating the two forms of knowledge in MRR. Banwell *et al.,* (2018) states that integration is used to describe the bridges and connections between concepts in the domain of DRR. Integration at multiple levels, various societal actors, knowledge sources, and disciplines for DRR will increase the relevance of decision-makers in policy and practice (Weichselgartner and Pigeon 2015). Integration produces a sustainable solution to DRR as one form of knowledge, scientific knowledge will not be viewed as more superior than IK. It offers a holistic approach that values spiritual and cultural knowledge that is identified by communities (Alexander *et al.*, 2011). It is highly possible to integrate scientific knowledge with IK for the effectiveness of DRR interventions (Hiwasaki *et al.*, 2014; Baudoin *et al.*, 2016; Masipa 2016). Science and technology on its own to some extent fails to help communities single-handedly as it does not fit into their local knowledge (Briggs 2013; Basdew *et al.,* 2017). Weather services, for example, are given in scientific terminology that some local individuals cannot understand (Macherera and Chimbari, 2016b). Alexander (2011a) brings out that it is important to integrate scientific and IK as IK may serve as a proxy record and enormously help those in remote areas who do not have access to scientific temperature data.

2.11 Summary

This chapter unpacked the major concepts, frameworks and models upon which the research problem for this study is hinged on. Literature findings revealed that both scientific and indigenous knowledge have their own weaknesses. Scientific knowledge on its own to some extent fails to help communities single-handedly as it does not fit into their local knowledge. On the other hand IK is relevant in particular contexts and taking it out of the context is a great challenge. It has also been noted that not all IK and practices have desirable effects. Some knowledge has proved to be unsustainable hence could be harmful (i.e.some IK based prevention measures). Some of the knowledge cannot be explained empirically or scientifically. There is a confirmation from various authors that both forms of knowledge can be integrated into an early warning system to avoid disasters linked to malaria outbreaks. The following chapter introduces the theories and frameworks that this research is hinged on and how they were woven together to come up with a malaria early warning system that integrates indigenous and scientific knowledge.

CHAPTER THREE

POLICIES, THEORIES AND FRAMEWORKS

3.1 Introduction

In this chapter, the policies, frameworks, models and theories on which this research is hinged are reviewed. According to Rocco and Plakhotnik (2009) all empirical studies (qualitative, quantitative, or mixed methods) are supposed to be connected to literature or concepts that support the need for the study, be related to the study's purpose statement, and situate the study in terms of previous work. The researcher reviewed frameworks, models and theories that influenced the development of an EWS. This was important in ensuring that the researcher does not duplicate what other authors already operationalizing as well as to know the requirements for developing an effective early warning system. The chapter starts with discussing the initiatives that influence disaster risk reduction accordingly malaria risk reduction, in the context of this study.

3.2 Global Initiatives influencing disaster risk reduction.

The international community is stepping up in the improvement of DRR initiatives. The United Nations International Strategy for Disaster Reduction (UNISDR) is one of the global initiative influencing DRR. Its obligation is to enable societies to be resilient to natural hazards and disasters, as well as reduce human, social gains and economic losses. A conceptual shift has been from emphasizing on disaster management to DRR, integrating DRR into sustainable development with sustainable development in mind (Twigg 2015). It is recommended that DRR actions should not compromise future generations and must be able to continue without much help by the external organizations thus empowering the communities to face their challenges and improving their resiliency. Currently, there is the Sendai Framework for DRR and the sustainable development goals (SDGs) serving as global frameworks for DRR action for biological hazards.

3.2.1 Sendai framework for disaster risk reduction.

The Sendai framework for disaster risk reduction (SFDRR) 2015-2030, adopted by the Third United Nations World Conference is s follow-up and successor of the Hygo-Framework of Action (HFA). It recognizes and takes into account the experience gained from implementing the HFA. The SFDRR is a product of the World Conference on Disaster Reduction (WCDR) which was held in Sendai, Japan in March 2015. The framework draws up disaster reduction action from 2015-2030 and promotes a shift from disaster management to DRR. Among other issues, the SFDRR recommends the promotion of the need for;

- Improving understanding of disaster risk completely in all its dimensions of exposure, vulnerability and hazard characteristics.
- Strengthening of disaster risk governance.
- Recognition of stakeholders and their roles (UNISDR 2015).

SFDRR recognizes health as a DRR key contributor and includes biological hazards such as epidemics. It calls for the inclusion and consideration of hazards from biological and technological categories (UNISDR 2015). In the Sendai Framework for Disaster Risk Reduction (SFDRR), IK is acknowledged as a fundamental resource for building community resiliency cheaply and sustainably. It is also believed to be an important tool for solving poor rural community problems (International Organization for Migration 2015; Fernando 2003). The Framework also specifically calls for researches in disaster risk management to be solution-driven to address gaps, obstacles, interdependencies and social, economic, educational and environmental challenges and disaster risks (UNISDR 2015). In consistent with the SFDRR this research is focusing on coming up with a solution-driven innovation to assist in addressing gaps in MRR.

3.2.2 Sustainable development goals

The world officially began implementing the 2030 Agenda for Sustainable Development in January 2016. The Sustainable Development Goals (SDGs) are a transformative plan for action, based on 17 goals. This research is specifically in line with sustainable development, goal 3 which seeks to promote and ensure health by ending epidemics of major communicable diseases such as Malaria and HIV. It is also in line with goal number 13 which advocates for urgent action in combating climate change and its impacts and building resilience in responding to climate-related hazards and natural disasters (United Nations 2016). Regrettably, the departments of health continue to carry the burden of most biological hazard-induced disasters without the full involvement of other stakeholders that may help to relieve them (Macherera and Chimbari 2016). Natural disasters threaten prospects of achieving the sustainable development goals (SDGs).

3.2.3 Regional Initiatives influencing disaster risk reduction

The African Union (AU) Commission, the New Partnership for Africa's Development (NEPAD) Secretariat and the African Development Bank (AfDB) brought out a report "*Towards Sustainable Development in Africa – Status of Disaster Risk Management & Disaster Risk assessment in Africa*" (UNISDR 2004) as an ongoing effort for the integration of DRR into Africa's development processes. This is supported by the United Nations International Strategy for Disaster Reduction (UNISDR). A regional strategy for DRR was adopted at the African Ministerial Conference on the Environment (AMCEN) 10th Meeting held in June 2004 and submitted to the African Union (AU) Assembly Summit. This was an initiative for the implementation of a programme of Action. Currently, in Africa, DRR policies and institutions exist at various levels. According to the United Nations (2016), 83 countries had drafts of their own legislative provision in place for managing disaster risks in 2015. Unfortunately, most of these drafts are not biological hazards inclusive, as most epidemic outbreaks are believed to be exclusively the responsibility of departments of health.

3.3 Local Initiatives influencing disaster risk reduction.

Locally, South Africa also has DRR policies and institutions existing at various levels (national, district and municipal levels). Biological hazards are not included or mentioned in the disaster management policies. However, for the malaria hazard, there is an elimination strategic plan that is available. This was brought up by the National Department of Health (NDOH). The programme is vertical and based within the National Department of Health and Provincial Malaria reduction efforts in the three malaria-endemic provinces of South Africa which are KwaZulu-Natal, Limpopo, and Mpumalanga (RSA Malaria Elimination Strategy 2012). The National Malaria Programme (NMP) is responsible for the mobilization of national and regional resources. Within the three provinces, malaria plans have a programme manager, data manager and other supporting staff (RSA Malaria Elimination Strategy 2012). Malaria Elimination Strategic Plan was developed in consultation with malaria-endemic provinces, stakeholders and partners. Other units such as the Environmental Health, Health Promotion, Surveillance and Pharmaceutical Services are also involved. There is a partnership for the development and updating of strategies between health, agricultural, climatological, and water use government agencies (RSA Malaria Elimination Strategy 2012). However, when it comes to DRR auctioning during outbreaks, these agencies are not involved.

3.4 Frameworks

Not all frameworks work in every disaster situation as they vary depending on the hazard. In this research, the frameworks were mainly employed for their applicability in developing a "tailor-made" early warning system for malaria hazard. Frameworks that include clearly defined steps of actions to be taken were also considered.

3.4.1 Framework for integrating indigenous and scientific knowledge

Integration of scientific and IK requires the participation and engagement of communities from inception to implementation of a developmental project or research (Briggs 2013; Magni 2016). Baudoin (2016) concurs that communities are supposed to be engaged in their own development programmes. In consistent with Baudoin (2016) the researcher adopted the idea that EWSs are supposed to be designed and implemented from science expert-driven to a community-led process, and believes that involving the community could be a pathway to ensure the establishment of effective locally relevant EWSs. Magni (2016) also believes that the participation and engagement of the community is important as it ensures a balanced presentation of both scientific and IK systems. It is highly possible to integrate scientific knowledge with IK for the effectiveness of DRR interventions (Hiwasaki *et al.*, 2014; Baudoin *et al.*, 2016; Masipa 2016). Figure 2.3 shows the phases adopted by the researcher in the process of how scientific knowledge systems and indigenous knowledge systems can be integrated.

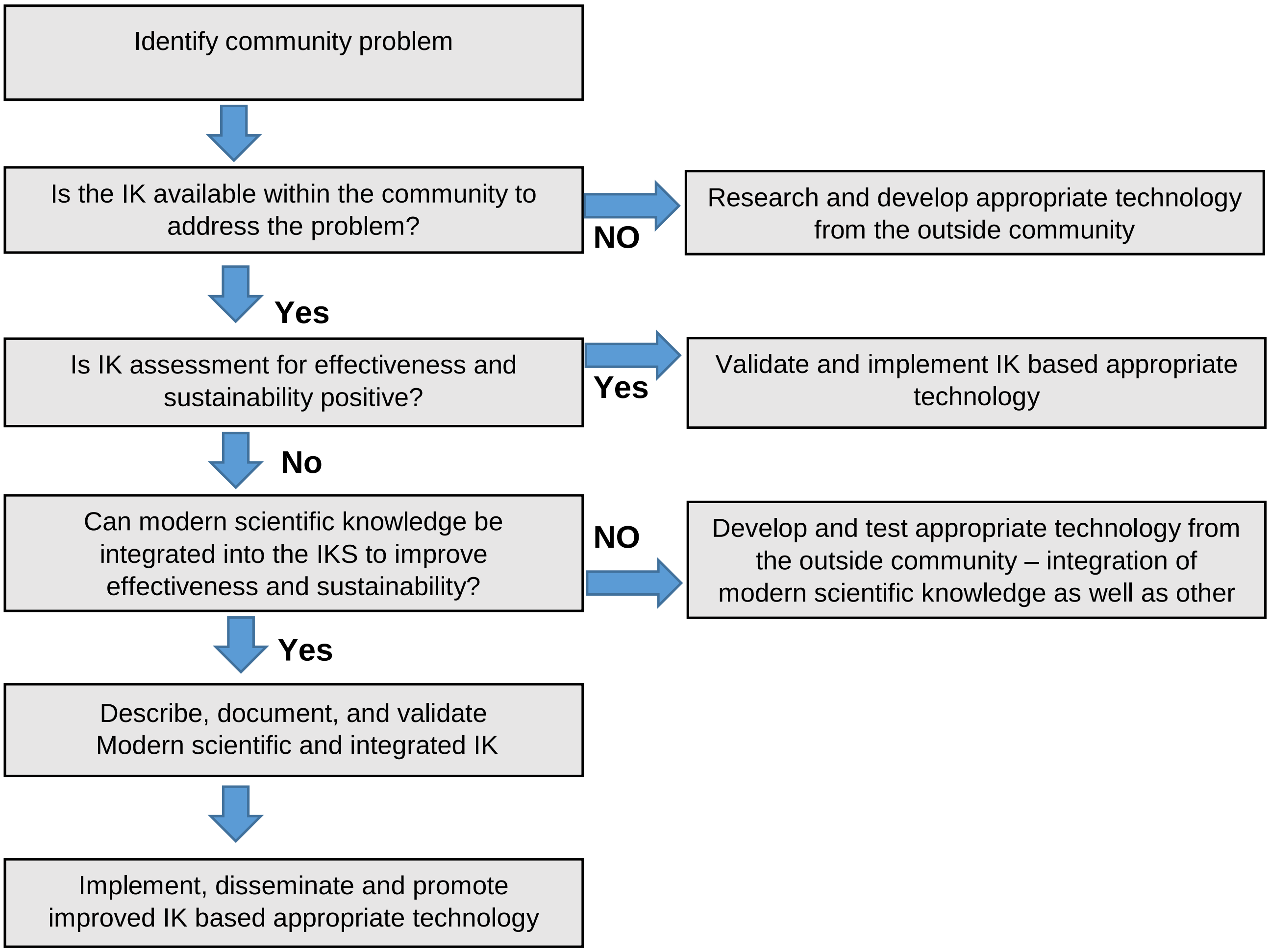


Figure 3.1 Heuristic for the integration of modern scientific and IK for appropriate technology development and implementation
Source: Adapted from Aluma 2004

Figure 3.1 shows that the heuristic for integration of modern scientific and IK for appropriate technology development and implementation. This framework was adopted in developing an EWS. The first stage was to identify the problem, and that was done in chapter 1 of this research. IK that helps to address the solution was then identified. The two forms of knowledge thus IK and MSK were then integrated and the EWS was then validated. The detailed process is explained in chapter 8 of this study.

3.4.2 Framework for elements of an integrated early warning system.

The framework for elements of an integrated EWS by the International strategy for disaster reduction (2006) was found relevant for this research as it determines the components that should be included in developing an integrated EWS. A complete and integrated people-centred EWS is comprised of four inter-related elements. The failure of one element could lead to failure of the whole system (Quansah 2010). For the system to succeed, the people within a community have a critical role to assist the government by providing IK, technical and scientific input for the development of an integrated EWS. However, where the capability exists in communities to issue warning timeously, the other three components of the EWS are usually weak, with the main focus being mostly on hazard monitoring and forecasting that neglects community vulnerability assessment (UN 2006). The four elements are risk knowledge, monitoring and warning services, dissemination and communication and response capability (ISDR 2006) as shown in figure 3.2 as follows;

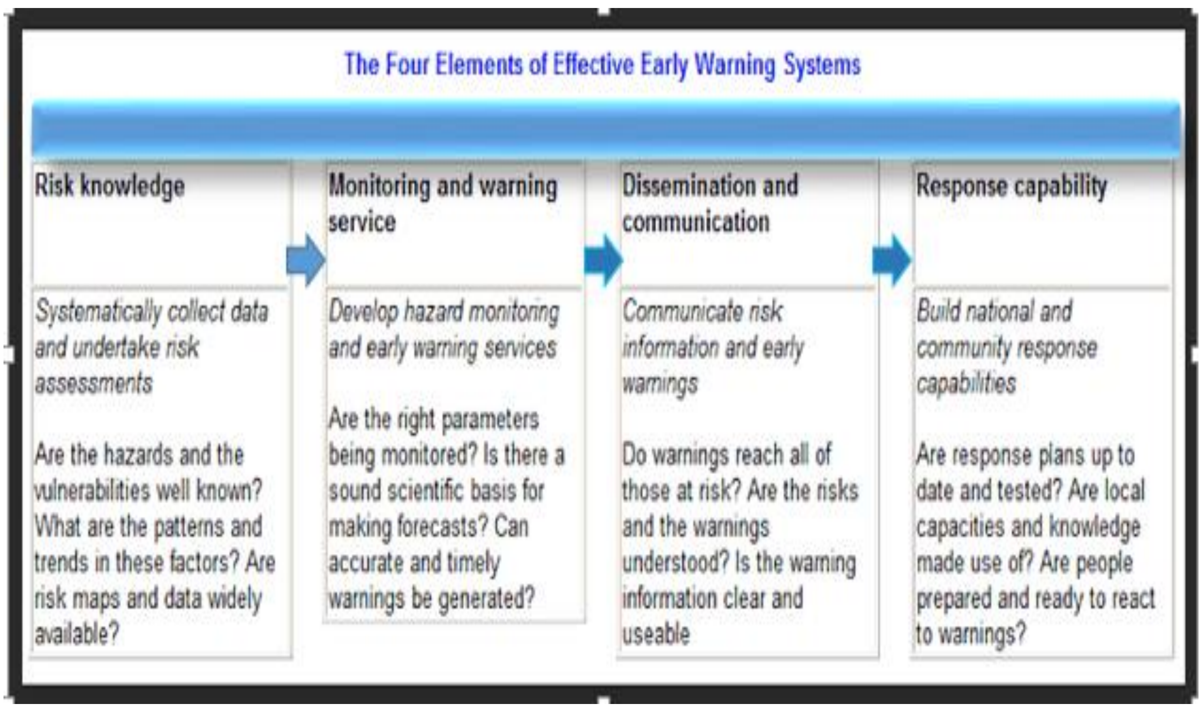


Figure 3.2 ISDR Framework for elements of an integrated early warning system
Source: Adapted from ISDR 2006.

According to Karanath *et al.,* (2014), all the key elements of an EWS is supposed to be functional hence it is important to anticipate different scenarios as well as measuring its performance. These elements of an EWS gave the researcher an understanding of the main requirements of an EWS.

3.5 Models

There are also some models that the researcher felt should not be left out as they play an important role in assisting to come up with an integrated early warning system. According to Nilsen (2015), process models are used for describing or guiding a process to translate research into practice, and this relates to the purpose of this study.

3.5.1 Disaster crunch model

To clarify the occurrence of disasters, the crunch model by Wisner is a tool that assists to show how vulnerable communities are caught up by a hazard event if they are unprepared. (Wisner *et al.,* 2012) explain how disasters are caused using the disaster crunch model which is also referred to as the "Disaster Pressure and Release Model". According to Smyth and Hai (2012), the model assists practitioners to understand people's vulnerability to disasters and come up with ways to react. When a hazard affects an unprepared vulnerable community, there is a high probability of a disaster occurring. The people are caught in between a hazard and their vulnerabilities, and as a result, they are crunched in the situation as shown in figure 3.3 below;

Figure 3.3 Communities crunched between vulnerabilities and hazards
Source: Adapted from Wisner *et al*., (2012).

Figure 3.3 indicates that if there is no hazard (malaria) threatening the community then there can never be a disaster (outbreak that causes morbidity and mortality). The root causes of disasters often result from political, economic, social processes or structures which affect the communities, and these are supposed to be addressed at national, regional and international levels (Twigg 2015). Social structures include traditional leaders, religious groups, powerful individuals and government departments. Structures have policies or implementation activities which could be good or bad, and these affect the communities. Structures and processes have deeper roots and are the underlying causes of disasters as they are frequently embedded in the culture and beliefs of a community. Some of the structures can operate from power bases far from the community in which it is influencing. According to St.Cyr (2005), the root causes could be spatial or temporal. The spatial causes include economic and political power for example while temporal causes include the historical pattern of the hazard or it could be bound in cultural assumptions, beliefs, and social relations (ibid). If people have insecure access to resources and livelihoods, their vulnerability is likely to be increased as they engage in activities that put them at risk (St. Cyr, 2005; Twigg 2015). They are also likely to end up not believing in their self-protection, mitigatory or adaptive methods based on local or indigenous knowledge.

3.5.2 Epidemiological triad model

According to Rockett (2016), the Epidemiological triad model is devised to enhance the understanding of communicable diseases. It is a requisite to help in understanding disease and its components since it enables the establishment of appropriate practical biological hazard prevention measures. The epidemiological triad model states that biological hazards result from the interaction of the agent, host and the environment (Rockett 2016). The agent is the cause of a biological hazard. The host refers to the organism that is capable of harboring the disease, in this case, it is the human. It may also mean a pathogen, which is the microorganism that causes a disease, which is the mosquito in this case. The environment refers to the conducive surrounding, thus external to human beings. Social, cultural and physical aspects of the environment are viewed as environmental factors.

It is important for biological disaster risk experts to find out where to break one of the sides of the triangle of the epidemiological triad to prevent or mitigate disasters which are of a biological nature. In addition to the complementary EWS, this enables the stopping of continuous outbreaks of epidemics, such as malaria outbreaks where the disease is endemic. According to Rockett (2016), outbreaks can be prevented when one of the elements in the triad is altered, interfered with, changed or removed from existence. This study sought to alter the link between the agent and host by coming up with a practical EWS that alerts a community about an impending danger (malaria hazard). The possible interventions between the two (agent and host), is protection, education and altering exposure. An EWS also fits at that phase as it is an essential component and useful tool of DRR (Meissen and Voisard, 2010). It protects communities as it provides timely and effective information to allow individuals exposed to the hazard to take action so that they avoid or reduce risk and prepare for an effective response (ISDR 2006).

3.5.2.1 Specific parasites and conditions for breeding

Malaria is essentially an environmental disease since the vectors require specific habitats with surface water for reproduction and the development rates of the vector and parasite populations are influenced by temperature (Paaijmans, 2010). The infectious vector borne disease has a spectrum of different pathogens some which are asymptomatic and others symptomatic severe infections leading to life threatening complications such as cerebral or even death. There are four common plasmodium species that affect human health and these are plasmodium, *P. falciparum, P. ovule, P. malarae and P. vivax* (Paaijmans 2008)*. P. falciparum* is the most virulent and fatal species (Aboda 2012) predominating in Africa (Ngarivhume *et al.* 2015) having an optimum temperature window is 30-32ºC (Ngarakana-Gwasira *et al.* 2016). The Anopheles mosquitoes have different breeding preferences depending on the specie, some species such as *Anopheles arabiensis* prefer shallow collections of fresh water and Anopheles *funestus* favours permanent water bodies (Komen 2015) Malaria is the most common fever specifically in the area of study (thus Mopani District) (Komen *et al*. 2015). In this area the major vector species are *Pasmodium falciparum* and *arabiensis*. Cases peak in summer to autumn thus March-May declining in June (ibid). The possible interventions between the agent and host, is mainly through altering exposure in Mopani District for malaria control the adult *Anopheles* mosquito and *plasmodium* parasite are the main target (refer to the epidemiological triad model).

3.5.3 The disaster reduction continuum

The disaster continuum outlines the chain of events that follow a natural disaster. In this case, it is a malaria outbreak that has the potential to affect the function of the community.

According to Twigg (2015), disasters are not once-off events to be responded to but are constantly recurring problems that are supposed to be well planned for. It is recognized that disasters in an area, have patterns and sometimes recur after a certain period. The period could be after weeks, months, years or decades and this depends on the nature of the hazard. In Limpopo Province, malaria hazard threatens communities between September and May and cases peak usually during Christmas and around Easter holidays (Raman *et al.*, 2018). Taking the disaster continuum into consideration and analyzing its phases, contribute immensely to risk reduction. It improves pro-activeness as the continuum illustrates the main phases of disaster reduction, thus the pre- and post-disaster phases. The phases in the disaster continuum are prevention, mitigation, preparedness, response and recovery. This study concentrates on protection initiatives in the pre-disaster phase, thus prevention, mitigation and preparedness, through prediction, early warning and planning of relevant stakeholder coordination.

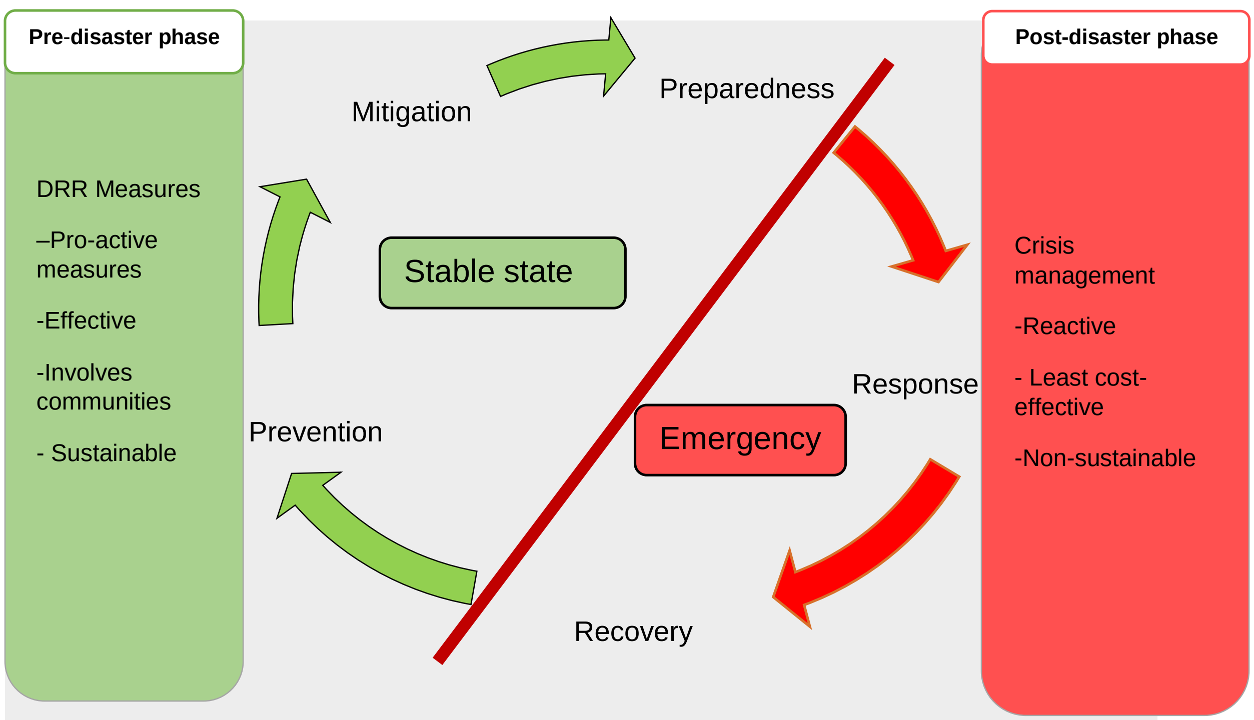


Figure 3.4 The disaster management continuum
Source: Adapted from Adams (2002).

Communities with their IK can contribute to improved activities in all the four phases of the disaster management continuum as IK is an indispensable empowerment tool that can be used in all the stages of DRR (Masipa 2016). The customary role of disaster management used to focus on taking actions immediately before a disaster, during and shortly after to avoid losses. There is now a growing understanding that disaster reduction is a long-term issue that is not confined in time and risk prevention culture is now being promoted through EWS (Alfieri *et al.,*2012; IFRC 2012). It is very much possible to prevent malaria as it is a preventable disease (Shimaponda *et al.,* 2017; WHO 2015). This can be done by taking appropriate precautions. Proactive measures during the pre-disaster phase are more important as they try to prevent people from being exposed to a hazard even at its embryonic stage. Pro-activeness continues even when the hazard has reached the decaying stage and at the recovery stage in the disaster continuum phases, so that disaster does not recur. According to Masipa (2016), ignoring IK in all the phases in the disaster management continuum exacerbates the occurrence and effects of disasters.

The EWS that is developed should not be restricted to certain phases of the disaster management continuum or stages of the hazard since disaster risk management is a continuous process which is not confined to time. A continuous and uninterrupted continuum of a natural disaster provides a basis for improved DRR measures. Systems are supposed to undergo frequent testing, practice, review and warning refinement (Twigg 2015). The same way with the silk of a spider web, after some time, it gets loose in terms of its stickiness and becomes inefficient at capturing prey. The spider recycles the silk to make a new strong web. The mitigation and prevention phases seek to provide a safety-net that intercepts the hazards. This is the phase of the continuum in which communities are shielded from the effects of the hazard. Preparedness towards natural hazards is essential in DRR so as to reduce their impacts on society. Preparedness is important from individual, community and institutional levels. Twigg (2015) points out that the forecasting of events and issuing warnings is also part of preparedness. According to Masipa (2016), the use of the communities` IK contributes immensely in enhanced actions in all phases of the DRR continuum. IK is a precious resource that can facilitate the processes of the disaster continuum sustainably and effectively in terms of cost (Masipa 2016).

In the emergency response phase, activities designed to preserve lives and protect properties should be actioned. In malaria hazard context, it is the phase in which medical care and resources should be readily available. This is the phase that demarcates the end of the embryonic stage of the hazard into the growth stage and failure to handle the emergency can result in morbidity and mortality. Resources and coordination of activities are very important, especially during the beginning of the malaria season to prevent outbreaks. It should be noted that emergency relief far exceeds the investment in the resources for DRR capacity development (Zubir and Amirrol 2011). The handling of malaria outbreaks is still a cause for concern since the practice of relying on customs to deal with emergencies is unable to fit in the disaster management domain. Outbreaks due to the biological hazard are considered an exclusive mandate of the Department of Health, which by nature has management activities that are overarching and not strictly confined to one domain.

The successful elimination of a hazard requires that the response to emergencies be done through a multi-sectorial approach as opposed to the existing mono-sectorial management system. Integrating various sectors guarantees adequate and combined actions in the recovery phase (De Paula *et al.,* 2017). All disaster recovery-related sectors should have the same view for long term development objectives in the recovery effort (De Paula *et al.,* 2017). It is important to start mitigating both the social and economic impacts of malaria on the affected population in the recovery process. Lessons learnt during the recovery stage should be considered for communities to return to normalcy as soon as possible. Plans for re-establishing medical services in preparation for the next season are important in case there is a recrudescence of the epidemic in a short space of time.

3.6 The systems approach to disaster management (Theory)

DRR has to be a full or complete set of elements coming together to form a safety net that should shield people from the risks and not leave any loophole for disastrous mishaps. According to Marczyk, *et al.,* (2010), a theory is a conceptualization or description that attempts to integrate all that is known about a phenomenon into a conscious statement. Merriam (2001) refers to a theoretical framework as “the structure, the scaffolding and the frame of a study. The development of an integrated EWS in this study is centered on the systems theory. Integration of different essential elements of an EWS improves the identification of problems so that an effective solution can be implemented. The knowledge about a phenomenon is derived from an understanding of a whole system and not just individual elements (Aristotle's Holism). Heils (2010) is of the notion that integration is centered in the systems theory as systems are comprised of subsystems with smaller entities that create a larger system. According to Mele *et al.,* (2010), the systemic perspective claims that a phenomenon cannot be fully comprehended by breaking it up into elementary parts and then reforming it, instead there is need for applying a total vision to understand its functioning. Simonovic (2010), highlights that all systems are a collection of diverse elements which are linked by strong interactions, specifically the disaster management system is comprised of four linked subsystems. These include individuals, societies, organizations and the environment.

The systems theory assists in clarifying other sub-systems such as individual and societal relationships as well as organizations (Simonovic 2010). The systems approach shifts attention from single elements to the whole, permits the inclusion of various factors and interactions to be taken into account as well as helping in dealing with complexities of interacting non-linear systems (Mele *et al.*, 2010; Simonovic 2010). This study, therefore, adopts the systems approach developed by a German scientist named Ludwig Von Bertalanffy, which was later advanced by Simonovic into the systems approach to disaster management. The systems approach was applied in this study as an attempt to integrate elements of the EWS to come up with a comprehensive MEWS and to explore the type of EWS that exists in Mopani District. The ISDR (2006) reveals that the EWS with best practices contains strong inter-linkages and effective communication channels between elements.

This theory can lead to a much-needed integration of DRR as each element is affected by at least one other element in the system. According to Simonovic (2010), the systems theory also allows a better analysis of the problem and to identify why there is a problem. Simonovic (2010) also reveals that problems are a sign of malfunctioning processes within a system. The systems theory considers all possible sources of a problem by examining each individual element, including the role it plays in the system. Since Mopani District is failing to prevent malaria from affecting its communities, this is evidence of a malfunctioning EWS. It is imperative to examine each component of an early warning system and the processes and measures that are being employed in DRR to establish where the system is failing to prevent malaria outbreaks.

The systems approach is suitable since the study seeks to come up with an integrated MEWS. The systems theory for disaster management is accredited for its integrative character of concerned components and the interrelationships among them, as well as the ability to integrate the knowledge of existing tools in their application to a practical problem. An integrated MEWS can be more effective than unconnected elements operating in an autonomous manner. Several theories of management have demonstrated that their application is inappropriate in the management of disasters involving various stakeholders for risk reduction. None of them has managed to give a comprehensive management solution which embodies all the diverse complexities involved to achieve effective DRR for biological hazards such as malaria in this case. (Simonovic 2010) discloses that individuals are decision-makers in their own right, with direct roles in disaster management (preparedness, recovery and response). The actions of these individuals drive the behavior of societies and organizations (systems). As such, individuals cannot be regarded as passive recipients of DRR actioning (Williams and Jones 2004; Twigg 2015). Organizations (systems) are the platform used to produce outcomes that are not possible at the individual level to achieve certain goals.

Organizations or systems have inputs, processes and outputs, and failure in one element or component affects these elements. The systems approach to disaster management allows complex dynamic characters and interdisciplinary needs of management options to be addressed (Simonovic 2010). In this case, the inputs include all resources required in preventing malaria, thus in risk awareness, warning services, dissemination and response which are elements of an integrated EWS. Processes include activities carried out by individuals, societies and organizations in prevention, these include monitoring and evaluation processes. The output is supposed to be effective in protecting individuals and societies from the threatening hazard, the focus being on disaster risk reduction.

According to the UN (2006), warning, dissemination can be jeopardized if the feedback on the system is ineffective to affect its performance (UN 2006). To continually revolve, a system requires formal feedback processes and these improvements based on feedback and learning from previous experiences (ibid).

3.7 Brainstorming how an ideal early warning system should be.

In this section, the models and frameworks involved in developing an EWS that integrates scientific and IK are highlighted, as well as how they are brought together to develop the system. Bringing together models and frameworks that are supposed to be included in the EWS is a very fundamental stage. Through analyzing the remarkable structural characteristics of an orb web, the process of designing an integrated EWS is almost like that of a spider weaving an elaborate (orb) web using its silk thread (resources). Spiders have important ecological roles in maintaining a healthy and stable community, which is the same role as EWS in a community. The orb web is circular in shape and the characteristic features are, a center portion and a series of radiating lines supporting the framework (Lawania and Mathur 2015). The lines make a series of wheel-shaped concentric outlines as they extend from a center. "*In this study, the center (focus) is integrating scientific and indigenous knowledge in a MEWS*". The EWS is supported by integrated scientific knowledge and IK hence the system extends from this focus (center).

An orb web allows a spider to catch prey without having to expend energy by running. Some orb webs help the spider to detect prey through vibrations (Lawania and Mathur 2015) and this is an efficient method of gathering food. Similarly, EWS should have methods that detect hazards for their timely prevention. Constructing the orb web is an energetically costly process because of the large amount of protein required, in the form of silk. Time and resources are needed in developing the EWS likewise, however, it eventually rewards in the long run. Investing in EWS serves resources of managing disasters reactively as the hazards are intercepted by the safety net (web) at the embryonic stage of the hazard (refer to figure 3.5) before it extends to people.

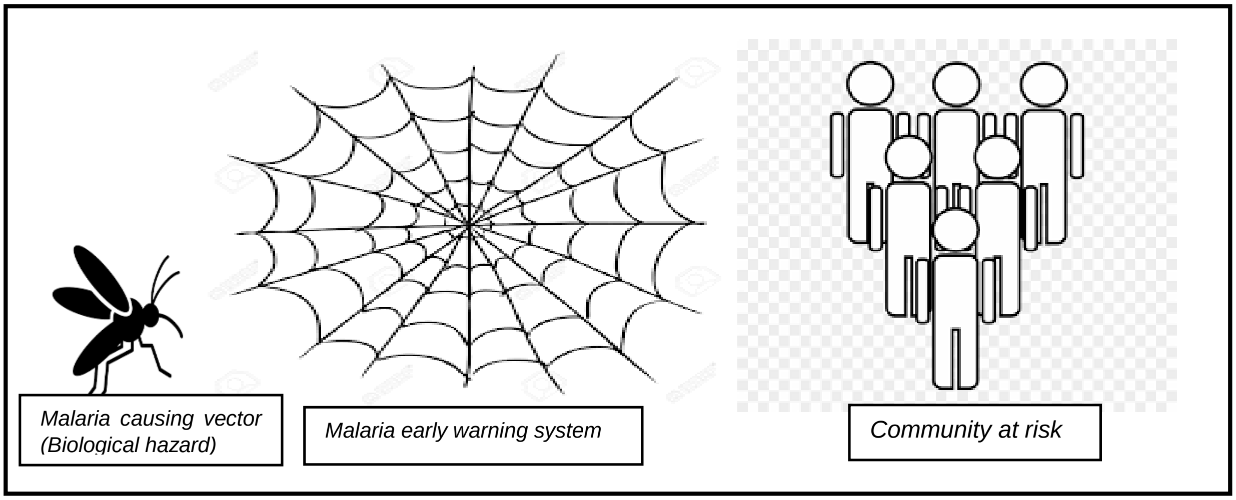


Figure 3.5 Illustration of an ideal effective EWS that prevents malaria hazard from affecting communities
Source: Authors' work.

On the other hand, less resources are required for pro-active measures. Organizations must not just wait to react when there is an emergency. Reactiveness requires more resources hence an EWS is worth investing in (Zubir and Amirrol 2011). Orb Web (EWS) design may affect capture efficiency (Lawania and Mathur 2015). The EWS should be designed in a way that loopholes are minimized for hazard capture efficiency. EWS reliability and effectiveness, as well as the precursors for monitoring and predicting events, is automated with the aid of human decisions that influence it. Agreeably, it is imperative to interweave all salient constituents (threads) and tailor-make a (orb) web of associations which protects (prevents) people from being affected by a hazard. Figure 3.5 shows an illustration of how the web should protect or shield vulnerable people when finely woven to intercept malaria hazards.

The developed (orb) web acts as a safety-net that intercepts the biological hazard, shielding the communities (preventing) from being affected by the hazard. In other words, people are supposed to be prevented from the malaria-causing vector through scientific and indigenous knowledge prediction and prevention measures. Leaving salient models, frameworks, components and elements in the initial drafting of an ideal EWS model results in developing an EWS that is not effective in intercepting the malaria hazard. This leaves people unprotected to the hazard as the safety net has a (loop) hole as shown in figure 3.6.

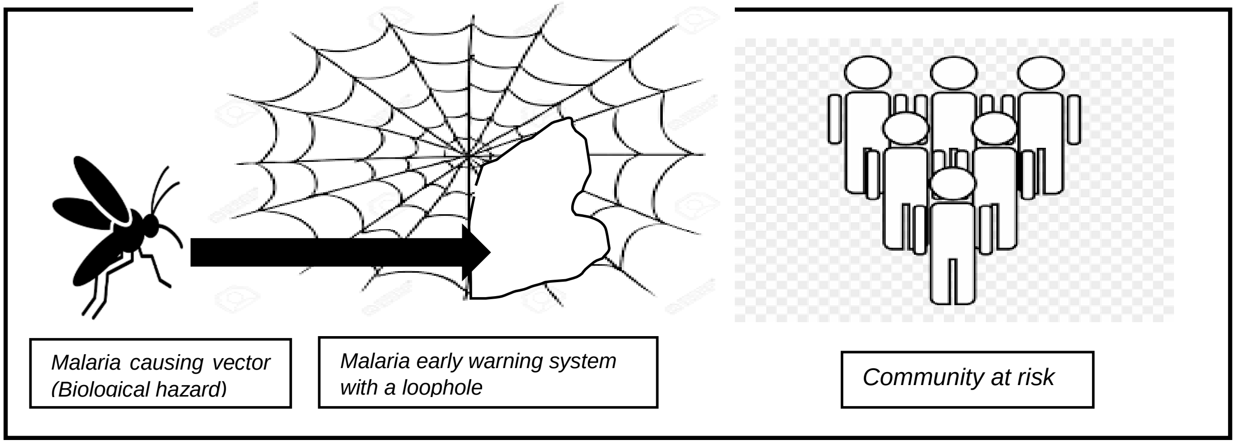


Figure 3.6 Illustration of an EWS with a loophole.
Source: Authors' work

Ostracizing some DRR constituents (threads) amongst other priorities in managing and controlling the hazard leaves a gap (ineffectiveness) in the system that is an opportunity for outbreaks to be permitted.

3.8 Integrating components of a climate-sensitive malaria early warning system.

Integration of MSK and IK, as well as quantitative and qualitative data in the quest to find the solution, could be the most rational way. This could give the researcher a comprehensive possibility for coming up with a way to prevent malaria in Mopani District.

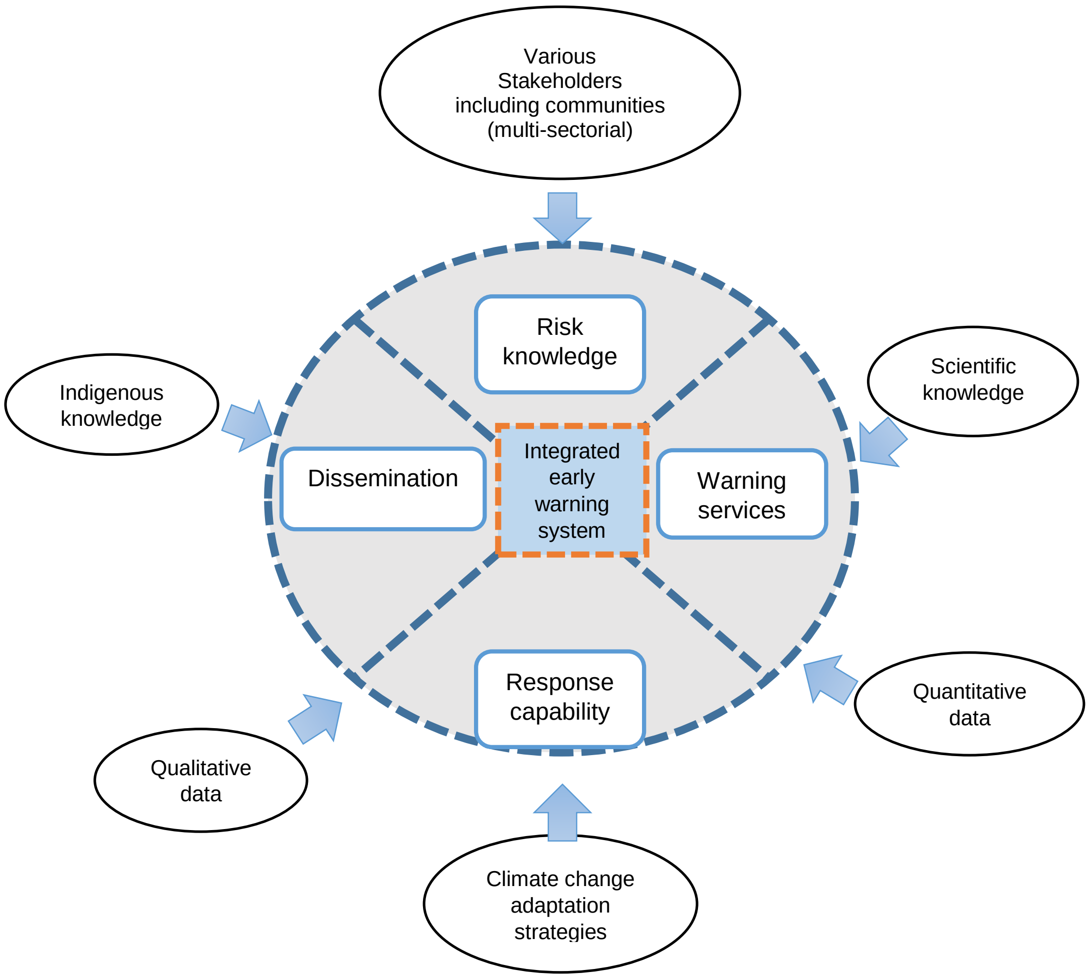


Figure 3.7 Integrated DRR components for a climate-sensitive MEWS.
Source: Authors' work

This study recognizes that there is a need to shift attention from single elements of an early warning system to a whole. All necessary elements of an EWS should be included in the development of an integrated early warning system, considering their interactions and interrelationships. An effective EWS can be achieved if there is an integration between forms of knowledge, data, and sectors. This includes communities for comprehensive DRR since there is no superior or inferior form in the knowledge corpus. There is a need to focus on DRR practical ideas that integrate CCA as well, emphasizing drawing data and knowledge that can be practically applied. This pragmatic approach in developing an integrated EWS might help to come up with a solution for MRR. It is also important to establish a concept that regards different forms of knowledge at par giving room for each form of data and knowledge to express its distinctive aspects as it is a precondition for integration. The light was shed by Macherera and Chimbari (2016) on the possibility of coming up with an integrated MEWS.

3.9 Weaving together concepts, models and frameworks to develop the early warning system (Orb web).

Bringing out various elements together simultaneously is crucial in the development of an integrated EWS. Not forgetting that DRR is "a conceptual framework of elements well-thought-out with the possibilities to reduce vulnerabilities and disaster risks thus to limit through mitigating and preparing for the adverse impacts of hazards" (Department for International Development 2011). The identification of nascent malaria hazards requires harmonizing information on environmental precursors with timely data and applying models for early detection as well as an early warning (Merkord *et al.*, 2017). It is not possible for the health sector alone to develop an integrated early warning system (Macherera and Chimbari 2016), the issue undeniably requires a multi-sectorial approach. A malaria risk reduction continuum web has been developed by the researcher embracing research concepts, models and frameworks which are customarily fragmented and unconnected in their application in hazard management.

DRR initiatives should underpin holistic management, involving related and connected issues that altogether influence resilience against disasters. Integrated knowledge and climate change adaptation should as well be incorporated in disaster reduction interventions, for an integrated intervention (Chianese 2016). A fusion of scientific and indigenous knowledge ensures overlapping of the weaknesses of the two forms of knowledge. Combining the two gives strength to DRR activities to become more effective (Masipa 2016). An integrative and target-oriented approach to disasters provides the best basis for preventing societies against threats posed by disasters. In the longer term, adaptation to climate changes should be emphasized for hazard prevention and mitigation. An integrative and target-oriented approach works best when informed by specific local conditions. The disaster management continuum should be divided into phases, pre and post-exposure. Each of the phases (mitigation, preparedness, response, and recovery) requires different forms of interventions (Twigg 2015).

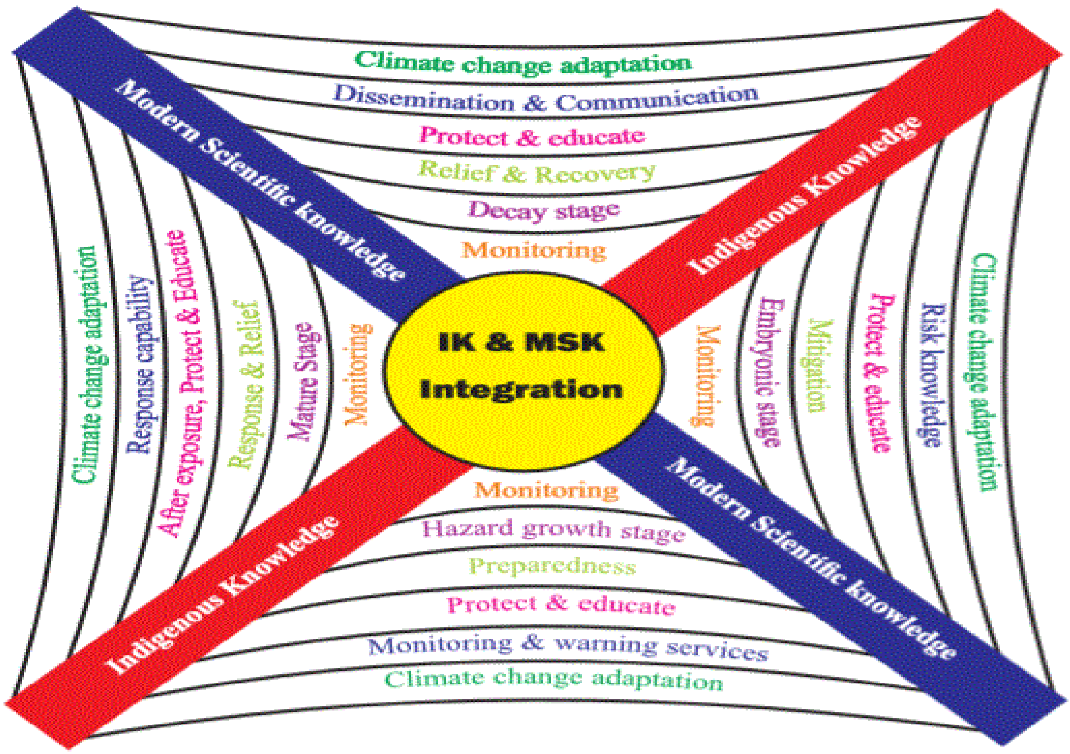
3.10 The woven integrated malaria management continuum web model

According to Gélinas and Bouchard (2013), it is vital to establish a precise and workable concept of knowledge that regards indigenous and knowledge at par, as epistemic items. The researcher gave room for the two to express their distinctive aspects. Gélinas and Bouchard (2013) further reveal that this is a precondition for approaching the problem of integrating indigenous and knowledge. In this study, both indigenous and scientific knowledge is regarded as the same as the solution to the problem identified in the study could be between the two forms of knowledge. Being open-minded helped the researcher to look for a solution for MRR regardless of where it comes from. A biased concept inevitably forces the promotion of one form of knowledge over the other right from the start (Gélinas and Bouchard 2013).

The following concepts, models and frameworks which were discussed in the previous chapter have been critically thought of and brought together to assist in bringing up an integrated EWS.

- Integrated western and indigenous knowledge
- Evolution of a hazard event
- Disaster management continuum
- Epidemiological triad model interventions
- Components of an integrated EWS by ISDR
- Climate change adaptation

The researcher believes that developing an EWS is just like how an orb-weaver spider develops its orb web. The spider develops an orb web to protect its life and eggs, the same way the communities develop EWSs` so that they protect their lives and properties. The first lines of the orb web serve as guidelines and signal lines, likewise, the first phases of an EWS serve to guide people to work towards mitigation and prevention. Signal lines, which are prediction measures should be able to predict hazards and alert communities of an impending disaster in time. Figure 3.8 shows how the researcher wove an orb web in an effort to try and understand the important concepts, models and frameworks which are supposed to be taken into consideration in developing an EWS.



Key for different weaving phases

- Evolution of a hazard event
- Disaster management continuum
- Epidemiological triad model interventions
- Components of an effective EWS by ISDR
- Climate change adaptation

Figure 3.8 Integrated malaria management continuum web model.
Source: Authors' work

According to Lawania and Mathur (2015), the orb web is circle like shaped as resembled by the malaria management continuum web on figure 3.8. The characteristic features are, a center portion as well as a series of radiating lines supporting the framework (Lawania and Mathur 2015). The frame is built first and attached to plants or other objects. In the same way, an EWS should be built on a strong institutional background. If there is no support from the institutions, the whole system can fail to function the way it is intended. In other words, if the object on which the spider builds its web is not strong, this jeopardizes all the efforts. The other part of the orb web is the radii, this radiate out from the midpoint just like bicycle spokes. The center of the EWS is supposed to be resilient for it to be able to cushion the communities from threatening hazards.

The sticky radii transmit vibrations when something has been caught to alert the spider of danger or threat in its territory. Likewise, both scientific and indigenous knowledge-based indicators should assist in giving a warning. Furthermore, such a warning should be noticed as early as possible to alert people when the hazard is still in its embryonic stage. Vibrations which represent warning services should be issued in time to prevent people from getting affected by Malaria. Some spider webs can even catch bigger animals such as birds. Therefore the strength of the orb web should be durable. Similarly, EWS should be so effective that even the worst anticipated scenarios can be handled. Though investing in an EWS requires costly resources, it is worth having it to overcome the underlying risks of not having it. It is better to invest in an EWS as it is a proactive measure than just waiting to react to disasters as EWS act as safety nets.

It is also prudent to note that, after some time, the silk of the spider web loses its stickiness and becomes inefficient. This normally happens when it is capturing prey. Similarly, in the EWS, some elements and activities need to be continuously improved to maintain their effectiveness and efficiency in protecting communities from hazards. Any hole in the orb-web gives a chance for what is meant to be caught by a web to pass through. Loopholes in an EWS web, on any element, causes hazards to pass through the safety net and affect people who are meant to be protected. The spider, after spinning its web, waits on or near the web, in the same way, the communities should always be alert and prepared for action. DRR has to be a full or complete set of elements coming together to form a safety net that should not leave any loophole beyond uncertainty.

3.11 Conceptual framework of the study

After the conceptualization of major concepts and discussing the policies, theories and frameworks influencing the study the researcher developed a conceptual framework. The conceptual framework categorizes and maps relationships among the concepts of the study.

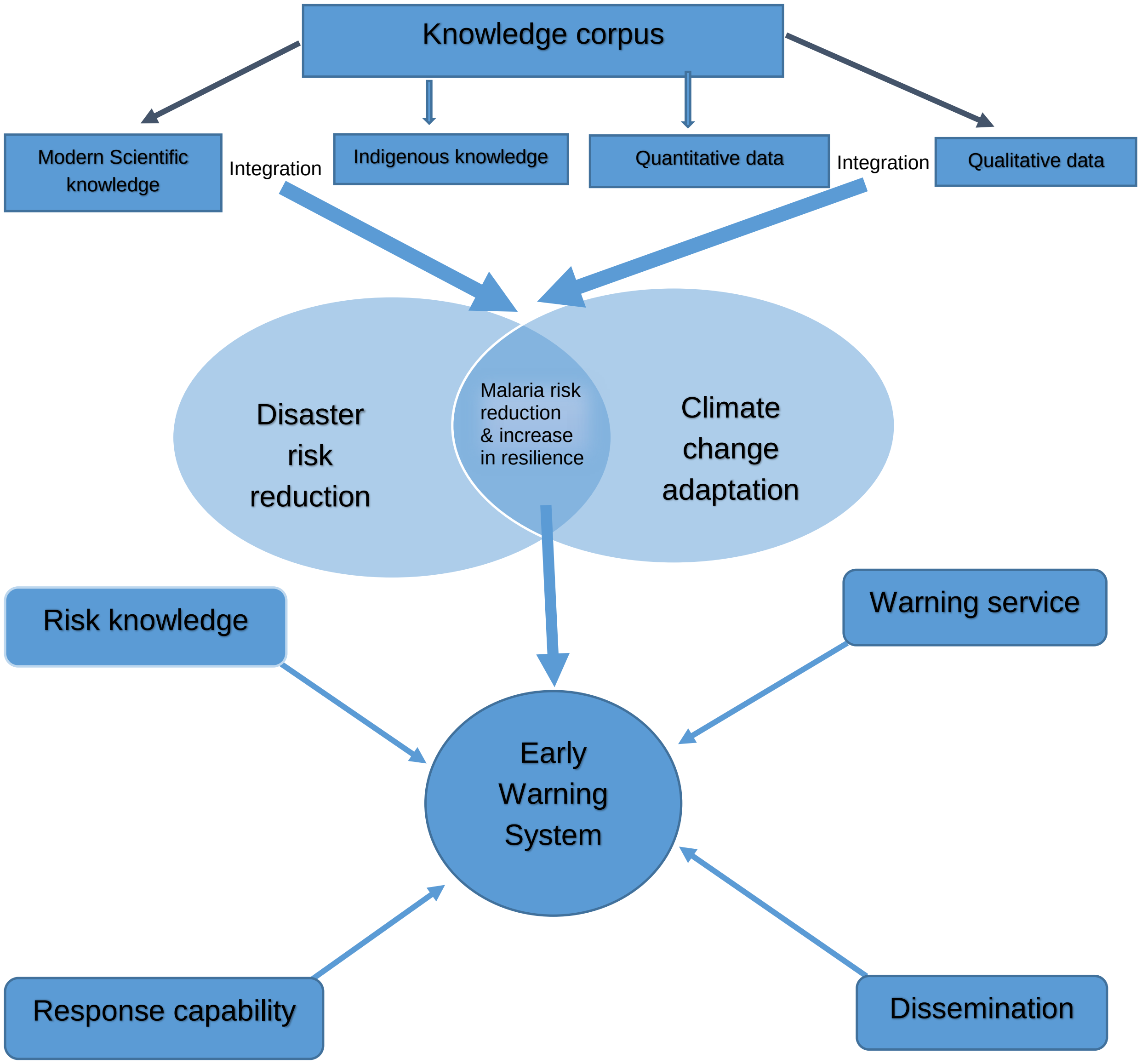


Figure 3.9 Research Conceptual Framework
Source: Authors' work

Figure 3.9 shows the research conceptual framework in terms of the elements and concepts that are important in coming up with an integrated MEWS for malaria risk reduction. The components in the framework are interconnected to influence each other and these were laid to provide a roadmap that gave a direction and guide towards the development of an early warning system. According to (Oktay 2012), a conceptual framework is similar to theoretical sensitivity in grounded theory and it presents theoretical perspectives that shape the worldview of the researcher. The conceptual framework serves as a guide on the requirements of a comprehensive EWS development. According to Wilhelmi and Morss (2013), research in DRR, including assessments should embrace innovative approaches that integrate data across disciplinary domains. This influenced the researcher to adopt a mixed-method approach in the next chapter 4.

3.12 Summary

The chapter, discussed the policies, frameworks, models and theories on which this research is hinged are reviewed. It helped to situate the study in terms of previous work and it opened an insight into the requirements for developing an integrated early warning system. The chapter opened the researcher on how ideally an integrated early warning system should be developed. The researcher discovered a lacuna in malaria risk reduction as the theories, models and frameworks that should be involved are customarily fragmented and unconnected in their application in malaria hazard management. A malaria risk reduction continuum web that embraces research models and frameworks guided by the theory was developed as a result of reviews made in this chapter. The following chapter discusses the underlying philosophical assumptions of the study as discusses the methodology of the research.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 Introduction

This chapter discusses the underlying philosophical assumptions of the study. It also describes and justifies the research process. The stages and processes used to achieve the objectives of this research (refer to section 1.5 in chapter 1) are discussed. The research process followed Saunders' onion as a guide. Each of the instruments used is justified and discussed in this section. A sequential multiphase that was adopted as a design allowed the researcher to collect data using the qualitative phase to build a quantitative phase (Guetterman *et al.*, 2019). In terms of weight attribution, both qualitative and quantitative methods have the same priority as complementing the two strengthened the research since a practical solution of the existing problem was being sought for. Finally, to ensure the trustworthiness of the research findings, the appropriate criteria for the mixed methods are discussed.

4.2 Research Process

The research process for this study was guided by a philosophical process as espoused by Saunders (2009), that is a research onion. In this study, the Saunders` (2009) research process was considered as it clearly demonstrates the approach to the problem. It provided a roadmap that gives direction towards the study and guided in the achievement of the research objectives. This is consistent with Marczyk *et al.,* (2010) who reveals that a research approach refers to various ways in which the study can be conducted to answer the questions through identifying appropriate methods with which to approach a research problem. Saunders (2009) posits that the research onion occurs in layers that are supposed to be peeled off before arriving at research data collection and data analysis methods. The first step was to identify the philosophical positioning of the study as shown in figure 4.1.

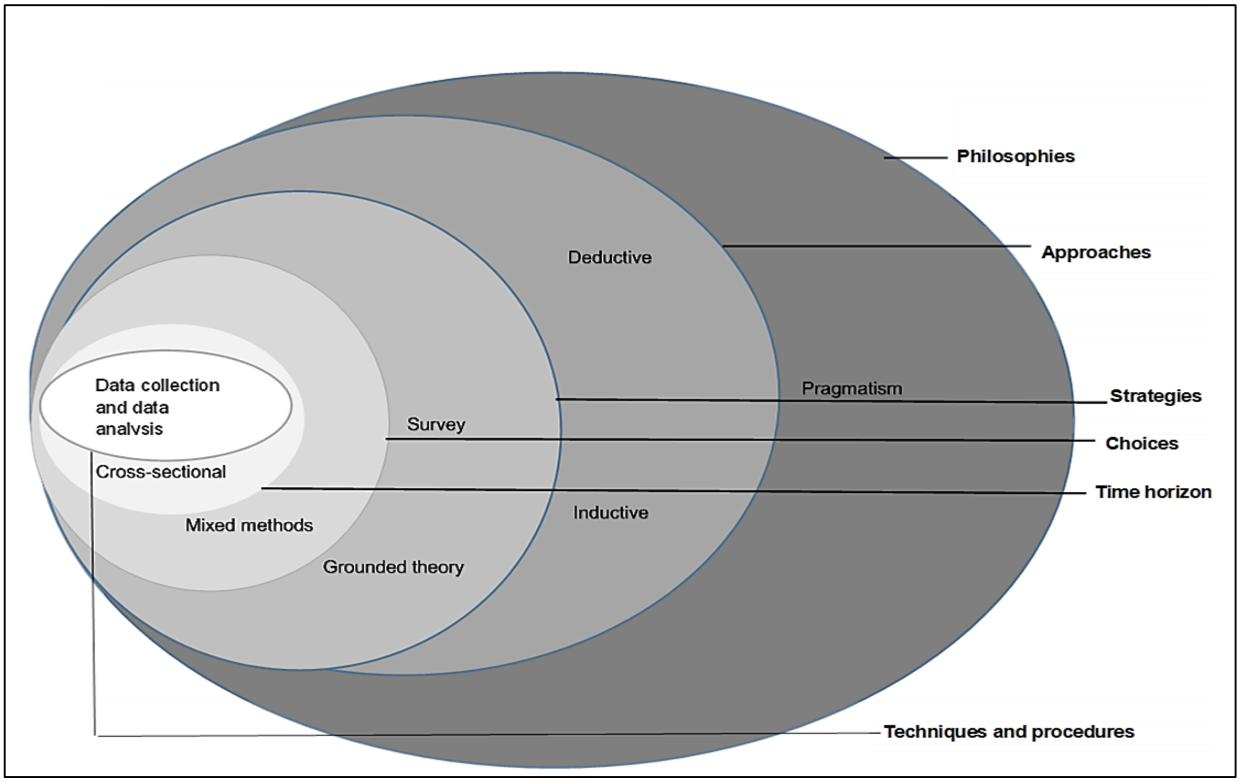


Figure 4.1: Research process (onion) by Saunders
Source: Adapted from Saunders research process (2009).

4.3 Philosophical positioning

In approaching a research problem, the researcher understood that assumptions were supposed to be identified first and this depends on the way in which the world is viewed (epistemology) as well as the phenomenon (ontology). These philosophical assumptions are a foundation of research and knowledge production (Goduka 2012) and they constitute what is 'valid' research. The assumptions are a central feature for any kind of scientific research as they give shape and definition regarding the conduct of an inquiry (ibid). The study assumes a relativist ontological position and takes both positivism and interpretive/constructivism epistemological paradigms, hence a combinative research paradigm (pragmatism epistemological approach). The pragmatism epistemological approach befits this social study that falls under Human and Social Geography. Pragmatism research philosophy was adopted and it emphasizes the relevance of concepts when they are supported by action (Saunders *et al.,* 2009). This relates to the study of social phenomena in its natural environment. This viewpoint was considered in this study, since a single viewpoint on what was being studied could not give an entire picture of a phenomenon. The researcher believed that reality may not be single but multiple. Pragmatism supposes that the research problem is the prelude or drive of the enquiry as it is initiated by enthusiasm to solve the problem which is the case in this study. According to Driscoll (2011), pragmatism entails both elements of deductive and inductive approaches hence it perfectly fitted in this study.

Constructivist grounded theory was then used to complement the pragmatic approach making it a Mixed Method-Constructivist Grounded Theory (MM-CGT). It was expected, in this study that the inductive approach would assist in conceptualizing the context of malaria risk reduction to generate concepts, categories and principles intended for developing a theoretical framework, and the early warning system resultantly. According to Charmaz (2017), the two can complement each other as methods and theories. Padmaja (2016) also claims that the grounded theory is a general research method and its use is not restricted to one school or discipline hence the researcher could use it in Human and Social Geography in the disaster risk reduction domain. Such a pragmatist approach was adopted in this research as it offered and assisted in achieving a critical qualitative inquiry while constructivist grounded theory offered strategies for doing it (Charmaz 2017). The method enabled the researcher to be flexible and rigorous in gathering views and opinions. Peeling away the Saunders` onion (philosophical and choice layers) leads us to the next layer which is the research approach.

4.4 Research approach

This researcher took a mixed approach that employed both quantitative and qualitative approaches. The most commonly used term is “mixed methods” and can also be referred to as “integrated/combined research,”. This allowed the researcher to view the phenomenon being studied with both lenses (thus qualitative phase and quantitative phase) giving a greater advantage than using a quantitative or qualitative approach alone. Integration of qualitative and quantitative data was fused to produce information that supports each other mutually in this study. Another reason for taking a mixed approach was considered that some of the objectives of this research required a quantitative approach while the other required a qualitative approach. The inductive (qualitative) approach involved the collection of data, discovering patterns and developing a theory from the data after its analysis while the deductive (quantitative) approach enabled the researcher to test hypotheses. The mixed approach, as a method collects, analyzes and combines both quantitative and qualitative data in a single study. The use of both quantitative and qualitative approaches in a study provides a better understanding of the research problem than applying either one of the approaches alone. After this layer of the Saunders` onion, we get to the next layer which is the research strategy.

4.5 Research strategy

Two research strategies were found appropriate for this study and these are survey and Grounded Theory strategies (refer to figure 4.1, Saunders' onion). This enabled the researcher to collect qualitative data that enabled the discovery of patterns of associations as well as quantitative data for two or more variables, this is in consistent with Bryman (2014). This was to ensure complementary strengths and non-overlapping weaknesses as it again offered the researcher a complete picture of the phenomenon being studied. After the research strategy layer of the Saunders` onion, we get to the next layer which is the research design.

4.6 Research design

A sequential multiphase design with 3 phases was used in this study. It accommodates grounded theory that informed the development of a quantitative instrument. The designs allowed a qualitative phase to precede and build a quantitative phase, and lastly, another qualitative phase was employed. The qualitative phase was conducted first so that the quantitative phase could also be built. This in consistent with authors such as Guetterman *et al.,* (2019); Morgan and Morgan (2007) and Creswell (2012). The qualitative phase was used to build a theory, to develop a quantitative instrument and identify variables that were tested in the quantitative follow-up. The time horizon is another layer of the Saunders` onion that comes after the research design.

4.7 Time horizon

Time horizon comes just before reaching the core of Saunders` research onion model (refer to figure 4.1). This study was a descriptive cross-sectional survey as it was concerned with gathering information regarding the phenomena under study and in its real situation. A cross-sectional research is undertaken where a problem is studied at a particular time. This research was done from the year 2017 to 2020. The last layer of the sanders` onion involves the sampling techniques and procedures.

4.8 Sampling techniques

One feature of the GT method is that the sample size cannot be predetermined in advance as the method favours fewer participants but necessitating detailed and intensive interviews (Getaneh *et al.*, 2015). In addition, interviews based on the GT allows the process of data collection and analysis to continue until theoretical saturation has been achieved (Glaser 2013). In search of the nature of the existing malaria EWS and indigenous knowledge-based indicators and prevention measures for malaria, the snowball sampling technique was considered. Interviewees suggested others who fall under the selected criteria since the population sizes for the malaria control and management experts was unknown. The other reason was that the researcher did not know the custodians of indigenous knowledge in the area of study. The semi-structured interviews were administered in the 4 municipalities of Mopani District. The age and the time which the interviewee had spent in the areas and their experiences were considered.

4.9 The data collection procedures

This research started by collecting qualitative data through an in-depth interview technique. This was chosen as it is an essential data gathering method that assists the researcher to get rich and in-depth real-life experiences from participants. This method remarkably fits with the abbreviated constructivist grounded theory approach. It is reckoned as one of the most appropriate methodology of the study as it is a direct methodological descendent of the pragmatist tradition (Charmaz 2017). The researcher initially collected qualitative data to obtain information regarding measures employed to predict malaria outbreaks by the communities of Mopani District. This was done to avoid forcing themes and categories in the emerging data.

Since the grounded theory was used as a methodology to collect data, the researcher was theoretically sensitive to the research questions related to the topic of study. The concepts and categories that emerged were then used to guide the next phase of data collection that is quantitative data collection. Sampling continues iteratively until theoretical saturation is reached (Getaneh *et al.*, 2015). This study is taking a mixed approach using constructivist grounded theory which helped in designing and fitting methodological strategies to explore new discoveries along the way, since theory may spark new ideas and kindle new questions (Charmaz 2017). The theory facilitates in defining and developing emergent critical questions systematically (Charmaz 2017) and these were added in the questionnaire for quantitative data collection in this study.

4.9.1 Observations

According to Driscoll (2011), some important discoveries in human history were as a result of observations. The grounded theory that was employed in this study is inductive, hence it enabled observations to give rise to new ideas as consistent with Glaser (2013). Observations are possible to conduct in any subject matter depending on the research questions of the study (Driscoll 2011). In this study, observations were made to gain insights into IK based malaria prediction indicators and prevention measures. The researcher was a non-participant observer and observations were done concurrently with in-depth interviews as well as during administering the questionnaire. Critics of positivism argue that all observations are made from a particular perspective, in other words, they are standpoint-specific (Creswell 2012; Glaser 2013). In this case, what emerged from the observations depended on the position of the observer and in this case, the researcher's ontological perspective was that there are multiple realities.

4.9.2 In-depth Interviews

A semi-structured interview guide was designed and the items were based on the research questions of the study (see section 1.4.2 in chapter 1). Semi-structured interviews enabled the researcher to vary questions in terms of their sequence in search of real solutions to a problem that existed in Mopani District. The questions were broadly framed and the interviewer could ask further questions on important replies (in consistent with Bryman, 2014). Theoretical sensitivity was considered as well as theoretical sampling and the researcher stopped collecting data when theoretical saturation had been reached in consistent with grounded theory. The data gathering process using the grounded theory method may start at any place selected by the investigator (Getaneh *et al.,* 2015). The study was based on real-life experiences of Mopani District communities. The researcher was sensitive and consistent with the epistemological framework of CGT and made sure that relevant data was being explored. A non-directive method of questioning was adopted and the interview guide was used flexibly. Each interview lasted approximately 1 hour and was recorded using a digital recorder. Participants were permitted to use their native language if they were not literate or preferred to use it as an interpreter was present during the interviews. The researcher was aware that the potential participants would not likely speak in English but prefer their native language. According to Statistics South Africa (2011a), more than 40% of the adult population in Mopani District are illiterate. Consistent with the CGT, what came out in the earlier interviews led to changes and expansion of areas worthy of further investigation on the interview guide topics in the later stages.

4.9.3 Questionnaire

The questionnaire was used to collect data in the second phase of the survey thus quantitative data. The instrument enabled the researcher to broaden the understanding of the phenomenon being studied. It was administered to a statistically significant number of participants (347). A self-administered questionnaire gave the researcher many advantages as questions were explained when it was necessary in case the participant failed to understand and made sure that all questions were completed. The other advantages were that information was gathered even if the participant is illiterate and it was also be used with the observation method. The disadvantages were that the interviewer travelled to the participants and this was expensive since participants were sparsely distributed geographically. A pretest was done before using the self-administered questionnaire. This enabled the identification of tautological questions and to make sure that there are no questions that are confusing or misinterpreted by participants. The pretesting was done under actual field settings with the study population of Mopani District.

4.9.4 Focus group discussion

After conducting in-depth interviews and carrying out a survey using the questionnaire a focus group discussion was carried out. The participants of the Focus group discussion were selected purposively. A focus group discussion was held to bring together scientists and the custodians of IK to collate people's views and ideas. This was important as it helped in choosing and validating the indictors that were mostly used by the people in the study area. These indicators were to be used in developing the EWS. This allowed people to have a better understanding of the others` IK as it is a platform that offers fresh insights. Priority indicators were noted and validated for the practical IK based malaria EWS. In this section, research expert consultations were employed. The data collected as indicators was fed into the database.

4.9.5 Secondary data sources

Data of yearly recorded malaria cases for the 4 municipalities from 2006-2015 was obtained from a secondary source (Machimana-Gabaza 2016). Rainfall and temperature data from 2006-2015 was also obtained from the South African Weather Services. Journals, articles, books and published documents were also considered for literature review.

4.10 Study population

The study area was taken as a single aggregate and has 4 municipalities. In total, the 4 municipalities have a total of 232 772 households. Table 4.1 shows the number of households per each municipality that was involved.

4.11 Study sample

For in-depth interviews and the focus group discussion, the study samples were not predetermined since the study employed grounded theory. This is in consistent with Getaneh *et al.*, (2015) who reveals that one feature of the grounded theory is that the sample size cannot be predetermined in advance as the method favours fewer participants but necessitating detailed and intensive interviews. The target population for in-depth interviews were community members as well as all the experts involved in malaria management. The following people were interviewed, disaster risk experts, municipality environmental health head of department, health department officers and workers, and community elders. These were interviewed to get the relevant information on the nature of the existing EWS in Mopani District. The participants in the qualitative study were not the same individuals that provided quantitative data. This is a requirement as guided by the multiphase sequential design (Creswell 2014).

The survey sample was determined by an online sample size calculator (www.checkmarket.com). At 95% confidence level, 5% margin of error (confidence interval) and at an estimated response rate of 80%, the sample size required to administer the questionnaire was 480. Stratified (proportional) random sampling was used for selecting the households for the survey. The proportionate stratified random sampling method was used to calculate the number of households in which the questionnaires were administered. Table 4.1 shows the proportions of the households per municipality that were to be interviewed.

Table 4.1 Proportion of households to administer the questionnaire

Municipalities	Total households per municipality	Total Questionnaires per municipality
Greater Letaba	58 261	120
Greater Tzaneen	108 926	224
Ba-Phalaborwa	41 115	85
Maruleng	24 470	50
Totals	**232 772**	**480**

The households in which the questionnaires were to be administered was guided by the proportions of the strata since the total households of the municipalities were not the same. The sample survey had a total of 480 households, however, the researcher failed to administer all the household heads because of reasons such as "participation fatigue". The researcher managed to administer the questionnaire in 347 households. In the absence of the household head, the next person in the house was considered. This yielded a response rate of 72% which is a high survey response rate. This enhanced the study findings to be a representative of the total study population.

4.12 Profile of the participants

The profile of participants relates to gender, age and occupation. The study had participants from various cultural settings and backgrounds. A total of 381 participants took part in the study. Table 4.2 reflects the profiles of participants that took part in the in-depth interview, survey and focus group discussion (FGD).

Table 4.2 Profile of participants

Group	**Number of participants**	**Gender**		**Age**				**Occupation**		
		Male	**Female**	**<29**	**30-39**	**40-49**	**>50**	**None**	**Formal**	**Informal**
In-depth interview (Community)	21	8	13	-	-	-	21	7	8	6
In-depth interview (key informants)	4	2	2	-	-	2	2	-	4	-
Questionnaire (survey)	347	172	175	66	103	85	93	136	125	86
Focus group discussion (FGD)	9	5	4	-	-	4	5	4	3	2

Out of 21 participants that took part in in-depth interviews held in communities, 8 were males while 13 were females. All of them were above the age of 50. The old-age participants were very significant in this research as it was assumed that they are the custodians of IK and therefore have gained experience of using it over the years. This is consistent with Mercer (2010) who reveals that the custodians of IK are mainly the elderly people since they have acquired credible knowledge over time. Among these participants, 7 were not employed, 8 were formally employed while 6 were informally employed respectively. The informally employed were mostly vendors and farmers. All the key informants who participated in the interviews were formally employed by the institution involved in malaria management and control. These were all above the age of 40.

The eligible sample of the quantitative phase was derived from 347 household heads in the study area. The average age range of the survey participants was 30-39. Furthermore, 93 participants were above the age of 50. In relation to employment status, 136 were unemployed, 125 were formally employed and 86 had informal occupations. The total participants for the FGD were 9, of which 5 were males while 4 were females. The FGD consisted of 2 retired farmers, 2 traditional healers, a meteorologist, a system designer expert, a community leader, a teacher and a nurse.

4.12. Setup in which data was collected

The research took place in rural villages and urban areas of four municipalities of Mopani District (see section 1.9 in chapter one for the details of the study area). Initially, the researcher wanted to conduct the study in the whole Mopani District but failed to get a letter of approval from Giyani Municipality due to administrative reasons. The four municipalities that were involved in the study are Maruleng, Ba-Phalaborwa, Greater Letaba and Greater Tzaneen. Mopani District was chosen because it admitted in the media that it is failing malaria control at the prevention stage, hence the researcher decided to find a solution to the real-life problem being encountered in the district. The selection was done through snowballing. Geographical and other practical considerations were also considered in the selection of areas to conduct an in-depth study as well as administer questionnaires.

4.13 Qualitative data analysis

Data analysis embraces a whole range of activities of both the qualitative and quantitative type (Kothari *et al.,* 2014). In this study, constructivism grounded theory (systematic design) by Charmaz (2006) was used as a methodology and to analyze the qualitative data. Theoretical saturation was implemented within the texts that were being analysed in consistent with Glaser (2013). The researcher did memoing, thus writing down notes whenever an idea or a question came up during coding. Constant comparisons were being done to see if there was any new emerging information. Transcriptions were first coded on MS Word documents using pseudo names for all interviewed participants (see appendix 4 and 5 for transcriptions). This experience gave the researcher time to reflect and to be immersed in the data. The researcher transcribed a denaturalised representation of the participants' responses which did not include grammatical errors, repeated words and pauses. Initial coding was done by the researcher to establish the direction of the study related to the topic. According to Oktay (2012), initial coding impacts the direction that is taken by the study. Initial coding helped the researcher to narrow the scope of the study through the identification of the concepts that were to be saturated. According to Oktay (2012), there is no right way to code and it depends on what is to be brought out by the study. As soon as data was transcribed, tabulated in excel for storage and data sorting the data analysis process began. These steps were crucial in the application of the grounded theory method as it helped to bring out a theory.

4.14 Quantitative data analysis

A statistical analysis was carried out using SPSS version 23.0. The following tests were carried out to determine the relationship between malaria and climate variables (rainfall and temperature).

4.14.1 Pearson's correlation coefficient

To investigate the relationship between climatic variables and malaria cases Pearson's correlation was used. If the variables are highly correlated, their association is further investigated to find out if there is any causal relationship. It is used for examining relationships between interval variables.

It is calculated as follows;

$$\mathbf{r} = \sum(\boldsymbol{Xi} - \bar{\boldsymbol{X}})(\mathbf{Y}\boldsymbol{i} - \bar{\mathrm{Y}})\boldsymbol{I} \sqrt{\sum(\boldsymbol{Xi} - \bar{\boldsymbol{X}})^2 \sum(\mathbf{Y}\boldsymbol{i} - \bar{\mathrm{Y}})^2}$$

If r is closer to 1, the more the linear the data.

4.14.2 Spearman's correlation analysis

Spearman's correlation was carried out to analyze the association between the recorded cases of malaria in Mopani District and climate variables (rainfall and temperature) using

SPSS version 23.0. Spearman's correlation is used when both variables are ordinal or if one of the variables is ordinal and the other is interval.

4.14.3 Linear regression model

The multiple linear regression model was used to analyze the influence of rainfall and temperature on malaria cases. The equation of the regression line is as shown below;

$$\boldsymbol{Y_i = \beta_0 + \beta_1 X_1 + \beta X_2 + \varepsilon_i} \qquad \text{(ii)}$$

Where

$\boldsymbol{Y_i}$ is the dependent variable, (Number of people infected by malaria)

$\boldsymbol{\beta_0}$ is the intercept of the model,

$\boldsymbol{\beta_1, \beta_2}$ are the slope coefficients for $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ respectively,

$\boldsymbol{X_1, X_2}$ are the independent variables (Rainfall and Temperature).

4.14.4 Descriptive and inferential statistics

According to Yoep *et al.,* (2015) malaria should be mapped at different levels from the country level down to village level for quality control measures. The retrospective descriptive and inferential statistics were conducted on historical malaria data for periods 2005-2015 for 4 municipalities of the study area. This assisted the researcher to analyze, compare and rank the 4 municipalities according to their hazard risk. A map ranking the level of risk comparing the 4 municipalities was then produced.

4.15 Qualitative research evaluation

According to Jonker (2010), the measures of quality control for the study depend on the methodology chosen and are generally classified according to qualitative and quantitative research. The criterion for evaluation that was used in this research is the one proposed by Charmaz (2006), reflecting the epistemic repositioning of the CGT. According to Charmaz (2006), there are four criteria proposed for evaluating findings from CGT studies and these are originality, credibility, resonance and usefulness.

4.15.1 Originality

This study demonstrates originality as indigenous and scientific knowledge are being integrated to come up with a unique innovation for malaria risk reduction using an Information and Communication Technologies (ICT) as a platform to integrate the two forms of knowledge. The study could add on to the existing body of knowledge on malaria risk reduction as well as contributing around methodological considerations when conducting research in the DRR domain. There is a resultant theoretical significance as well in this study from the processes studied, therefore the current practices of DRR for climate-sensitive malaria can, therefore, be influenced by the findings.

4.15.2 Resonance

According to Charmaz (2006), resonance refers to the extent to which the findings make sense to the affected people. In other words, the participants should make sense of what resulted from the analysis of the data that was co-constructed between them and the researcher. The findings of this research might make sense if the people in the study area adopt the findings an outcomes in solving the current problem of malaria transmissions.

4.15.3 Usefulness

Usefulness refers to the usability of the interpretations of the developed theory in the everyday world. It is concerned with how the categories and theory emerged from the data (Charmaz 2006). The researcher sought for the relevance of the study so that it informs the actual practises (Malaria control initiatives) and its contribution to the existing body of knowledge. The theorising of the work in this study can be useful in malaria risk reduction. The usefulness results and output from this research does not lie in the hands of the researcher, but in the hands of those policy-makers, communities and scholars who might use the strategies in future. The study also provides suggestions for further study that relates to disaster risk reduction for climate-sensitive malaria hence it can be very useful for the targeted communities and stakeholders.

4.15.4 Credibility

The transcription of data through careful listening of the voices participants was an important process for the overall credibility of the data. During the study, the interview recordings, and detailed transcribing as well as memoing facilitated dependability and reliability. The researcher collected data with an open mind and this enabled an independent assessment of the claims made.

4.16 Measures of study quality control for the quantitative phase

Measures of quality control refer to the strategies implemented to ensure the gathering of relevant data, managing and utilising it with accuracy and precision. According to Jonker (2010) classification of quality control measures may be developed by distinguishing 3 stages in research thus in advance, during and after research. In advance, the researcher developed a conceptual framework (refer to chapter section 3.10) which was then operationalized. At conceptualization and operationalization, the researcher made sure that the conceptual framework accurately reflects the specific theoretical concepts that were being measured. During research measuring, instruments were also designed and after data collection the researcher calculated the response rate.

4.16.1 Reliability

According to Drost (2011) reliability relates to the consistency of measurement. (Punch and Oancea 2014) reveals that reliability of a study hinges on the reputation of sources of data used. In this research different sources of data were used to enhance reliability. Qualitative and quantitative data was obtained using a multiphase sequential design with three phases. Different participants were targeted per phase and this enhanced reliability of the study. More-so the study also used both primary and secondary data. Reliability tests were also run successfully in SPSS version 23 for each category of the questionnaire.

4.16.2 Triangulation

Goduka (2012) reveals that triangulation enhances confidence in findings. Particularly in this triangulation helped to study the phenomenon of interest at several dimensions than in one way. Mixing methods, designs and techniques in this research allowed triangulation of findings. The research combined the following shown in table 4.3 using the Saunders' onion on figure 4.1 as a guide for the identification of stages on which triangulation was ensured.

Table 4.3 showing stages on which triangulation was ensured

Layer of the Saunders' onion	**Triangulation**
Philosophies	Pragmatism (interpretivism and positivism)
Approaches	Deductive and inductive
Strategies	Survey and grounded theory
Methods	Qualitative and Quantitative approaches
Data collection techniques	In-depth interviews, Focus Group Discussions and a Questionnaire

Triangulation helps to strengthen validity and increase the usefulness of a research. Adopting combinations shown in table 4.3 helped to gain a more complete understanding of the phenomenon that was being studied (triangulation) as the strength of one method covered the weakness of the other.

4.16.3 Validity

Validity "*is the demonstration that a certain instrument measures what it purports to measure*" (Pandey and Pandey 2015). It governs the degree to which a research instrument manages to solicit relevant information for the study. The questionnaire for this study was developed using qualitative data and questions that came up from the in-depth interviews. It was also corrected based on the results of the pretest study that was conducted in the same setting that the research was to be conducted.

4.16.4 Generalizability

An appropriate technique of sample selection was also employed to form an appropriate sample as recommended in Kothari *et al.,* (2014) to ensure generalizability of the study. This approach was important as rich data was yielded in the 3 phases of the sequential multiple designs, improving the generalizability of the findings. In this study stage 1 employed the use of in-depth interviews, followed by the use of a survey questionnaire and again an in-depth interview to verify the themes that emerged from stages 1 and 2.

4.17 Ethical considerations

Informed written consent was solicited from all municipalities involved in this study. The researcher sought consent from individual interviewees and participants before data collection. Participants and interviewees were respected and urged to participate on a voluntary basis. If they had some reservations, they were excused. Privacy and confidentiality were maintained throughout the study.

4.18 Summary

The chapter presented the research paradigm, design and the methodology adopted in the study. The data collection, analysis and interpretation processes were also described. Pragmatism research philosophy underpinned and the constructivist grounded theory mixed method (CGTMM) design was adopted in this study. This design integrates both quantitative and qualitative methods, processes and perspectives in the same study. The paradigm employs what works, as it allows for the use of subjective and objective philosophical variables to achieve practical outcomes. A questionnaire was employed to collect quantitative data. Qualitative data were generated through the use of interview guides. Quantitative data was analysed using SPSS version 23 while qualitative data was analysed using grounded theory. The next chapter presents, analyses and interprets data to address objective 1 of this study.

CHAPTER FIVE

FACTORS INFLUENCING MALARIA TRANSMISSION IN THE STUDY AREA

5.1 Introduction

The chapter sought to answer the first research question. It focuses on data presentation and analysis of the factors influencing malaria transmission in the study area. Since a mixed-method approach (sequential multiphase method) was used. Data presentation, analysis and discussion of quantitative and qualitative data were integrated to complement each other. It should be understood that malaria transmission is complex and multifactorial. Kumar *et al.,* (2014) reveals that it is a dynamic process and involves many interlinked factors, from uncontrollable natural environmental conditions to man-made disturbances.

5.2 Identifying the factors that influence malaria in the study area

The researcher sought to investigate the factors influencing malaria transmissions in the study area. Literature review revealed that the malaria hazard distribution is dictated by variable climatic patterns (Tonnang *et al*., 2014). Several authors mention that malaria is sensitive to climatic factor variations and its occurrence can be predicted using climatic factors that include temperature and rainfall (Tonnang *et al.,* 2014; Macherera *et al.,* 2017). In consistent with the literature review the researcher first considered the effects of meteorological as factors that could also be influencing malaria in the study area.

5.2.1 Meteorological factors

Specifically for the purpose of this research, only rainfall and temperature will be considered because the two variables can be predicted by both indigenous knowledge and scientific knowledge. Macherera, *et al* (2015) confirms the possibility of predicting the occurrence of malaria using rainfall prediction indicators. Macherera, *et al* (2015) reveals that, rainfall indicators can be used in the development of MEWS. The two variables also have an influence in causing malaria outbreaks and are also widely considered as major drivers of malaria incidence variability in semi-arid areas of Africa. Malaria risk change with time, depending on factors such as rainfall and temperature (SA guideline for the prevention of malaria 2017) These variables will be used to develop an integrated MEWS as they also influence modern and indigenous knowledge based disaster warnings.

Initially, trend analysis for malaria cases in relation to climate variables was done. Two meteorological variables which are rainfall and temperature were considered in the analysis. There rainfall and temperature trends were analyzed using annual average data of a 10 year period from the area of study. The following is a trend (in figure 5.1) for climate variables in relation to the number of people affected by malaria in Mopani District from 2006-2015.

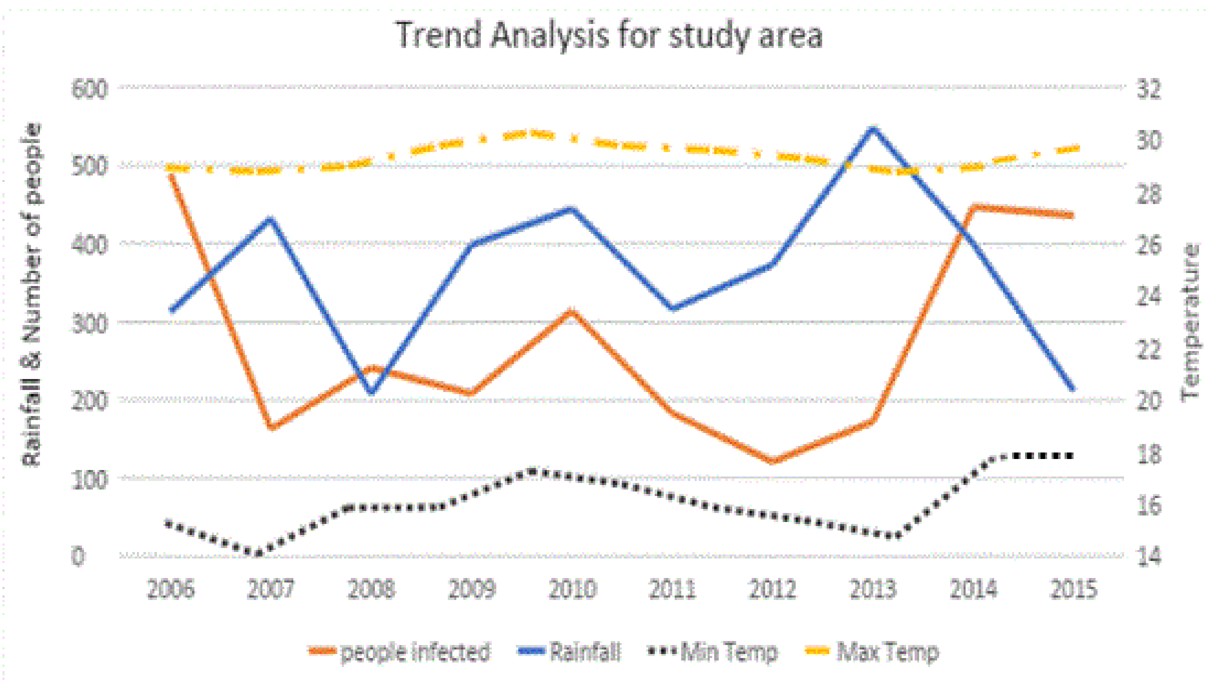


Figure 5.1 Trend analysis for malaria cases in relation to climate variables

A decrease in rainfall and increase in temperature is noted from 2013 to 2015 from the time series. Both maximum temperature (Tmax) and minimum (Tmin) exhibit a similar trend and this could be attributed to observed global warming. Glantz *et al.,* (2014) reveal that the world over, as each year passes it becomes more obvious that climate change is already occurring in many locations due to global warming. Significant peaks in the series were created by malaria infections and the annual rainfall amounts. It appears that there was a cyclical pattern between the annual rainfall and the number of people affected from the year 2009 to 2015 as the peaks of malaria infections follow a similar pattern of annual rainfall and minimum temperature. The highest peak of rainfall was reported in 2013, this was also followed by a peak of malaria-infected people in the following year (2014). It can be then anticipated that the malaria trends are being associated with rainfall and temperature (Tmin and Tmax). A diagnostic test was then performed to detect the association of independent variables with the dependent variable and the relationship that exists within independent variables. In addition, this test was also utilized in detecting multicollinearity.

Diagnostic test results (Pearson's correlation coefficient).

Prior to analysis, data for the whole study was subjected to necessary diagnostic tests. Since the research used time-series data, the tests carried out include multi-collinearity tests and overall model fit tests. Non-parametric tests were preferred since there were limited data points. Table 5.1 shows the correlation matrix for all the variables.

Table 5.1 Correlation matrix for all variables

		People infected	**Minimum Temperature**	**Maximum Temperature**	**Rainfall**
People infected	Coefficient	1.000			
	Sig. (2-tailed)				
Minimum Temperature	Coefficient	0.696*	1.000		
	Sig. (2-tailed)	0.025			
Maximum Temperature	Coefficient	0.361	0.221	1.000	
	Sig. (2-tailed)	0.305	0.540		
Rainfall	Coefficient	-0.522	-0.429	-.887**	1.000
	Sig. (2-tailed)	0.122	0.216	0.001	
	N	10	10	10	10

*. *Correlation is significant at the 0.05 level (2-tailed).*

**. *Correlation is significant at the 0.01 level (2-tailed).*

The correlation matrix was utilized for two main purposes. Firstly, in detecting the association of independent variables with the dependent variable. It is interesting to note that the minimum temperature had a statistically significant association (r=0.696) with the number of people infected. The maximum temperature had an insignificant positive relationship with the number of people infected, (r=0.361) while rainfall also had an insignificant strong negative correlation with the number of people infected, (r=-0.522). The correlation coefficient for the association between monthly mean minimum temperature and the number of people infected was greater than that of the correlation coefficient for the association between rainfall and the maximum temperature and number of people infected. This means minimum temperature was the most significant factor contributing to transmission dynamics as there is a correlation with the number of people infected in the area of study. These results are similar to those from a study that was carried out in South West Ethiopia which suggest that minimum temperature is a significant factor that correlates with malaria transmission dynamics (Alemu *et al.*, 2011).

Secondly, the correlation matrix was used to detect how independent variables relate among themselves and detect multi-collinearity. A statistically significant, very strong negative (r=-0.887) relationship between rainfall and maximum temperature was observed. To solve the problem of a strong association between any pair of independent variables, the maximum temperature was not included in the preparation of the final regression model. The model is specified as follows;

Model Specification

A Multiple Linear Regression Model (MLRM) was developed for the whole study area to ascertain the impact of temperature and rainfall on the number of people infected with malaria from 2006 to 2015. The results are presented in the preceding tables 5.2 – 5.4.

Table 5.2 Model Summary

Model Summary[a,c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0.738[b]	0.545	0.415	18.214	2.112

a. The whole study area

b. Predictors: (Constant), Rainfall, Min_Temp

c. Dependent Variable: People infected

Overall Model Fit

The R-Square and Overall F-statistic were used to test the overall model fit. The percentage of variation in the number of people explained by minimum temperature and rainfall is 0.545 (54.5%). This demonstrates a strong positive association between malaria infections and rainfall as well as the minimum temperature. Therefore, one can argue that the two variables have a strong influence on the number of malaria cases in the area of study. This means 54.5% of malaria cases for the study area are attributed to rainfall and minimum temperature and the other 45.5% is due to other causes.

Table 5.3 Analysis of Variance and F-Statistic

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2783.958	2	1391.979	4.196	.043[c]
	Residual	2322.142	7	331.735		
	Total	5106.100	9			

a. Whole study area

b. Dependent Variable: People infected

c. Predictors: (Constant), Rainfall, Min_Temp

Table 5.3 shows that the F statistic was 4.196 ($p<0.05$) this means these results suggest a statistically significant regression model. The coefficients in the tables above give rise to the following multiple linear regression model.

Table 5.4 Regression Coefficients

Coefficients[a,b]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	-70.180	79.989		-.877	.409
Min_Temp	8.758	4.276	.578	2.048	.040
Rainfall	-.044	.045	-.274	-.971	.364

a. Whole study area

b. Dependent Variable: People infected

Table 5.4 shows that the regression slope for minimum temperature is 8.758 with ($p<0.05$). This suggests a statistically significant positive relationship between the number of people infected by malaria and minimum temperature. This means the number of infected people increases with the increase of units at minimum temperatures. Evidently, the hazard is a climate-sensitive disease. According to Ngarakana-Gwasira *et al.,* (2016), CC plays a vital role in triggering and altering climate-sensitive epidemics such as malaria due to the exacerbation of hydro-meteorological and environmental conditions. The implications of these findings are that, in Mopani District, the responsible authorities should always take necessary precautions when they note increases in temperature. The minimum temperature is likely a contributing factor in producing conducive conditions for the breeding of mosquitoes. This is consistent with Alemu *et al.,* (2011) who reveals that temperature plays a major role in the breeding of mosquitoes.

The regression coefficient for rainfall is -0.044 with ($p>0.05$). This suggests a negative and insignificant influence on the number of people infected by malaria. In Mopani District, rainfall may not have a strong influence on the number of people affected by malaria because as rainfall increases, the chances that mosquitoes may breed becomes limited. Flowing water from the rainfall naturally destroys their habitats hence destroying their breeding levels. This is in consistent with Omonijo *et al.,* (2011) who mentions that excess rain can destroy breeding sites.

5.2.2 Correlation test on the survey data

The nature of strength and magnitude of the relationship between items of the survey instrument was done to find out the other factors besides rainfall and temperature influencing malaria in the study area. This was done by performing a correlation test on the survey data. To test the nature of strength and magnitude of the relationship between other items of the survey instrument, spearman's rho was used for this analysis. The following table 5.5 is a correlation matrix showing a summary of the major relationships between variables using correlation analysis.

Table 5.5 Summary of the major relationships between variables using correlation analysis

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Dwelling type	1.00															
2	Age	0.04	1.00														
3	Education	-.211**	-0.10	1.00													
4	Occupation	.166**	-0.09	-.557**	1.00												
5	Media	-.146**	-0.09	.273**	-.270**	1.00											
6	Received alert message	-.149**	0.03	.145**	-.150**	.151**	1.00										
7	How alert was received	-0.08	0.07	.140**	-.154**	.193**	.641**	1.00									
8	Adjustments made	0.05	0.00	-.162**	0.05	-0.11	-.154**	-0.08	1.00								
9	Type of assistance	-0.03	-0.10	0.07	-.148**	0.06	-.226**	-0.05	-0.04	1.00							
10	MRR measures employed	-0.04	.131*	-0.09	0.10	-0.05	-0.02	0.06	.174**	0.01	1.00						
11	Method of prediction	0.03	0.04	-.129*	.132*	-0.09	-0.05	0.00	0.10	-0.03	.287**	1.00					
12	Number of affected family members	.128*	0.06	-0.01	-0.04	-0.08	0.04	0.07	0.06	-0.08	-0.03	0.03	1.00				
13	In case of no assistance	0.04	-0.02	0.00	0.02	-0.07	-0.03	-0.04	.106*	0.03	.231**	.171**	0.04	1.00			
14	Weather pattern changes noted	0.02	-0.08	-0.03	-0.03	-0.09	-0.06	0.05	0.04	.142**	0.07	0.00	-0.05	0.04	1.00		
15	Knowledge on climate change	0.02	.162**	-.353**	.255**	-.204**	-.182**	-.185**	.138*	-0.09	0.08	0.09	-0.02	0.08	.109*	1.00	
16	Effects of climate change	0.02	.183**	-.186**	0.09	-.119*	0.05	-0.04	.116*	-.149**	0.10	0.02	-0.04	0.04	0.03	.281**	1.00

*Note *Correlation significant at the 0.05 level (2-tailed). ** Correlation significant at the 0.05 level (2-tailed).*

Source: Primary data.

5.2.2 Socio-economic factors

From the correlation matrix, it was noted that the dwelling type was among the other factors influencing the high number of people affected by malaria in the study area. Table 5.6 below is a cross-tabulation for dwelling type and the number of malaria-infected family members.

Table 5.6 Dwelling type and the number of malaria-infected family members

			Number of malaria-infected family members						Total
			0	1	2	3	4	5	
Dwelling type	Very formal	Count	17	1	1	0	0	0	19
		% within Dwelling type	89.5%	5.3%	5.3%	0.0%	0.0%	0.0%	100.0%
		% of Total	4.9%	0.3%	0.3%	0.0%	0.0%	0.0%	5.5%
	Formal	Count	212	42	6	0	2	1	263
		% within Dwelling type	80.6%	16.0%	2.3%	0.0%	0.8%	0.4%	100.0%
		% of Total	61.1%	12.1%	1.7%	0.0%	0.6%	0.3%	75.8%
	Informal	Count	23	17	2	1	0	0	43
		% within Dwelling type	53.5%	39.5%	4.7%	2.3%	0.0%	0.0%	100.0%.
		% of Total	6.6%	4.9%	0.6%	0.3%	0.0%	0.0%	12.4%
	Traditional	Count	20	2	0	0	0	0	22
		% within Dwelling type	90.9%	9.1%	0.0%	0.0%	0.0%	0.0%	100.0%
		% of Total	5.8%	0.6%	0.0%	0.0%	0.0%	0.0%	6.3%
Total		Count	272	62	9	1	2	1	347
		% within Dwelling type	78.4%	17.9%	2.6%	0.3%	0.6%	0.3%	100.0%
		% of Total	78.4%	17.9%	2.6%	0.3%	0.6%	0.3%	100.0%

Table 5.6 reveals that in total 5.5%, 75.8%, 12.4% and 6.3% of the participants stayed in very formal, formal, informal and traditional dwellings respectively. About 78.4% suggested that their families had no cases of malaria with the rest recording at least one person. Proportionally, more people affected were from informal dwellings (39.5%) while those who dwell in traditional houses (9.1%) were less affected. This could be attributed to the fact that DDT lasts longer on rough surfaces of traditional houses as compared to other types of dwellings as mentioned by of the Key informants who said;

For traditional houses in rural areas chemicals used for IRS stay on the walls for a longer period. The nice modern houses have slippery walls and DDT does not last.
KI 2

The reason why people in informal settlements are mostly being affected could be that Local governments may refuse to provide services to informal settlements because this implies recognition of people's right to the land they have settled on (Twiggs 2015). Boadi (2005) reveals that urban people living in slums and shantytowns are more exposed to pest infestation, particularly malarial mosquitoes, flies, cockroaches and rodents. This means that people living in informal dwellings are more vulnerable to diseases than those staying in traditional or formal dwellings. Since there was a correlation between the number of family members affected and the dwelling type as shown in the correlation matrix in table 5.5, further Chi-square tests of independence were used to test the statistical significance of the relationship between the type of dwelling and the number of people infected by malaria.

Table 5.7 Chi-Square test results for dwelling type and number of affected family members

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	28.692[a]	1	.018
Likelihood Ratio	25.173	1	.048
Linear-by-Linear Association	.705	1	.401
N of Valid Cases	347		

A chi-square test of independence was conducted comparing the frequency of malaria cases and the type of dwelling. A statistically significant interaction between the two variables was found *(X2(1)* = 28.692, *p* < 0.05). From these results, it can be argued that indeed the type of dwelling has a bearing on the number of people affected by malaria in the study area.

Table 5.8 Measures of association for dwelling type and number of affected family members

Symmetric Measures					
		Value	Asymptotic Standardized Error[a]	Approximate T[b]	Approximate Significance
Nominal by Nominal	Phi	0.288			0.018
	Cramer's V	0.166			0.018
Interval by Interval	Pearson's R	0.045	0.045	0.839	0.402[c]
Ordinal by Ordinal	Spearman Correlation	0.128	0.055	2.391	0.017[c]
N of Valid Cases		347			

The phi coefficient and Cramer's V were the suitable measures of association for determining the strength of the relationship between ordinal variables. The results show a phi coefficient of 0.288 (28.8%), $p<0.05$ and a Cramer’s V of 0.166 (16.6%), $p<0.05$ suggesting a statistically significant strong association between type of dwelling and number of people infected by malaria. The findings correspond to what is revealed by Twiggs (2015), that people in poor quality housing are vulnerable to a variety of hazards as most of the related infrastructures have poor drainage and sanitation systems. Garbage collection services also tend to be poor in the affected areas resulting in the breeding of vectors.

5.2.3 Anthropogenic and environmental factors (from data analysed using CGT)

Results of the study show that there are also anthropogenic and environmental factors that were mentioned by the participants. These were collated from the results of the in-depth interviews, survey and focus group discussion. Table 5.9 shows a summary of the risk factors that are likely to be contributing to malaria transmissions in the area of study.

Table 5.9 Anthropogenic and environmental factors

Categories of risk factors	**Environmental**	Endemicity of malaria in the area
		Proximity to other countries with malaria and game parks
		Poor soil drainage
		The abundance of fruits e.g. Amarula fruits and mangoes
		Stagnant water in dams and rivers as well as during the rain season
	Anthropogenic	Reluctance, inconsistency and late spraying by responsible institutions
		Water harvesting (storing water in ponds and drums), water accumulating on gutters
		Overcrowding
		Informal dwellings
		Sewerage ponds
		Free movement of people from areas with malaria
		Human actions e.g. migration
		Pit latrines
		Kraals

Source: Primary data

One of the participants who was a pastor made a remark that;

> *The reason contributing to malaria risk is that more people are now travelling. Movement long ago was limited than now, foreigners were also few in this country. People used to live a pure life and respected themselves, and they were law-abiding but now they have left the laws of God.* **P 14**

The participants' remark might imply that there has been a lot of negative changes contributing to an increase in malaria transmissions in the area. The participant is of the opinion that an influx of foreigners in the area is a contributing factor to the increase of malaria as some of them are from malaria-infested areas. This is consistent with the Roll Back Malaria Partnership (WHO 2008) which reveals that countries that have porous borders can experience an inflow of people from high transmission zones. Mopani District is close to the borders of Mozambique and Zimbabwe (see scope of the study section 1.9), therefore, the district experiences influx of foreign nationals at a high rate. According to the Mopani District Development Plan (2016), facilities and services are overburdened because of the influx of foreign nationals and this has jeopardized the quality of services which are meant for the few citizens. This also converges with the statement made by another participant who said;

> *People from other countries are living in crowded conditions, even 40 people are staying in one household. Sometimes they have 10 children and the other family 10 children in one household because they invite each other here and stay together. They are overcrowding this place.* **P 13**

Some of the illegal migrants establish settlements in unsafe land such as swampy areas and construct unsafe informal dwellings. Such living conditions expose people to the risk of malaria hazard. According to Adams (2002), the potential for epidemics is more prevalent to weakened populations living in crowded conditions.

5.3 Malaria risk ranking in the study area

A comparison was done for comparison of risk levels between the municipalities involved in the study. The following table 5.10 for descriptive statistics enabled the ranking of the study area in terms of the malaria hazard risk.

Table 5.10 Descriptive statistics for the area of study

Municipality		N	Minimum	Maximum	Mean	Std. Deviation
Ba-Phalaborwa	People_infected	10	122	490	278.40	134.884
	Min_Temp	10	14.10	17.60	15.895	1.095
	Max_Temp	10	28.78	30.28	29.329	.5107
	Rainfall	10	208.40	549.20	365.449	105.585
	Valid N (listwise)	10				
Greater-Tzaneen	People_infected	10	69	277	157.30	76.133
	Min_Temp	10	12.30	31.10	14.898	5.715
	Max_Temp	10	25.80	28.10	26.410	.626
	Rainfall	10	499.00	1208.40	871.230	220.895
	Valid N (listwise)	10				
Greater-Letaba	People_infected	10	37	144	81.80	39.508
	Min_Temp	10	12.75	13.40	13.155	.226
	Max_Temp	10	22.90	52.50	26.629	9.102
	Rainfall	10	154.20	635.90	386.070	132.184
	Valid N (listwise)	10				
Maruleng	People_infected	10	22	87	49.30	23.819
	Min_Temp	10	14.27	19.50	15.989	1.572
	Max_Temp	10	24.90	30.55	26.576	1.843
	Rainfall	10	206.40	678.00	470.818	149.491
	Valid N (listwise)	10				

From table 5.10, it can be noted that the highest mean of the number of infected people is from Phalaborwa thus 278.40. This is followed by Tzaneen with 157.30, Letaba 81.80 and lastly Maruleng with 49.30 as the mean for infected people in the area. It can also be noted that Phalaborwa recorded the highest average annual maximum temperature (28.78). Phalaborwa also received the lowest mean annual rainfall (365.449) than all the other municipalities. Low rainfall could be contributing to the high number of malaria-infected people in the area compared to the other municipalities. This is consistent with Omonijo *et al.,* (2011) who reveals that usually there is a tremendous rise in malaria cases when rain increases mosquito breeding sites, however, excess rain can also destroy breeding sites as high rainfall may wash away mosquito larvae. Figure 5.2 is a map that was produced after ranking malaria hazard risk in the 4 municipalities involved in the study.

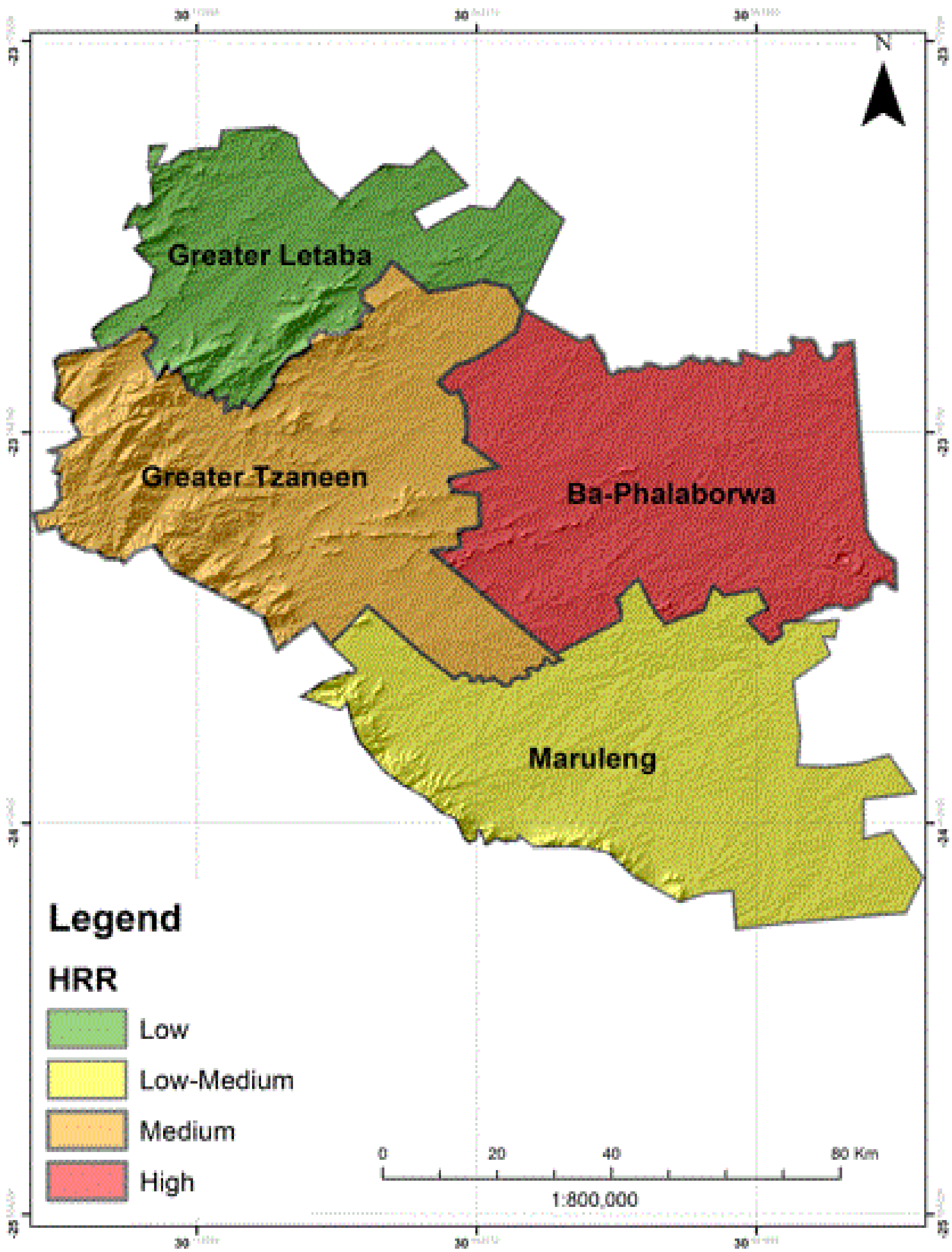


Figure 5.2 Malaria hazard risk ranking (HRR)
Source: primary

5.4 Summary

The chapter assisted in bringing out the variables to be adopted for early warning system development as data to be fed is required for the early warning system. Based on the findings, it was concluded that rainfall and minimum temperature have an influence on malaria cases in the study area. The results also brought out anthropogenic and environmental factors influencing malaria in the study area. There is also empirical evidence that Phalaborwa had the highest mean number of infected people comparing to other Municipalities in the study area. This was followed by Tzaneen, Letaba and lastly Maruleng. A hazard risk ranking map was produced from the results. The following chapter explores the nature of the existing malaria EWS in the study area.

CHAPTER SIX

NATURE OF THE EXISTING MALARIA EARLY WARNING SYSTEM

6.1 Introduction

Chapter 6 concentrated and focused on answering research question 2 on exploring the nature of the existing malaria EWS in the study area. Specifically for this study, the researcher ascertained that an EWS must have all the required elements. Exploring the nature of the existing MEWS in this study was mainly guided by the systems theory for disaster management and the framework for elements of an integrated EWS by the International strategy for disaster reduction (2006). In inconsistent with the systems approach to managing disasters, it requires an analysis of all possible sources of a problem by examining each individual element (Simonovic´2010). The theory brings out that an integrated system can be more effective than unconnected elements operating autonomously. The researcher, therefore, used all the elements that make an EWS complete (whole) in exploring the existing EWS of the study area.

6.2 Elements of an integrated early warning system

The framework for elements of an integrated EWS highlights that an EWS should be comprised of four inter-related elements and the failure of one element could lead to failure of the whole system. The four elements are risk knowledge, monitoring and warning services, dissemination and communication and response capability as laid out by ISDR (2006). The researcher used these in exploring the nature of the existing malaria EWS.

6.2.1 Risk knowledge

The results of the community in-depth interview show that most of the participants thus 17 out of 21 were aware of the malaria risk in their area. 3 participants had no idea of the malaria risk while 1 participant did not directly mention malaria as one of the diseases that affect people in the area of study. This participant specifically said that;

> *I don't know about malaria (Ni nga ta hemba) but since we were growing we know that if you get a headache and you survive two days then you are lucky.* **P 6**

Though the participant did not mention the term malaria, the symptoms that were brought up match those of malaria. Responding to a follow-up question the participant further added that;

> *Even now what I know is that someone can have a headache and become dizzy. We realized that it was because of the mosquitoes and I learnt that from the farms.* **P 6**

When asked what disease it was, the participant failed to give the name of the disease. The researcher deduced that the disease that the participant was referring to, is malaria since it has the same symptoms and causes hence the participant was aware of the malaria risk in the area. According to participant 13, the responsible institutions for malaria control are doing their best to reduce malaria. Participant 13 who is a community health care worker made a remark that;

> *We go door to door giving information so that when summer comes they know what to do. Some remember, some don't until they are infected by malaria that is when you see them coming to the clinic.* **P 13**

Based on this remark, it can be concluded that communities are assisted to gain an awareness of the malaria hazard. The results from the survey on figure 6.1 reveal that 69% of the population was aware of the risk.

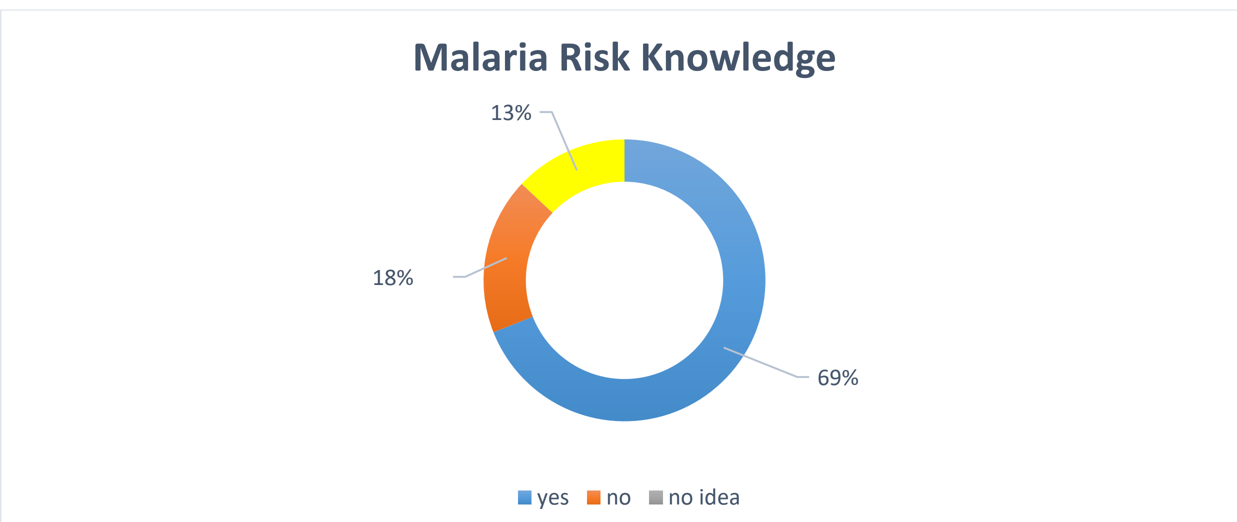


Figure 6.1 Malaria risk knowledge

Approximately 18% thought there was no malaria risk and 13% had no idea if there was a risk of malaria at all in the area. The results of the survey match those of the in-depth interview which depict that many people were aware of the malaria risk in their area. This means the institutions responsible for alerting communities on malaria in the area are doing their best. Such action is supported by Lenton (2013) who mentions that risk knowledge to a large extent can provoke action among communities hence members need to know common hazard risks in their areas. Alessa *et al.,* (2016) also recommend that key stakeholders should give advance information on the risks that people are facing so that it can be readily translated into prevention, preparedness, and response actions.

Table 6.1 shows the frequency and percentages of participants from the survey on malaria risk knowledge.

Malaria risk knowledge					
		Frequency	Percentage	Valid Percent	Cumulative Percent
Valid	Yes	239	68.9	68.9	68.9
	No	63	18.2	18.2	87.0
	No idea	45	13.0	13.0	100.0
	Total	347	100.0	100.0	

The results show that the majority of the participants were aware of the malaria hazard in the area. This constituted 68.9%. 18.2 % indicated that there was no malaria risk in their area and 13% had no idea if there was any risk of malaria at all. These results, therefore, satisfy the assumption of the study, that the Mopani District communities are aware of the malaria risk in the area. This also means that the existing initiatives are good in terms of alerting people about malaria risk. This converges with what is recommended by ISDR (2006) that there is a need to effectively disseminate messages and warnings to ensure that there is a constant state of preparedness among those that are facing hazard risks.

When people know their risks they can cushion themselves. According to Sättele *et al.,* (2015) warning people at risk to avoid losses.

However, despite that, there was a high number of participants who were conversant of the malaria risk and contributing factors, some of them were very ignorant. In relation to this, Key informant 4 who was a health care worker specifically mentioned that;

> *Most of them just don't care and they do not listen or practice what we tell them.*
>
> **KI 4**

It can be deduced that even if people know their risks, their attitude is very important. This is consistent with Nkulikwa (2018) who noted that the negative attitudes among those that are vulnerable may lead to the disregarding of relevant training and seminars about malaria. Nkulikwa (2018) commends that the level of acceptance, attitude and perceptions on malaria initiatives to be introduced in any community are supposed to be assessed in advance.

Using results from the survey, a correlation test was performed and spearman's rho was used to find out the association between different variables from the data collection instrument. The results are presented in the following table 6.2

Table 6.2 Correlation matrix

		Age	Education	Method of rainfall prediction	Weather pattern changes noted	Knowledge on climate change risk	Effects of climate change
1	Age	1.00					
2	Education	-0.10	1.00				
3	Method of rainfall prediction	0.04	-0.129*	1.00			
4	Weather pattern changes noted	-0.08	-0.03	0.00	1.00		
5	Knowledge on climate change risk	0.162**	-0.353**	0.09	0.109	1.00	
6	Observed effects of climate change	0.183**	-0.186**	0.02	0.03	0.281**	1.00

*Note *Correlation significant at the 0.05 level (2-tailed). ** Correlation significant at the 0.05 level (2-tailed).*

Source: Primary data.

The results show that there is a moderately strong negative correlation on knowledge of CC risk and level of education (-0.353**) as well as the level of education and observed effects of climate change (-0.186**). This means as we move down the education scale, more people indicated that they were not knowledgeable on climate change issues. As we also move down the education scale more people were not alert of the changes that are occurring in terms of climate change effects. Results also show that there is a significant correlation between age and knowledge on climate change (0.162**) as well as knowledge on climate change and the observed effects of climate change (0.281**). This means that, as people grow older they become more aware of the changes that are occurring. Thus, time and experience enable one to provide a rich source of information.

Since there was a moderately strong negative correlation on climate change risk and level of education in the correlation test that was performed, the researcher further sought to find out the distribution of participants by level of education and knowledge on climate change risk. Figure 6.2 below shows the distribution;

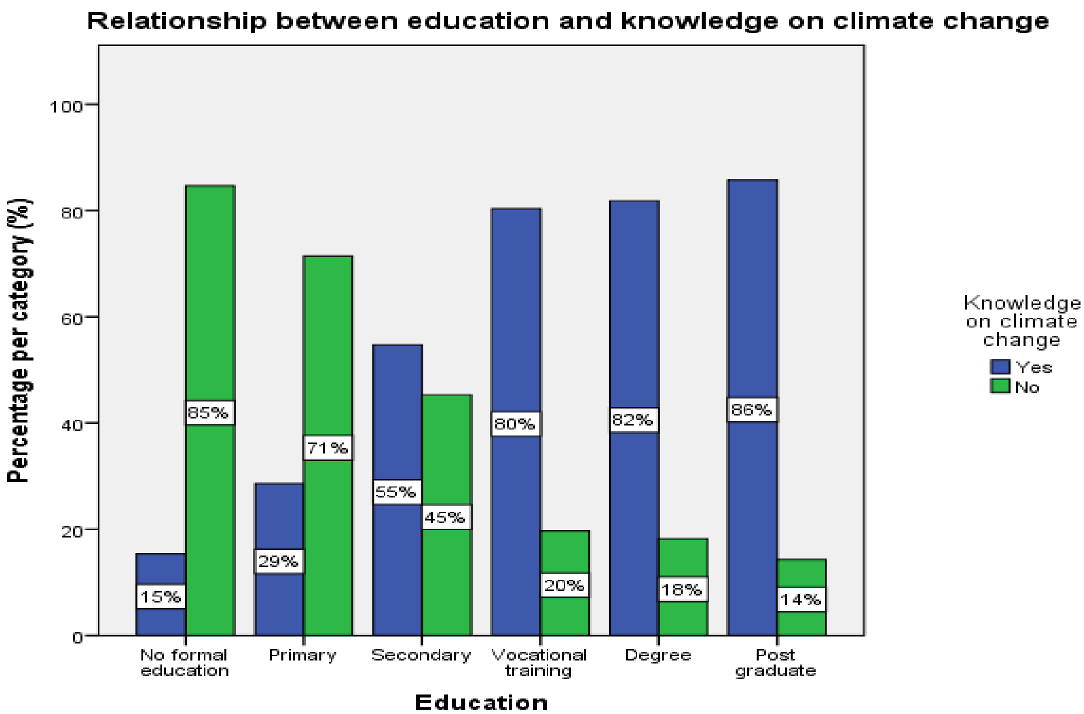


Figure 6.2: Distribution of participants by level of education and knowledge on climate change.
Source: Primary data

The results show that as the level of education in participants' increases, they become more knowledgeable. This, in turn, implies that, when they have lower levels of education, their knowledge is also affected significantly. 86% of the participants who indicated that they were postgraduates were aware of climate change risk. As we move up the education scale, more participants revealed that they were knowledgeable about climate change issues. On the other hand, low levels of education were associated with limited knowledge of climate change. Only 15% of those who indicated that they had not received any formal education indicated that they did not know much about climate change. The major implication of these results is that the responsible authorities should improve literacy levels in the district since it has an effect on the understanding of climate change which is a major factor influencing malaria cases. These findings concur with Alessa *et al.,* (2016) who reveals that people are supposed to have adequate knowledge on the risks they are facing as this can be translated into prevention, preparedness, and response actions. Risk knowledge to a large extent can provoke action among the communities (Lenton 2013).

6.2.2 Monitoring and warning services

The results of the study also show that by nature, the existing EWS emphasizes monitoring activities. The responsible institutions for malaria control consider the detection of malaria season by the number of recorded cases. One of the key informants who noted an urgency to modify such interventions highlighted the need for a forecasting model that can predict rainfall, 3 months prior to the rain season for effective MRR. Key informant 1 stressed that;

> *The issue of climate change is a problem, our push is that researchers should come up with a model that can predict rainfall maybe 3 months before it happens, to say Mopani is going to have low rainfall level for this year, but Vhembe is going to have high rainfall level for this year starting in November so on. That would mean our interventions will have to change, we have to plan accordingly.*
> **KI 1**

According to key informant 1, monitoring and warning services might be improved if prediction measures can be done 3 months before the malaria season. This was highly considered in developing the EWS. Early prediction was regarded as an urgent call that has a capacity to enhance the issuing of warning in time. This means the existing malaria monitoring and warning services are not timeous. Consistent with literature review findings, if there is an EWS in place there is an attempt to predict epidemics before an unusual transmission (Teklehaimanot *et al.*, 2004; Macherera, Chimbari and Mukaratirwa, 2015). It is imperative, therefore, that the institutions for malaria control advocate for initiatives that can predict the epidemics in advance instead of placing their attention on early detection. The participants also expressed the need for an improvement in warning services and highlighted that they needed to be alerted timeously before an outbreak. Participant 2 also recognized that the warning services for the malaria hazard were not timeous and said;

> "*Actually, when we are alerted, that is when people start dying. Prevention is rare, it's too scarce they are not preventing as they should. They wait until people start dying then they start trying to contain the problem that's what I have noted. They wait until there is an outbreak then they start saying 'hee heheee' be careful there is malaria. You must do this, you must not do this. Now we are in winter, according to the programme they should have started spraying since we are getting into summer in no time. They must highlight to us and send awareness messages that the season is coming, that season of malaria, you should do this and this, so that it must be in our mind all the time. Malaria kills, that's what they must tell us".* **P 2**

Evidently, there is a need to improve malaria warning services in the area of study so that warnings are issued early enough for those at risk to implement suitable prevention measures. This is consistent with what is also recommended by IFRC (2012) that an early warning should be augmented by a system that enables people to take action. Twigg (2015) also suggests that warning services lie at the core of the system and it is best to rely on locally tailored warning systems that as engage communities. As such, the researcher developed an EWS that integrates one prominent local language in the area. In this case, it is coherent that the existing EWS in the study area encourages and assists people to act against malaria using their IK knowledge and local resources.

6.2.3 Dissemination and communication

The results demonstrated that the element of dissemination and communication was present in the existing EWS. Both in-depth interviews and survey results enlightened the researcher that even though dissemination was part of the elements, information was not reaching to all intended people. Some reasons that were given by participants of the in-depth interview of why they had not received the malaria alert messages were that;

> *The problem is that, I wake up at 5 am early morning to catch a taxi to go to work. I come back at 5-6 in the evening. It's just only during the weekend when I stay*

home. The people who will be at home know much about malaria because sometimes they are told at the community meetings held at the clinic. **P 4**

Another participant who complained that he had never received any warning on malaria indicated that he knew through donating blood. The participant exclaimed that;

For me to know that Tzaneen has been declared a malaria area, I knew it because of the blood transfusion group. I am a blood donor, so every year I donate blood, almost every quarter I donate blood. We have to answer if we have been to a malaria area in the past 2-3 months in their questionnaire. We used to say no, so they told us that Tzaneen was declared a malaria area. That is when I became alert that there is a risk of malaria. **P 3**

The results of the survey on the number of participants who received alert messages also support those of the in-depth interview and revealed that quite a large number of people had not yet received the malaria alert messages. The following is table 6.3 showing the frequencies and percentages of participants who received malaria alert messages;

Table 6.3 Number of participants who received alert messages

Number of participants who received alert messages			
		Frequency	Percentage
Valid	No	135	39
	Yes	212	61
	Total	347	100

As shown in table 6.3, a larger percentage, thus 61% of the participants indicated that they had received alert messages while 39% had never received such messages. This might mean that a significant number of people in the study area was not receiving alert messages. Concerning this, Cools *et al., (*2016) state, that, unfortunately, the dissemination of early warning remains a challenge to communities. Nevertheless, on the same note, the key informants emphasized that they were making a tremendous effort in trying to alert people in various ways. This was mentioned by two participants who worked for the departments involved in malaria control as they said;

> *Alerts are sent to people especially in summertime over the radio and TV. Campaigns are done to tell them how to prevent themselves e.g. by wearing long-sleeved clothes and using mosquito nets and coils.* **P 9**

Participant 13 also mentioned that:

> *Campaigns are done to teach people about malaria symptoms and the areas in which mosquitoes breed. We do more campaigning in this area because they do not have the information.* **P 13**

From the results of the survey, the 61% that received early warning further clarified that they had got the relevant messages through various media mechanisms as shown in the following figure 6.3;

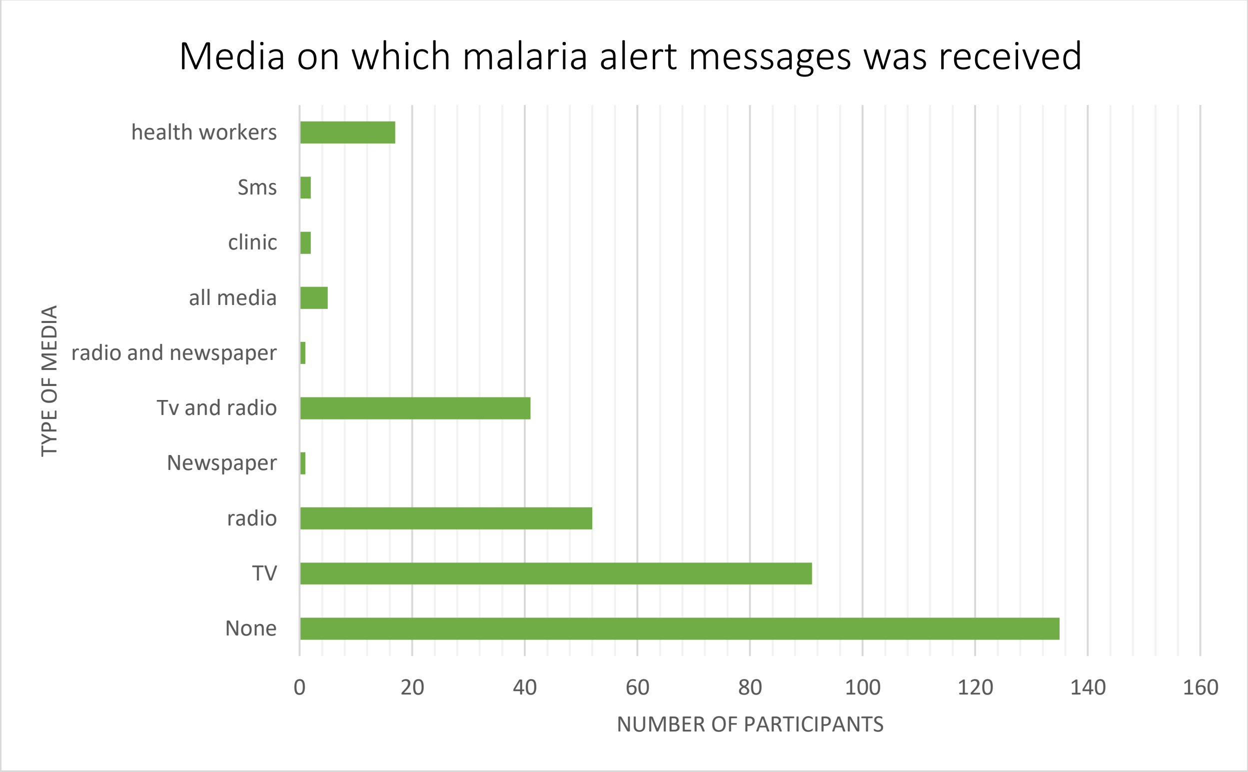


Figure 6.3 Media on which malaria alert messages were received
Source: Primary data.

The participants reported significantly higher use of television and radio as sources of malaria alert messages. This could be due to their ubiquitous nature. This means that media plays a very important role in making people aware of malaria as revealed by Chirebvu, *et al.,* (2013). People can only know about their risks when they are alerted. The main source of media was via Television. 91 out of 212 participants from the survey indicated that they had received the message on TV while 52 participants received the message on radio and 41 received on both television and radio respectively. Only 17 participants indicated that they had received the message through door to door visits by health care workers. As shown in the bar chart, most people do not attend community meetings or buy newspapers as they are the least used forms of media. The reason for failure to disseminate information successfully to the intended group could be that the largest group of people in the study area are illiterate (Mopani IDP 2016). In Mopani district, the level of illiteracy is at 27.1% (ibid), hence some of the people who received the warnings might not have understood it. Garcia and Fearnley (2012) are of the idea that the language used for dissemination should be non-technical and understandable to community members. The United Nations (2006) recommends that warning dissemination methods should be locally adapted, thus, accommodating the capacities and preferences of the target communities.

As highlighted in the literature review, Villagrán de León and Pruessner (2013) states that the warning or alert messages should be in understandable language and format so that they have an impact on the target group or people. This also means that it is essential for an EWS to be tailor-made for each community set up. The other reason why malaria alerts are not reaching to all people could be physical remoteness as some areas have poor communication network. Mopani District Integrated Development Plan (2016), reveals that there is still a need to establish a communication network down from district to ward level. Dissemination and communication can also be affected by lack of access to technologies such as cellphones and social media, of which social networks are often the most important channels of communication (Twigg 2015). A correlation test was performed and spearman's rho was used to analyze results obtained from the survey conducted in this study. The results are presented in Table 6.4 below. The results are shown in the following correlation matrix;

Table 6.4 Correlation Matrix

		Education	Media	Received alert message	How alert was received
1	Education	1.00			
2	Media	0.273**	1.00		
3	Received alert message	0.145**	0.151**	1.00	
4	How alert was received	0.140**	0.193**	0.641**	1.00

*Note *Correlation significant at the 0.05 level (2-tailed).*
** Correlation significant at the 0.05 level (2-tailed).*
Source: Primary data

The results of the correlation test that was performed revealed that there was a positive correlation on the level of education and media use (significance of 0.273**). Also, another relationship was noted between the level of education and receiving of alert messages (significance of 0.145**). This could mean that with higher levels of education people tend to seek more information on various forms of media. This opinion concurs with Nkulikwa (2018) who discloses that education is a force which enables one to acquire knowledge. It is noted that it should be taken into account that the world over communities are not homogeneous in terms of media use from a suggestion made by Twigg (2015). Twigg (2015) further mentions that people have their own preferred ways of receiving and sending information. Methods that work well for one group may be inappropriate for others in the same area of study since the area has different municipalities with different cultures and languages. Baudoin (2016) also posits that response capability depends on warning dissemination and includes training and risk awareness among vulnerable groups. The same should be done in the area of study accordingly.

6.2.4 Response capability

The nature of the existing EWS on response capability demonstrates that experts involved in malaria control initiatives in the study area are assisting communities without dialoguing. This portrays a conventional End to End EWS that is typically command and control in nature and uses a linear model in consistent with Basher (2006). According to Basher (2006) such a linear model that adopts a top-down approach from the scientific experts to the public. This seems to be similar to the system that exists in the study area. From the literature review, the researcher noted that a traditional End to End EWS mainly uses an expert-driven approach. With such a system it is believed that technical expertise are considered more important than the communities (Glantz *et al.*, 2014). On the contrary, experts should not impose solutions for problems to communities (Mercer *et al.*, 2010). According to Twigg (2015), most disaster experts believe communities do not scientifically understand their risks and hence they consider the members as passive. Karanath and Dashora (2014) are also of the idea that to enhance EWS effectiveness, technical agencies that generate warning information, DRR experts as well as vulnerable communities are supposed to be connected. In this case, the malaria control initiatives appear to be more of top-down in nature. This was brought out when Key informant 4, emphasized that;

> *The community members should just understand and practice what we tell them to do. If they do that, then malaria can end.* **KI 4**

In such a case, communities are made to believe that they should mainly concentrate on what they are told to do as the only effective option that can save them. This is consistent with the idea from Gaillard and Mercer (2013) and Lunga (2015) who reveal that in most cases, governments and scientists still dismiss communities' contribution. When asked if the key stakeholders are promoting IK in the communities for MRR. Key informant 1 made a remark that:

> *We can't stop them. That one we are promoting 100% it is just that the knowledge is not scientifically proven but they are using it. If it works for them it works that we cannot dispute.* **KI 1**

The researcher was enlightened that the promotion of IK and use of local resources in malaria control was a "lip-service" by the stakeholders as at grassroots level it was not being practically promoted. When the researcher verified the association that exists between adjustments made and MRR measures being employed using data from the survey, the results indicated that the prevention measures that are mostly advocated for are MSK based. This is shown in table 6.5

Table 6.5 Chi-Square test results for adjustments made and malaria risk measures employed

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	23.786[a]	3	0.000
Likelihood Ratio	23.231	3	0.000
Linear-by-Linear Association	10.190	1	0.001
N of Valid Cases	347		

Source: Primary data.

Table 6.6 Measures of association for adjustments made and malaria risk measures employed

Symmetric Measures					
		Value	Asymptotic Standardized Error[a]	Approximate T[b]	Approximate Significance
Nominal by Nominal	Phi	0.262			0.000
	Cramer's V	0.262			0.000
Interval by Interval	Pearson's R	0.172	0.054	3.236	0.001[c]
Ordinal by Ordinal	Spearman Correlation	0.174	0.054	3.283	0.001[c]
N of Valid Cases		347			

Source: Primary data.

A statistically significant interaction between the two variables was found ($X^2 (3) = 23.786$, $p < 0.05$). Table 6.6 shows that the phi and Crammer's V coefficients were all 0.262,

$p<0.05$, suggesting a statistically significant weak relationship between the two variables. Based on these results and the cross-tabulation, it can be argued that the more the people adjust to malaria message alerts, the more they are likely to use MSK than IK. It is highly likely that alert signals being received by people in the study area are encouraging the use of MSK than IK. It can also be argued that people are preferring MSK as it has been proven and to be smart and effective while IK is believed to be knowledge of the poor. These findings are contrary to Twigg (2015) who pointed out that communities, especially in countries where government capacities are limited, mainly rely on their IK and resources to enhance coping strategies in dealing with hazards. This means that the communities are being left to practice their IK if they wish though it is not being prescribed by the MRR experts. Evidently, MSK is being taken as the best option among the two in MRR. It is also apparent that experts in malaria control and management are not involving themselves in the use of IK and local resources. This is brought out from the statement that;

"*If it works for them, it works that we cannot dispute*". **KI 1**

It can be concluded that experts acknowledge the existence of IK based methods though they are not conversant with related activities. It can also be understood that experts fear that IK might not always be the right intervention for all hazards and disasters affecting communities. As noted in the literature review, in some cases IK may exacerbate communities' vulnerability to disasters (Masipa 2016). Briggs (2013) correspondingly states that IK cannot be trusted though valued unless its approval has been stamped by science. The aforementioned author also further mentions that when scientifically validated, IK can then be taken seriously, otherwise denigrating IK as a knowledge system on its own has contributed to its dismissal in DRR and development. It is imperative that experts in the area of study start considering IK as a possible solution to the malaria hazard. This is in consistent with the opinion by Gaillard and Mercer (2013) who submits that, DRR solutions basing only on MSK may not be successful as it does not fit within local wisdom. On the same note, key informant 3 accentuated that;

If it works they should use that because it has worked for them over the years.

KI 3

Masipa (2016) noted that the valuable capacities possessed by communities in the form of IK empower them to cope with various hazards and disasters. Regrettably, the nature of the EWS in place has conditioned Mopani community in such a way that they cannot do without the assistance of external support in malaria risk reduction. In terms of response, the participants also gave the researcher a clue that they are relaxed. Participant 2 particularly said;

> *But the fact is that in our area people have relaxed though there have been some cases of malaria and even some have died.* ***P 2***

The results of the survey revealed that a relatively high percentage thus 38% of the survey participants indicated that they do nothing upon receiving the malaria alert messages. About 62% of the participants indicated that they make adjustments upon receiving a malaria alert message. For those who make adjustments, 37.2% indicated that they use MSK while only 1.4% highlighted that they use IK. This is presented in table 6.7.

Table 6.7 Cross-tabulation of adjustments made and malaria risk measures considered

			Malaria risk reduction measures				Total
			MSK	IK	Both	None	
Adjustments made	Yes	Count	129	5	58	23	215
		% within Adjustments made	60%	2.3%	27.0%	10.7%	100.0%
		% of Total	37.2%	1.4%	16.7%	6.6%	62.0%
	No	Count	62	6	24	40	132
		% within Adjustments made	47.0%	4.5%	18.2%	30.3%	100.0%
		% of Total	17.9%	1.7%	6.9%	11.5%	38%
Total		Count	191	11	82	63	347
		% within Adjustments made	55.0%	3.2%	23.6%	18.2%	100.0%
		% of Total	55.0%	3.2%	23.6%	18.2%	100.0%

Source: Primary data

The results show that a large percentage of the survey population thus 38% does not make any adjustments upon receiving an alert. The reason could be simply because of ignorance or perhaps they are aware that the disease is treatable. They know that the local health facilities are very much ready to treat them as the hazard is treated as a communicable disease in the country. It is apparent that this influences people's behaviour since they rely on health facilities disregarding malaria as a fatal disease. The researcher understood that this has accustomed people to running to the clinic when they notice malaria symptoms hence they make no adjustments. This is supported by participant 2 who thinks that;

> *People are ignorant, the government is trying to highlight that during the evening you should close our windows and wear long-sleeved clothes to protect yourself from mosquito bites which people are not doing.* **P2**

According to Alessa *et al.*, (2016) individuals and communities are supposed to be empowered to confront hazards and to act in sufficient time. When a key informant was asked if communities' play any role in the malaria control program the response was that;

> *Malaria control is community-driven, without the community's help we cannot do much. This is why we always have a problem when we have people refusing their homes to be sprayed. If we have refusals and we spray DDT in some houses leaving other ones, isn't it that mosquitoes will affect everybody? It is good for the community to understand the reason why we want to spray.* **KI 1**

Key informant 1 also added that

> *Refusals are there and some will give you lousy reasons and it is a very serious challenge. The only plus is when people hear of a case maybe if it's a neighbour that has been infected, that is when they corporate but in the areas where they never got malaria it is difficult to spray when you go there to spray there is some resistance.* **KI 1**

This reveals that the communities have a minimum role in the malaria control program. Their task is just to follow what the MRR experts want them to do. Instead of imposing practices on communities, they should be encouraged to participate as it enhances the overall effectiveness of a system (Cools *et al.,* 2016). Individual responses are influenced by how people perceive risk which varies according to differences in socio-economic differences that include education, age, religion, ethnicity, gender and access to resources (Twigg 2015). As proposed by Owusu (2014) communities such as those in the study area are supposed to be made to recognize that they have local health challenges through participation so that they can also end up trying to develop solutions for their problems.

When the researcher asked a follow-up question, on whether they were hoping to stop spraying DDT, key informant 1 commented that;

> *In 1996, we once made a resolution to stop the use of DDT and used* pyrethroids*. Between 1999 and 2000 that is when South Africa reported 6000 cases. That was for the first time to record such cases, in 2001 we brought back DDT and it was very effective. That is why we cannot stop using both because they complement each other. So DDT is very effective, because of the long-lasting effects.* **KI 1**

According to the World Health Organization (2013), DDT is currently recommended for IRS since it is the one with the longest residual efficacy when sprayed on walls and ceilings. Unfortunately, there is pressure by the international community to ban the use of DDT because of its environmental effects as mentioned in the literature review. If DDT is to be banned in such an area that relies on it, this leaves people more vulnerable to the malaria hazard. The researcher noticed the need to come up with other interventions besides heavily relying on DDT.

In terms of response capability, it is also evident, that the existing system in the study area was more of reactionary and not proactive in nature. Key informant 1 stated that they are using thresholds to see if malaria is on the increase and said;

> *We are using the thresholds and these show us that malaria is on the increase. We don't have a malaria early warning system.* **KI *1***

This reveals that malaria detection is being taken as the major indicator of the onset of the malaria season. Correspondingly with this study as highlighted in the literature review, most EWS for bio-hazards consider detection as part of early warning of which people would have been already affected (Baudoin *et al.,* 2016; Macherera and Chimbari 2016a; Khosa *et al.,* 2013). Such a system that exists in the area of study is consistent with the opinion by Sewe (2017) that in many countries malaria early detection systems have been used for such hazards whereby alerts are triggered when a high number of malaria cases are observed. According to key informant 1;

> *When we see that the cases are on the increase the chairperson of the outbreak response team will be informed because we have thresholds for all our clinics. We have to be alert to see if the cases are now on the increase, so we have an alert line and an action line. Once the number of cases passes the alert line, we raise an alert for outbreaks once they touch the action line.* **KI 1**

Evidently, there is a provision of information when there is an onset of a malaria outbreak. The warnings are prompted only when an unusual transmission is underway exceeding the threshold, alert line and action line. The researcher is of the view that observing the rise in malaria cases cannot be referred to as a prediction measure for malaria infections since some people would have been already affected by the biological hazard. This indicates a system that is reactive and not proactive as mentioned earlier. With an effective EWS in place contrary to early detection, there is an attempt to predict epidemics before an unusual transmission is detected (Teklehaimanot *et al.*, 2004; Macherera, *et al.*, 2015).

It was noted from correlation tests that were performed on survey data, that there were relationships between various items of the instrument in line with community response. To test the natural strength and magnitude of the relationship between other items of the survey instrument, spearman's rho was used. However, some of the relevant results have been discussed in previous sections. The results also show that there is a correlation between MRR measures used and age (0.131*). This means the elderly are the ones who are mostly using IK whereas, with lower age categories, IK use is not common. This could be attributed to the fact that IK is threatened by formal education. This corresponds with Mutekwe (2015) who reveals that western forms of education (modernity) denigrates African IKS by creating a superiority complex.

Magni (2016) correspondingly states that formal education systems conceptualized under western norms serve as the means of western ideology transmission and has denied and destroyed IK for centuries. This could also mean that despite the fact that elders in the study area had knowledge, it was hardly accepted by the younger generations. Magni (2016) also mentions that elders are primary holders and transmitters of IK. This, therefore, means that the assumption of the researcher laid out in chapter 1 (section 1.5) that elderly people (50 years and above) are the custodians of IK is true. From a survey that was conducted, results show that MSK is the one that is commonly used or relied on.

The following in figure 6.4 are also results of the measures opted for by the participants in case they fail to get assistance in the form of spraying by the malaria control institutions.

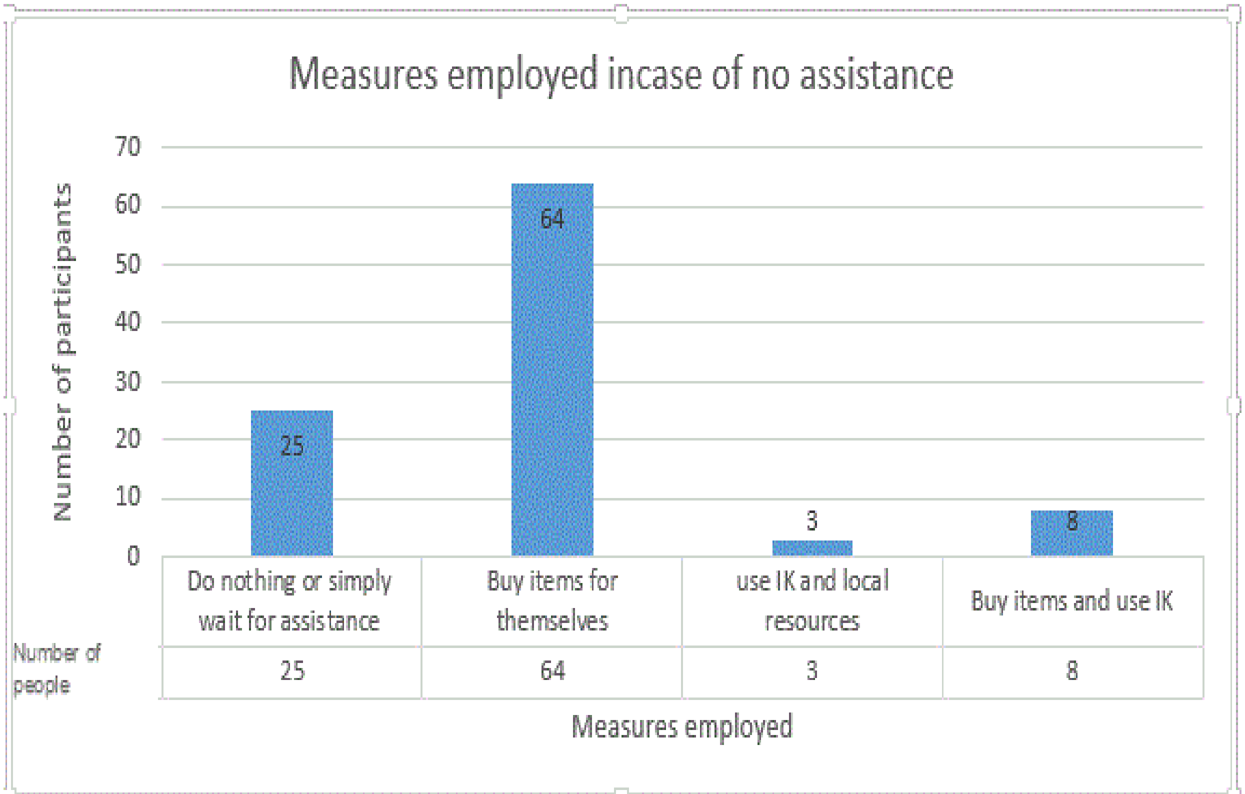


Figure 6.4 Measures employed in case of no assistance.
Source: primary

A large percentage (64%) of the participants indicated that they buy items for malaria prevention. Only 3% highlighted that they use indigenous knowledge and local resources while 25% do nothing to prevent themselves from the disease or simply wait for assistance. According to one of the participants from an in-depth interview;

"There is no excuse for not buying prevention items because even those who do not work are receiving grants". **P4**

6.3 Summary

Empirical findings in the chapter brought out the nature of the existing EWS in the study area as guided by the systems approach to disaster management and the elements of an early warning system. It was found out that even though all the elements of an early warning system were present in the system there were some loopholes in it. By nature, the existing system emphasizes monitoring as the number of malaria cases detected is considered as the major indicator of the onset of the malaria season. It was noted that disseminated information is not reaching to all the intended people and communities have a minimum role in the malaria control program. Results showed that a relatively large number of people remain relaxed as they do nothing upon receiving the malaria alert messages, there is a heavy reliance DDT spraying and the initiatives are more of reactionary and not proactive by nature. The next chapter discusses the indigenous knowledge-based malaria indicators and the malaria prevention measured being employed in the study area.

CHAPTER SEVEN

INDIGENOUS KNOWLEDGE-BASED PREDICTION INDICATORS AND MALARIA PREVENTION MEASURES EMPLOYED

7.1 Introduction

This chapter investigates the indigenous knowledge-based malaria indicators as well as malaria prevention measures being employed in the study area. The analysis in this chapter was based on grounded theory to code and categorise the indicators and prevention methods into different groups. According to several authors, local communities can predict weather conditions using IK and it is possible to utilize the knowledge for the development of a community inclusive MEWS (Macherera *et al.,* 2017; Audefroy *et al.,* 2017; Ngarivhume *et al.,*2014; Baudoin *et al.,* 2016).

7.2 Indigenous knowledge-based prediction indicators

The results of in-depth interviews that were held in the communities around the study area also confirmed that local communities were able to monitor and forecast rainfall basing on their IK based indicators. The results revealed that particularly rainfall indicators were being used as a proxy indicator for the malaria season onset. 15 out of 21 participants indicated that rainfall prediction using indigenous knowledge indicators was reliable to them and they were using that IK in monitoring the malaria hazard at an individual level. This is also in consistent with Baudoin *et al.* (2016) who reveals that IK can also be used by communities as bio-indicators for climate-related hazard predictions. The results also correspond to the outcomes by Okonya and Kroschel (2013) who realize that IK seasonal weather forecasting can assist in decision making at the village level. Other several authors also support the same notion and reveal that local communities can predict weather conditions using IK.

The first step in analysing data on IK based prediction indicators was to initially open code all the indicators that were brought up from the in-depth interviews, survey and FGD. The coding process was based on the constructivist grounded theory as indicated in chapter 5 (Methodology) and was done line by line checking for relevant wording phrases and context on the transcripts. This allowed the researcher to be immersed in the data. The initial coding process brought out initial codes and this led to the building of major categories of the indicators. The major categories that were built from the initial codes were then organised into different categories of malaria season indicators to bring out the following 6 main categories as follows;

Category 1 – Plant phenology

Category 2 – Types of birds

Category 3 – Meteorological indicators

Category 4 – Celestial bodies

Category 5 – Insects

Category 6 – Other indictors

7.2.1 Category 1 – Plant phenology

Several plants were mentioned to be rainfall indicators and according to Makwara (2013) plant phenology is used widely by communities in seasonal rainfall forecasting. In Macherera and Chimbaris` (2016) study plant phenology was also found to be the most used predictor of malaria. Among the plants that were found to be mostly used in Mopani district for predicting the onset of malaria season, there is *Kirkia acuminate (*Mvumaila, in Xi-Tsonga). When *Kirkia acuminate* starts to develop new foliage according to the participants it is an indication of the approach of the malaria season. The new foliage usually develops around October. This is supported by Basdew *et al.,* (2017) who mentions that *Kirkia acuminate* tree species indicate imminent rainfall. As an indication that it is going to be a good rainy season Participant 16 reported an observation that;

"*uMvumaila wo tshuka soo"*. **P 16**

This means that people notice new brownish foliage on the trees as a sign of imminent rainfall*.* According to some participants when the *Mangifera indica* (*mongo* in Xi-Tsonga) fruits start ripening, usually that is when most of the malaria outbreaks occur hence it is also an indicator of a high malaria hazard risk period. Normally the fruits start ripening in November. Nkomwa *et al*., (2014), supports that tree species are used in weather prediction and also mentions that unusual late flower production is an indication of an impending drought. The *Scelerocarya birrea* (Mukanyi) species, also assists the Mopani District people to predict malaria. It can be used as a biological calendar as developing new foliage is a sign of a change in season. The new foliage usually starts developing between September and October before the onset of the rain season. The fruits also start to ripen in December and during that time malaria outbreaks become prevalent. This was an observation made by the study participants. .

When the *Ficus sycomorus* tree species (Nkuwa in Xi-Tsonga) also start shading off leaves, it is also a sign of change of season. According to participant 21;

> *Nkuwa tree in most cases it is green in winter and usually, it starts falling leaves in summer when it becomes hot as a way of adaptation.* **P 21**

According to various authors, this tree can be used for weather forecasting (Basdew *et al.,* 2017, Okonya and Kroschel 2013). The dropping off of leaves from the *Nkuwa* tree which usually occurs around September /October indicates the onset of summer (Mafongoya and Ajayi 2017; Kaya and Koitsiwe 2016). The people in Mopani District also expect to receive rain when the *Colophospermum mopane* (*Nxanatsi* in Xi-Tsonga) starts growing new leaves. The *Combretum apiculatum* tree species (*Xikukutsu/Mpotsa* in Xi-Tsonga) is another indicator species mentioned by the study participants. Many flowers on the trees are an indication of seasonal high rainfall. Usually, flowering starts around September/October. The *Diospyros Mespiliformis* tree (*Ntoma-* in Xi-Tsonga) is also an indicator of the beginning of a warm season. The plant develops smooth brownish new leaves around the beginning of September as a sign of the beginning of a warm season. It was also established that other unidentified plants and flowers start to bloom in spring which is between winter and the summer period. Generally, it begins to turn green as new foliage shoot to mark the transition between the winter and summer. Participant 14 stated that:

> "*There is a clear transition between winter and summer so from winter you will find out that as summer is approaching, it is the beginning of new life. This happens as*

a sign of promise that we are getting into a season where we should receive rains." **P 14.**

This means that people in the area of study noticed tremendous changes from winter to the summer period, therefore, that can be used as a biological calendar as developing new foliage is a sign of a change in season. Using that transition between winter and summer "seasonal calendar" as an indicator for the approach of malaria season can give a greater prediction of the hazard. Armatas *et al.,* (2016) are of the idea that such a calendar is not fixed like the commonly used Gregorian (western) calendar. It is composed of flexible seasons separated by weather and climate events correlating with diverse biological indicators. In other words, seasonal calendars are dictated by phenological events that have been observed through experiences by local people for generations.

7.2.2 Category 2 – Types of birds

The study participants also indicated that some birds help them to predict the onset of the rainy season (thus malaria season). Among the birds that were mentioned are, the Partridge (*N'wharhi* - Xi-Tsonga), Woodpecker (*Gongoswani* - Xi-Tsonga), Jacobin Cuckoo/ levaillants Cuckooo (*Tihunyi* - Xi-Tsonga), Stock (*Gumba* - Xi-Tsonga) and the Swallow (Mbewulani - Xi-Tsonga). When the behaviour of these birds becomes unusual, it is a sign of imminent rainfall (Okonya and Kroschel, 2013). The unusual movement and crying of birds is an indication of the onset of rains (Macherera *et al.,* 2015; Kaya and Koitsiwe 2016). The partridge bird makes an unusually chirping sound flying up. The woodpecker starts excavating tree trunks while the Jacobin Cuckoo makes an unusual sound. Stocks fly at high latitudes when there is imminent rainfall and the swallows gather into big flocks flying high according to the participants. According to Kaya and Koitsiwe (2016), certain birds can be seen only when rains start and not any other time. Unfortunately, some of the participants who mentioned birds as indicators of the rainy season failed to name or identify them. This could be attributed to the fact that most people are no longer using their IK but constantly rely on predictions made by weather services forecasted on television and radio.

7.2.3 Category 3 – Meteorological indicators

Several meteorological indicators were identified as prediction measures for the onset of the malaria season in this study. Among the identified measures are types of clouds. Participant 5 highlighted that;

> "*During winter if you see most of the time an appearance of a reddish cloud that changes into white as the day progresses then it means there is going to be a good rainy season*". **P 5**

The observation is supported by Makwara (2013) who states that elders can interpret clouds. More-so, Makwara (2013) also states that the morning sun illuminating on clouds is also an indicator of an approaching depression. A gradual rise in temperatures from the winter period marks a seasonal change and also alerts people in the study area that they should be ready for the malaria period. This is also in agreement with Kaya and Koitsiwe (2016) who reveal that the rising of air temperatures to above normal levels during August to October nights can be an indicator of high seasonal rainfall. The appearance of dew during the winter period is also an indicator of high rainfall during the rainy season. This was revealed by participant 21. Also, when it is humid, people expect that there will be a lot of mosquitoes as the warm humid conditions are conducive for the proliferation of mosquitoes hence the spreading of the malaria disease. In relation to this, Participant 1 said;

> "*When it is humid you will know that malaria is coming because that is when mosquitoes breed, that is how I know mostly that we are getting into a season where malaria will spread. I can feel it that we are now in the malaria season".* **P 1**

This is in consistent with Kipruto *et al.* (2017) who reveals that even in areas where control is strongly altered, humidity or warmer temperatures can modify the distribution, duration and increased transmission. According to the views of most participants, malaria also becomes a problem if the first summer rain is not received "*mpfula ya ku bhorisa mahlanga*" as they call it in Xi-Tsonga. Participant 8 mentioned that;

> *"After harvesting that is when we expect* "*mpfula ya ku bhorisa mahlanga*". *The*

rain would come to cleanse the land and take all dirt away to the rivers". **P 8**

Unfortunately, participants indicated that rains were no longer received during the expected season and whenever it rained, the amount of rainfall received seemed rather too low to adequately cleanse the land and this resulted in the breeding of more mosquitoes. This opinion diverges with the idea by Participant 4 that;

"When it starts raining that is when you know everything here will go wrong because of the water. There are a lot of mosquitoes when it is raining". **P 4**

According to Omonijo *et al.* (2011) usually, there is a tremendous rise in malaria cases when rainfall reaches its peak in summer because of the increase of mosquito breeding sites. Excess rain, on the other hand, can also destroy breeding sites as high rainfall may wash away mosquito larvae (ibid). This, therefore, means that the opinions by both preceding participants are accurate.

7.2.4 Category 4 – Celestial bodies

This category consisted of a small group of indicators that includes the moon and stars. According to the research findings, a full moon with a dark circle predicts a good rainy season. This is consistent with Macherera *et al.,* (2015) who reveals that if the moon is surrounded by a ring it is an indication of a good rainy season. Stars were also mentioned as rainfall predictors and in this regard Participant 14 said;

"*I can tell if we are going to have rain by observing the star that will be near the moon. It is bigger than other stars it is called Nala (in Sepedi) and it indicates that there will be rain*". **P 14**

According to Ayal (2017), weather prediction that is based on stars' position and their alignment with the moon is considered to be the most effective method. A full moon between October and December indicates the coming of rains. Concerning this, Ayal (2017) states that forecasting can be based on the size of a star at the time of observation. If the star is observed to have a seemingly greater size than normal, then a good rainy season could be expected.

7.2.5 Category 5 – Insects

The singing of Cicadas (Swicherere) was also mentioned by the participants, according to participant 15;

> "*If you hear Swicherere (Xitserere) Cicadas making loud noises you know it will rain"*. **P 15**

Mafongoya and Ajayi (2017) also reveal that the high noise of cicadas is followed by precipitation (showers and thunderstorms) as they make sharp noise when temperatures rise above 38ºC. Its prediction signifies imminent rainfall among traditional African people (Okonya and Kroschel 2013; Mafongoya and Ajayi 2017). Alves and Albuquerque (2018) also reveals that cicadas predict precipitation in 2-3 weeks when they start singing. The following is photograph 7.1 showing Cicadas;

Photograph 7.1 Brevisana brevis (cicadas)
Source: Google pictures

Termites (Jenjhe- Xi-Tsonga) are also a good indicator of imminent rainfall among the Mopani communities. When they start collecting food and building anthills it is a sign that there is going to be a good rainy season. This is also supported by (Macherera *et al.,* 2015; Makwara 2013; Nkomwa *et al*. 2014) who mentions that the appearance of many termites indicate the onset of rainfall especially when they start carrying grass and moving rapidly. The participants also highlighted that the appearance of termites increasing their anthills' sizes also signifies the approach of a good rainy season. This is also consistent with Kaya and Koitsiwe (2016), anthills usually mushroom around August to September. On the contrary, if the termites do not gather or show any activity then an impending drought could be expected (Ayal 2017). Samardžija *et al.,* (2018) also state that when ants start carrying their eggs and larvae to safe places, this could be an indicator of a good rainy season. More so, the movement of ants in a straight line predicts a normal rainy season and if there are dispersed in search of food, then this could be a sign of drought (Ayal 2017). The Increase in annoying biting mosquitoes is also a sign of the approaching malaria period. This was observed to be the case in Mopani communities.

7.2.6 Category 6 – Unclassified indictors

Bats (*Dewulana*- Xi-Tsonga) that move in large numbers towards the rainy season were also reported by participants as an indicator of imminent rainfall. According to Samardžija *et al.,* (2018), if bats are seen flying low, it is a sign of forthcoming rainfall. The participants also reported that when frogs (Chela – Xi-Tsonga) also start croaking it is believed to be an appreciation of the promising rains. Macherera *et al.,* (2015) notes that the croaking of big frogs between September and October is a sign of good rains and a high incidence of malaria. Makwara (2013) and Samardžija *et al.,* (2018) also reveals that the sight and vocalizing of frogs is a sign of an imminent wet spell. Participant 10, said over the years she has observed that;

> "*When those people who practice circumcision go for initiation it rains. We heard that they perform rituals so that it rains. During the initiation ceremony, they make rain according to their knowledge and tradition. It is not raining from God but their rain so their ceremony ends with rain."* **P 10**

Another participant also indicated that the birth of many baby boys is a sign of a good rainy season suitable for profitable farming. Besides IK based indicators, participants also revealed that there are other signs that show them the approach of the malaria season and these are seeing mad people become worse, more reports of headaches, and increase in morbidity and mortality during the period. Also, when the malaria control institutions start the spraying activities, this alerts them that it is time for malaria.

Regardless of all the rainfall indicators that came from the in-depth interviews, the results of the survey reveal that there is over-reliance on MSK based prediction measures. Makwara's (2013) believes that this is one of the biggest challenges threatening the sustainability of IK. Survey results show that 75% of the participants prefer using MSK for hazard monitoring while 19% prefer using both IK and MSK. Only a few participants, thus 6%, prefer using only IK for hazard prediction. The following figure 7.1 of a pie chart shows the preferred methods of malaria prediction.

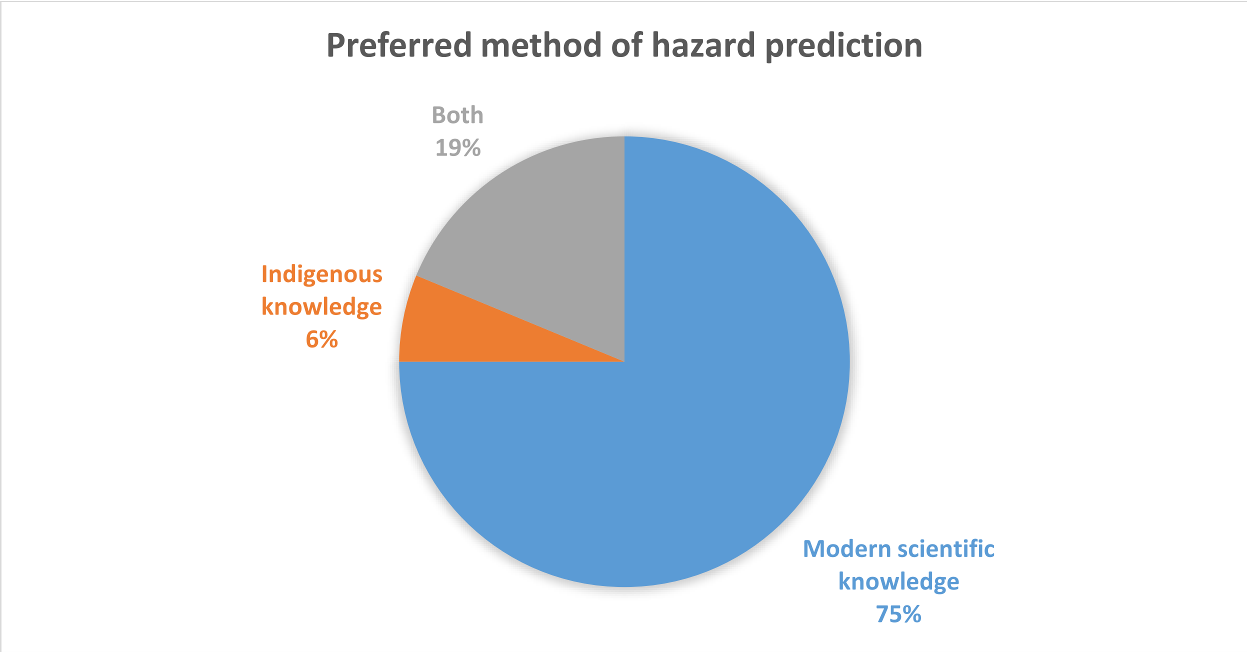


Figure 7.1 the preferred method for prediction

From the pie chart, it can be deduced that IK is the least used in hazard monitoring. This could be attributed to the fact that some DRR experts still doubt the relevance and effectiveness of IK (Dube *et al*., 2018).

7.3 Malaria prevention measures

The initial coding process based on grounded theory for malaria prevention measures brought out initial codes. These were then categorised into different groups depending on the material being used. The categories were developed basing on the prevention measures that are mostly used by the communities in the area of study. The codes of the malaria prevention measures were then organised as follows;

Category 1 – Indigenous knowledge-based

- Subcategory 1- Animal waste
- Sub-category 2- Plant material

Category 2 –Scientific knowledge-based

- Aerosols
- Repellents

Category 3 – unclassified prevention measures

7.3.1 Category 1 – Indigenous knowledge-based

Most participants mentioned that burning of various items was one of the major traditional methods that offer a protective benefit. The findings of the study depict that vector control is the main prevention measure and the named materials in the following categories are mostly used;

Subcategory 1- Animal matter

Burning animal waste to prevent mosquito bites is also a common practice in the area of study. 9 out of 21 of the participants that took part in the in-depth interview indicated that they had use cow dung (*malonga ya ti homu* in Xi-Tsonga). The dried dung is burnt on lit charcoal in a room the whole night, and the smoke repels mosquitoes. Those with traditional homes indicated that they throw the cow dung in the fire when they are having their family time around the fire. Some also indicated that everyone should leave the room when burning the cow dung and this is to be done with doors and windows closed. A study by Amadi *et al*., (2018) also reveals that the burning of cow dung has been reported to be a traditional mechanism for repelling mosquitoes and other biting insects.

Sub-category 2- Plant matter

Participants also reported that the burning of plant leaves is effective. Several plants were identified to have repelling effects on mosquitoes by the participants. Among them is the *Epaltes gariepina* plant (Munywani in Xi-Tsonga)**.** The plant is mostly found around the edges of pans and vleis. It can also be found in riverbanks or grasslands as well as cultivated lands. Most of the Tsonga people indicated that they put fresh Munyani in their homes to deter mosquitoes as it has a very strong smell. This is consistent with Liengme and Park (1981) who reveals that the plant has a very strong smell. The *Epaltes gariepina* (Munywane) can also be burnt when dry for the same purpose. It can also be used to make rough traditional brooms. The following are photographs 7.2 showing *Epaltes gariepina.*

Photograph 7.2 *Epaltes gariepina (*Munywani in Xi-Tsonga)
Source of pictures: Author

The other plant that is commonly used by people to deter mosquitoes in the area of study is the *Lippia javanica (Musuzwane in Xitsonga)* The plant is mostly found in Southern Africa's malaria areas during wet summer seasons (Wells and Leonard 2006). According to Lunga (2015), the use of indigenous mosquito repellents like *Lippia javanica* are also common in Zimbabwe. The people in Mopani district usually burn it, wet or dry to deter mosquitoes. According to participant 6, this also repels snakes. Mavundza *et al.,* (2011) also support the notion that *Lippia javanica* has repellent effects. Wells and Leonard

(2006) also reveal that natural repellant is more effective than some commercially available mosquito repellants. The following picture 7.3 shows *Lippia javanica.*

Photograph 7.3 *Lippia javanica*

Source: Author .

Dodonea viscosa (Mudodivisa - Xi-Tsonga) is another plant mostly used to deter mosquitoes by Mopani district communities, especially in Phalaborwa area. This is grown as a hedge or live fence in most Mopani district villages. It can also be grown as an ornamental plant for its shiny foliage. The following is a picture of the *Dodonea viscosa plant*.

Photograph 7.4 *Dodonea viscosa* (Mudodivisa in Xi-Tsonga)
Source: Author

The sisal plant (Dhinda in Xi-Tsonga) is also used to deter mosquitoes in the area of study. The leaves are processed to remain with the fibres. These fibres are then mixed with grass and chillies (capsicum species) before being burnt in a closed room. The smoke produced is believed to have a capacity of killing mosquitoes. The following pictures 6.7 and 6.8 also show the unprocessed sisal plant and a sisal sack.

Photograph 7.5

Photograph 7.6

Photographs 7.5 and 7.6 Sisal plant (*Agave sisalana perrine)* and a sisal sack
Source: Google pictures

Other participants indicated that they use sisal sacks if the sisal plant is not available. This produces the same intended results. According to Amadi *et al.* (2018), local plant leaves can be used as traditional mechanisms for repelling mosquitoes and other biting insects. Participant 6 added that the sisal smoke also prevents flue and stops nose bleeding as well. Participant number 1 also indicated that he takes chillies orally during the malaria season to prevent him from catching the disease. This might be possible because *capsicum* species have been reported to have remarkable antimicrobial activity (Gurnani *et al.*, 2016). However, there is a need for further studies on the effect of ingested *capsicum* spp. on plasmodium. Most participants (18 out of 21) indicated that IK based methods were effective.

The researcher expected to get more form the traditional healers on the plants that can be used to prevent malaria. The traditional healers were not willing to divulge much. The reason could be that they generate income from the medicinal plants hence if they divulge some of the information then that may affect their income. This is supported by Namukobe *et al*. (2011) who states that herbalists and traditional healers generate income from medicinal plants. The results show that indeed people of Mopani have prediction indicators as well as preventative measures against the climate-related hazard. However most some people indicated that they had forgotten most of the IK since they are no longer applying it.

7.3.1.1 Factors driving decreasing use of the IK methods

Despite the above mentioned indigenous knowledge based prevention measures it was noted that there is decrease in the use of IK in this study. Most people preferred using scientific knowledge prevention measures. Results of the study show that the least number of people (3.2%) indicated that they use IK while a higher percentage of 55% indicated that they use modern scientific knowledge (see Appendix 13). It can be deduced that for malaria prevention MSK is mainly promoted in the study area by the malaria management and control stakeholders. The reason could be that IK is being threatened by formal education. This reason corresponds what is revealed by Mutekwe (2015) that western forms of education (modernity) denigrates African IKS by creating a superiority complex. One of the participants also specified that;

We are no longer burning dung because the smoke irritates and my daughter has asthma. **P 6**.

It can be deduced that people might be preferring SK as it has been proven and to be cleaner and effective. Another participant also added on that;

I don't believe in IK, there is no direction on how to use the herbs and I wouldn't want to overdose myself. **P20**

Apart from that reason misidentification of the herbs could have adverse effects. These are some of the reasons that were mentioned by the participants for not using the indigenous knowledge prevention measures.

7.3.2 Category 2- Scientific-based prevention measures being employed.

Participants reported that they are using several scientific-based prevention measures. The scientific-based products that were mentioned are aerosols, coils, nets, repellants, antimalarial injections and pills. The challenges that were brought up by the communities on using scientific knowledge products were that mosquitoes had gained resistance to some of the products they were using and the more effective ones are very expensive. Some fail to use the products properly as narrated by one of the participants who said:

> "*I just remembered that when I had a small baby I bought a repellent and I applied on the baby all over his body but I did not apply on to the head. In the morning when we woke up I found out that his head was full of bumps because of mosquito bites. I didn't know that I was supposed to also apply to his head and hair*". **P 10**

Participant 2 also felt that the products are expensive and mentioned that:

> "*If you feel your financial muscles are strong enough then you can go and buy something to protect yourself with. People do not think of buying that, the little they have they think of buying food".* **P 2**

7.3.3 Category 3- unclassified prevention measures

As a way to prevent malaria other participants indicated that they make sure that they practise good hygiene around their homes by cutting tall grass and avoiding wet areas as well as wearing long-sleeved clothes. It was also interesting to note that some of the participants use fans as well as burn toilet paper and egg crates to keep away mosquitoes.

7.4 Summary

Empirical findings in the chapter brought out the malaria prevention measures and prediction indicators. People in Mopani District have indicators for the malaria season onset based on rainfall. Several rainfall based indicators used to predict the malaria season onset mentioned by the study participants were then used to develop a functional EWS in this study. The results of the study also show that several plants are used to repel mosquitoes for malaria prevention with the burning of various items as one of the major traditional methods for vector control. The next chapter demonstrates how the EWS was practically developed.

CHAPTER EIGHT

INTEGRATED MALARIA EARLY WARNING SYSTEM DEVELOPMENT

8.1 Introduction

The development of a practical early warning in this study is initiated from a strong theoretical basis. Concepts, models, and frameworks, as well as the data, analyzed informed the development of the integrated malaria early warning system. According to Alfieri (2012) developing an early warning system for natural hazards is an important holistic approach to disaster risk management. Several authors revealed the possibility of integrating indigenous and scientific knowledge in an EWS for DRR (Macherera *et al.,* 2017; Audefroy *et al.,* 2017; Ngarivhume *et al*. 2014; Baudoin *et al.,* 2016).

8.2 Developing an early warning system model

The researcher used information communication technology (ICT) as a platform for the development of an integrated EWS. This was consistent with Lodhi and Mikulecky, (2011), who reveals that ICT enhances the blending of indigenous, scientific, and technical knowledge. Karanath *et al.,* (2014) also supports Lodhi and Mikulecky, (2011) and reveals that ICT can be used as the basic foundation of networking arrangements that assist immensely in meeting the desired objectives of an EWS. The following is a figure 8.1 of the conceptual model that was developed in this study.

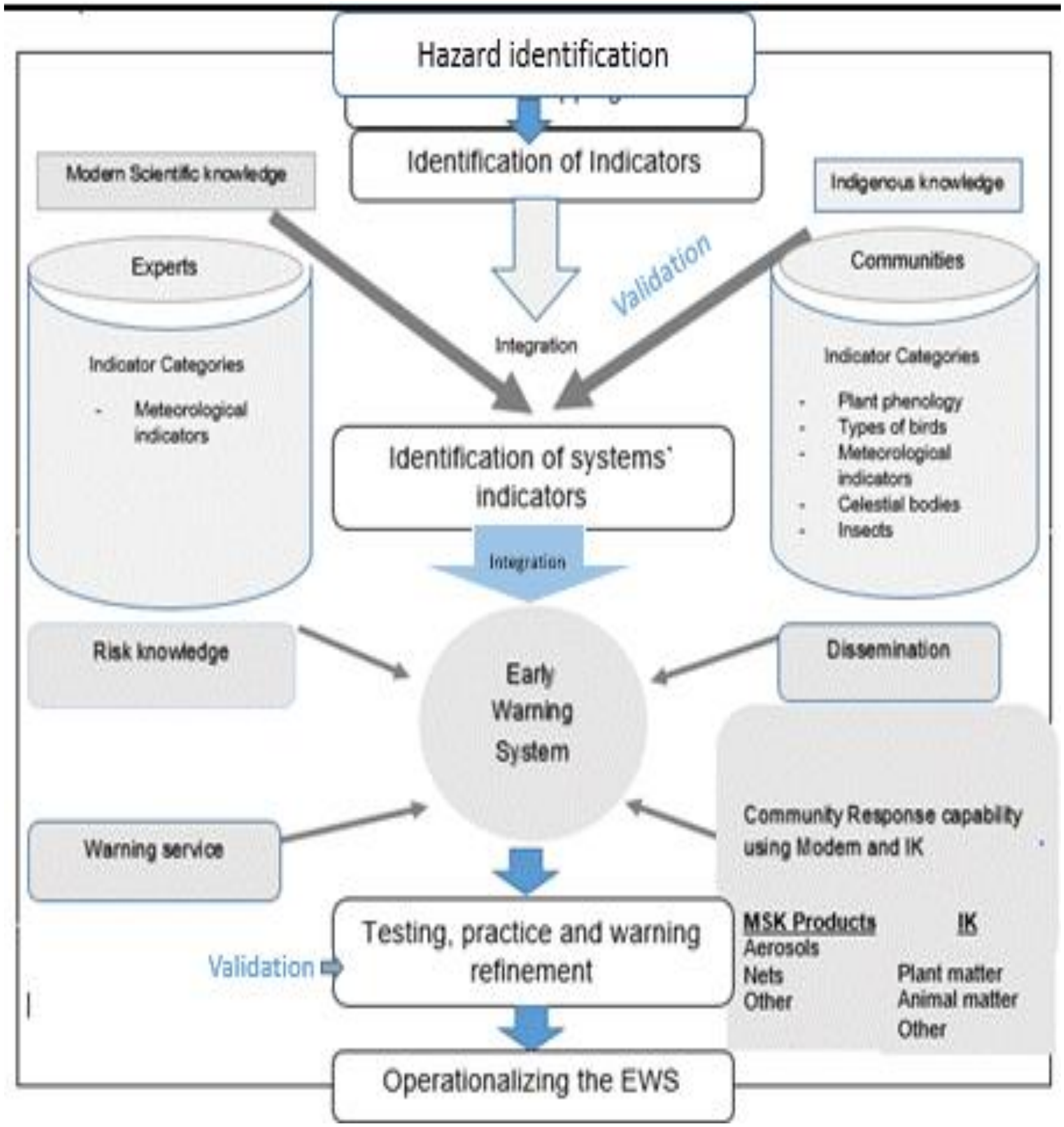


Figure 8.1 Proposed theory for the development of a practical malaria early warning system
Source: Authors' work

The model considers the elements of an effective early warning system, the heuristic for the integration of scientific and indigenous knowledge as well as the rainfall indicators and prevention measures grounded in the data that was collected in the area of study.

Table 8.1 Summary of the anticipated challenges and solutions

Challenges	Solutions
1. The custodians of IK are the old aged and most of them are illiterate taking into consideration that Mopani District's illiteracy rate is high. They might not understand the MEWS as it might be sophisticated for them.	It has to be as simple as possible but being able to carry out its functions effectively. Vernacular language to be used in the EWS
2. Most of the aged thus the custodians of the IK might be having basic phones	The system should accommodate the majority group for it to be useful, e.g. If most of the people have basic phones then there is no need to develop a cellphone application that caters for those with feature or smartphones.
3. The community representatives are supposed to send messages of IK indicators to feed the database from their cellphones. These have to know the keys of the indicators so that they can be recognized in the database. Failure to send the correct keys could distort the effectiveness and stimulate false determinism of the system resulting in a false alert	Few important keys should be put in the database.

4. Most community representatives might not be willing to be involved in the activity of sending alerts to the database if there are some costs involved.	The system should be made in a way that the people send messages to the database cost-free.
5. According to Sewe (2017), the incidence of a false alarm, an improvement in the performance of EWS, and decision-making has to include expected consequences of taking action in case there is a false or missed alarm.	This could be done by spreading the number of those that are to feed the database covering a wider area.

8.3 The development of an early warning system

This section outlines the hardware, software, and frameworks that were required for the development of the MEWS. The requirements are based on utilization and observed performance of the system. The development is also guided by the systems approach to disaster management and elements of an integrated EWS. Every chapter of the study contributed to the development of the EWS. Each preceding chapter marks each stage of the EWS development.

8.4 Requirements of the early warning system

This section outlines the hardware, software, and the frameworks that were required to bring out the MEWS. The requirements are based on utilisation and observed performance of the system as guided by recommendations of the study.

Table 8.2 software and hardware for the cell phone and desktop applications

Cell phone App		**Desktop App**	
Hardware	**Software**	**Hardware**	**Software**
Mobile device	Android operating system	PC device	Windows
	Node JS	Server	XAMPP (Apache and MySQL)
	JDK 1.8	Backup device	PHP scripting language
	Android development tool (SDK)	Hard drive (10 GB space)	
	Apache Cordova		

The frameworks that were used for both the cellphone application and the desktop application are HTML and Bootstrap.

8.5 Application Designs

The cell phone and desktop applications were initially developed first to allow community members and the administrators to feed in the scientific and indigenous knowledge-based data required in the establishment of the EWS. The researcher considered the types of cell phones used by most of the people who participated in the survey. Empirical evidence exists that most participants (59%) used smartphones, the steps for the development of the two applications are explained below.

8.5.1 Smartphone mobile application development

A cell phone application was required for allowing communication between the server and the custodians of IK. The custodians of IK in the EWS were presented as reporters. The smartphone mobile application was made specifically for android phones since it was cheaper to get the software for that operating system. The cell phone application was developed by firstly downloading and installing NodeJS software on a laptop. This supports the installation of Apache Cordova used for the development of the database. To start the installation the researcher went to the site https://nodejs.org/en/download/ and downloaded the necessary binary files. The researcher then double-clicked on the downloaded .msi file as part of the installation process. The “Run button” button on the first screen was clicked to begin the installation. On the following screen, the "Next" button was then clicked to continue with the installation. The step is shown in figure 8.2.

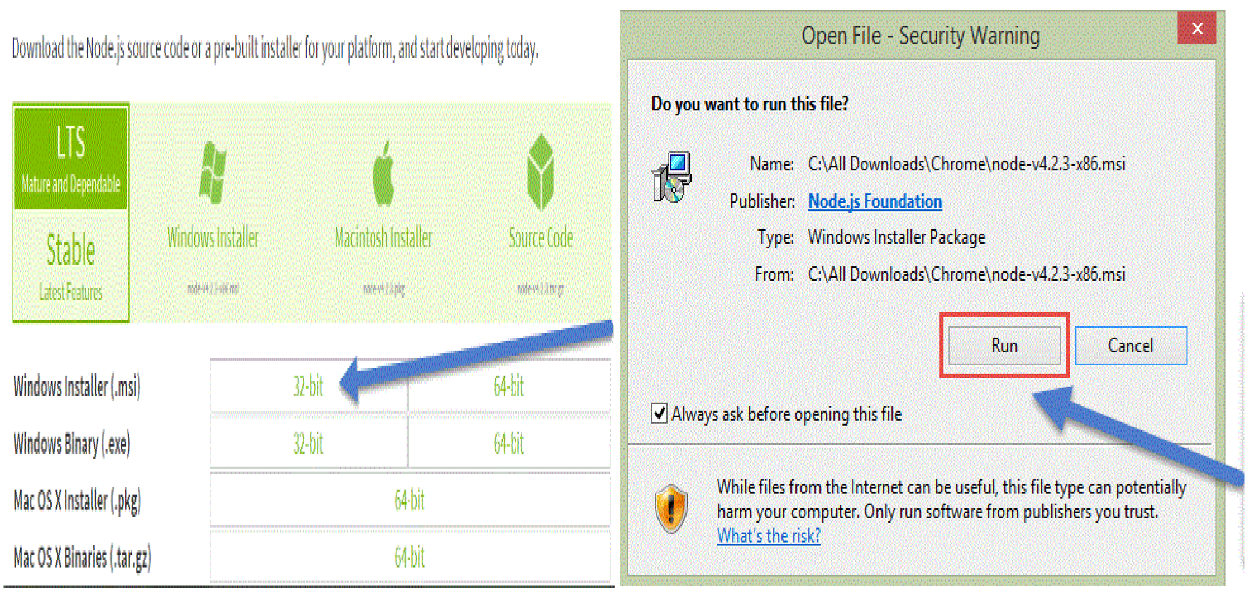


Figure 8.2 Demonstration of the application design for software installation
Source: NodeJS installation screenshots

License agreements were accepted in the process. The file location for the installation of

Node.js was then entered and this is where Node.js files were stored after the installation process. Default components were also accepted by clicking the “Next button” and after that one clicks again the install button to start the installation. After successfully installing node.js, it was then used for downloading all the components required for the development of the mobile application for the EWS. Since the mobile application is based on the Cordova platform, all libraries that are needed were installed using node.js. However, the command line was used to install all the modules. Before the development was completed, the libraries were installed using node.js and the researcher proceeded to the windows command prompt. Commands were then typed one after the other.

After all the packages had been installed the researcher made sure that the directory in which the application was to be created in was open. Platforms for this project including browser and android were then added using the command Apache Cordova add platform browser. After all the steps were completed, the application was made according to the desired specifications. To start the development of the EWS a text editor was required to edit and write the code. In this study, the sublime text was used as the text editor. The advantage of using this text is that it is light for the computers. Sublime text is found on the website for sublime text and installed like the aforementioned soft wares. After the sublime text is opened, the researcher clicked the file, opened the folder and navigated to the location of the project.

8.5.2 Algorithms used to develop the EWS

Cellphone application algorithms used

Pseudocode:

- Welcome page

Start

If start button clicked then

Open authenticate page.

End

- Login Page

Start

If user gives correct credentials then

Open main menu page

Else If

User is already authenticated then

Do not ask for credentials GOTO

Main menu page

End

- Alerts Page

Start

If alert is triggered from server then

Issue an alert

Else

Show no alert yet issued

End

- Indigenous Knowledge Options (Main menu)

Start

If option selected then

Open to feed information to server

Else

Do nothing

End

- Feed Indigenous knowledge to server

Start

Check for connection

If connection is valid then

Feed to server

Return

Success message

Else if

Connection error then user click configuration

Else

Do nothing

End

- Contact

Start

Check for connection

If connection is valid then

Post suggestions to server

Else

Do nothing

End

- Configuration

Start

Type new server address then

Save address to be used by the APIs

OR

Do not make any changes to use default

OR

To use previously saved address

End

- Information

Start

Check for authentication

If authenticated then

Display information

If edit is clicked then

Open server web page to edit

Else

GOTO

Authentication page

End

- Temperature and Rainfall data

Start

Check for valid network connection

Get data from API

If data is not null then display all readings

Display success message

Else

Display success message

End

Desktop application algorithms used to develop

- Login

Begin

Check for valid credentials

If credentials correct then Login

If credentials is admin then open admin portal

Else open reporter's self-service portal

Else ask for correct credentials

End

- Main menu

Begin

Check credentials type

If admin show all submenus for the system

Else

Show reporter's portal submenus

End

Profile

Begin

If credentials is equal to admin then show all utilities

Else show nothing

End

Adding Information

Begin

If credentials is equal to admin then allow adding

If validation is passed then

Save to database

Else show error messages

Else do nothing

End

8.5.3 Community responders' portal

The developed cellphone application was to be configured on communities' phones. The administrators are ones that choose the responders at their discretion. The chosen responders can open their portal by entering a username and password that is put for security reasons after the installation of the cellphone application. The home page for the community responders is shown in figure 8.3 figure.

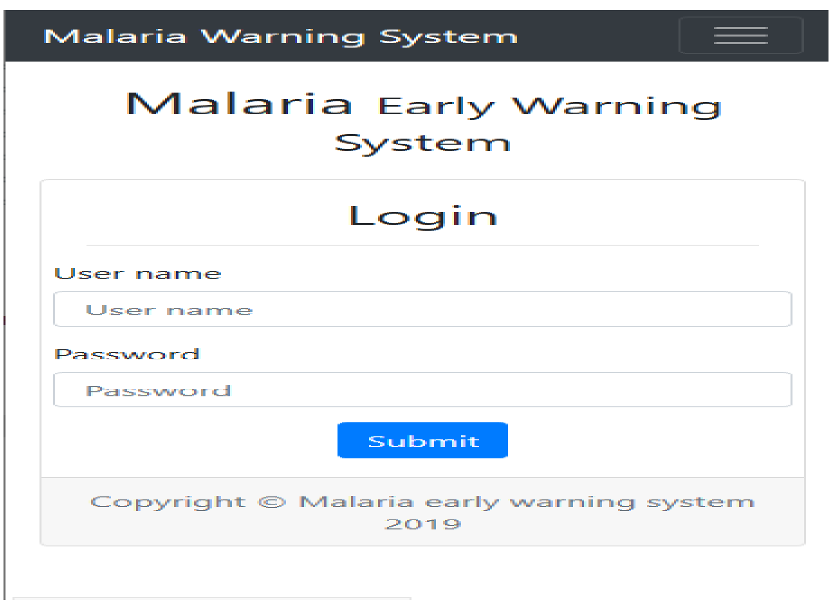


Figure 8.3 Community responders' mobile application login portal
Source: Mobile screenshot

When the responder enters details on the login page the main portal appears and that is where the IK based indicators can be fed into the system. The responders' portal is made in such a way that it is user friendly so that the community members are able to understand the interface to enter indicators. The information to be fed in by the participants depended on observed IK based indicators in their areas. There is also a section on the home page of the community responders which allows them to make suggestions and recommend additional indicators or features that they want to add on to the system. The portal login page for the responders is shown in figure 8.4.

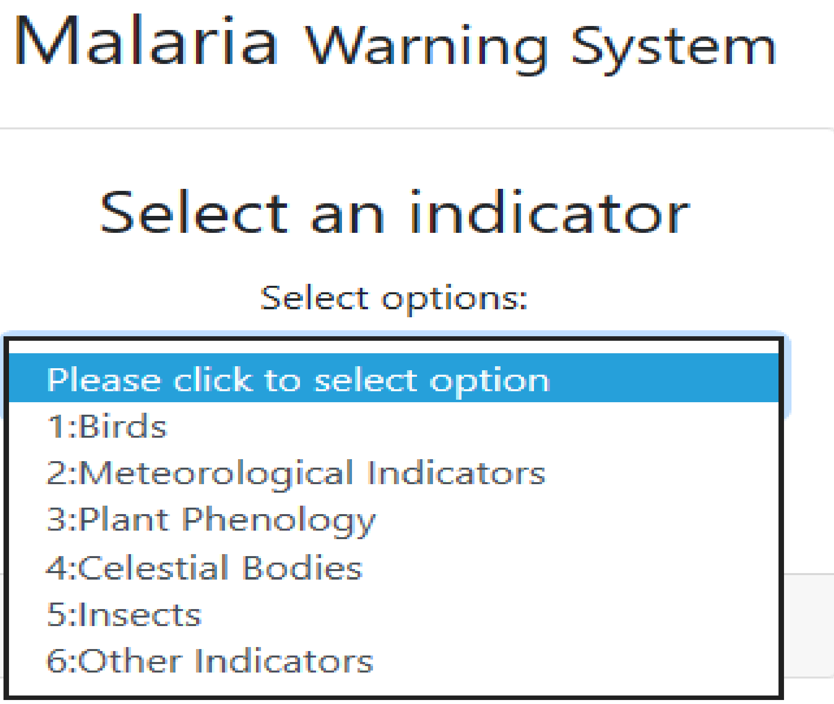


Figure 8.4 Community responders' mobile application indicator selection
Source; Mobile screenshot

The responder is supposed to click the indictors that they have observed that are on the indicator selection panel. Clicking one of the main categories of the indicators brings out a list of the specific indicators under the category, for example. If they have observed a bird that is an indicator species then the list of all the birds in the system appears as follows.

Figure 8.5 Indicator list for types of birds
Source: Mobile screenshot

8.5.4 Development of the desktop application

Database creation started by installing XAMPP on the computer. After installation, the XAMPP control panel appeared on the screen. It is on the XAMPP control panel where the webserver and the database server is started. The XAMPP control panel is shown in figure 8.6.

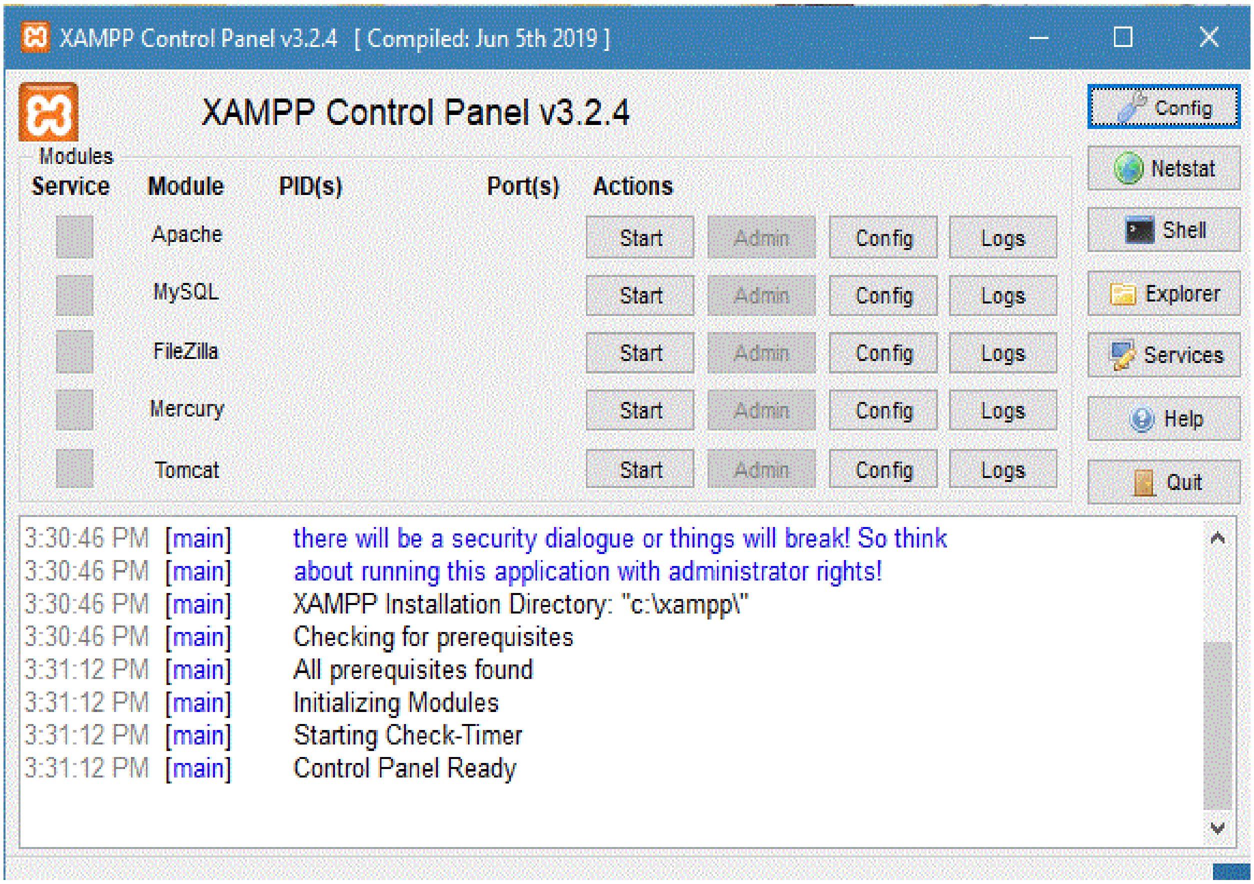
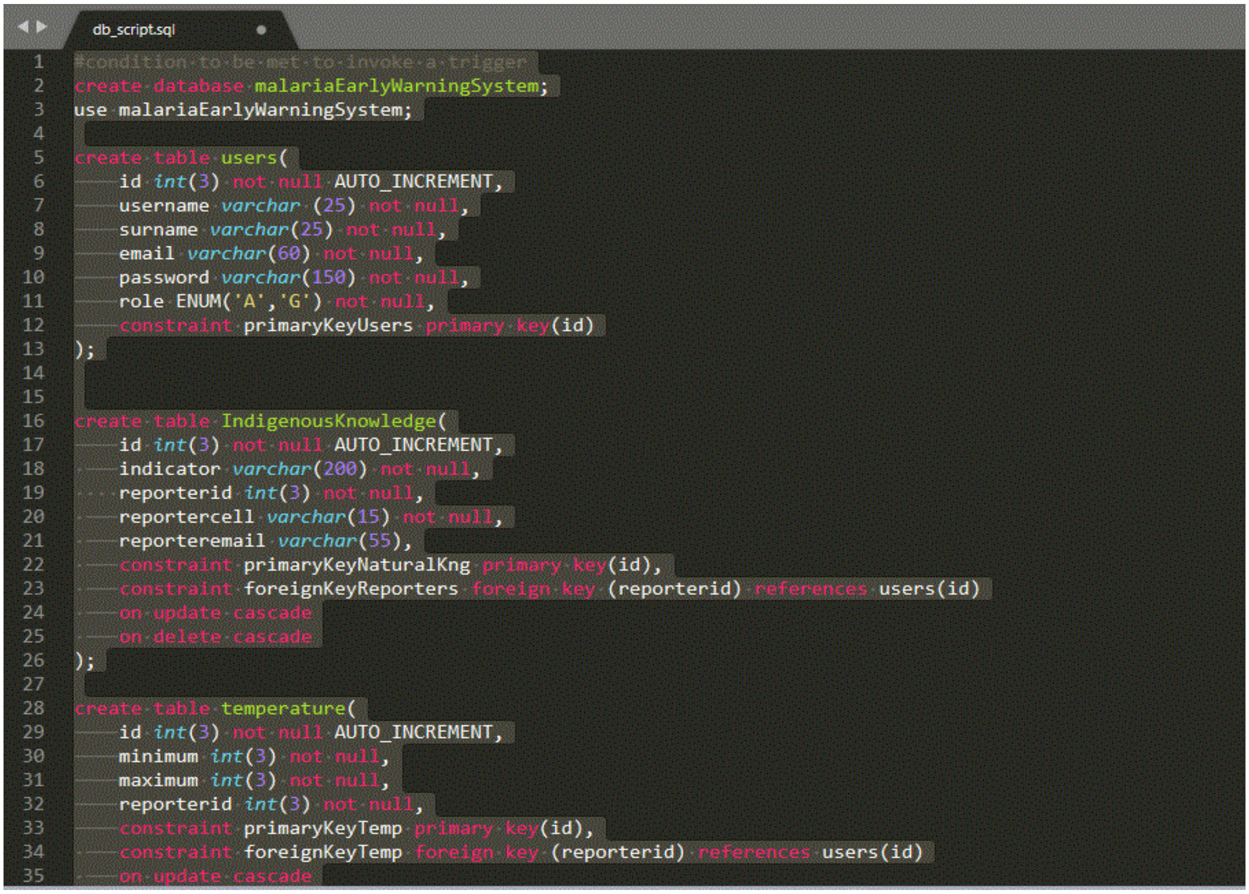


Figure 8.6 Demonstration of XAMPP control panel
Source: XAMPP installation screenshots

To manage databases and run database scripts one should click the start button in the same line with MySQL. A script of the XAMPP was then created in notepad. The created script was copied and pasted on to the admin of the control panel to finish off creating the database. After the code was copied without encountering errors the database is created with the respective fields for each table. The fields were created as desired by the researcher. The following is figure 8.7 of the database script.



db_script.sql

```sql
#condition to be met to invoke a trigger
create database malariaEarlyWarningSystem;
use malariaEarlyWarningSystem;

create table users(
    id int(3) not null AUTO_INCREMENT,
    username varchar (25) not null,
    surname varchar(25) not null,
    email varchar(60) not null,
    password varchar(150) not null,
    role ENUM('A','G') not null,
    constraint primaryKeyUsers primary key(id)
);


create table IndigenousKnowledge(
    id int(3) not null AUTO_INCREMENT,
    indicator varchar(200) not null,
    reporterid int(3) not null,
    reportercell varchar(15) not null,
    reporteremail varchar(55),
    constraint primaryKeyNaturalKng primary key(id),
    constraint foreignKeyReporters foreign key (reporterid) references users(id)
    on update cascade
    on delete cascade
);

create table temperature(
    id int(3) not null AUTO_INCREMENT,
    minimum int(3) not null,
    maximum int(3) not null,
    reporterid int(3) not null,
    constraint primaryKeyTemp primary key(id),
    constraint foreignKeyTemp foreign key (reporterid) references users(id)
    on update cascade
```

Figure 8.7 Demonstration of XAMPP control panel
Source: XAMPP database script

Once the database was created, the administrators who were in charge of controlling the database managed to secure it with a password. The login page is shown in figure 8.8.

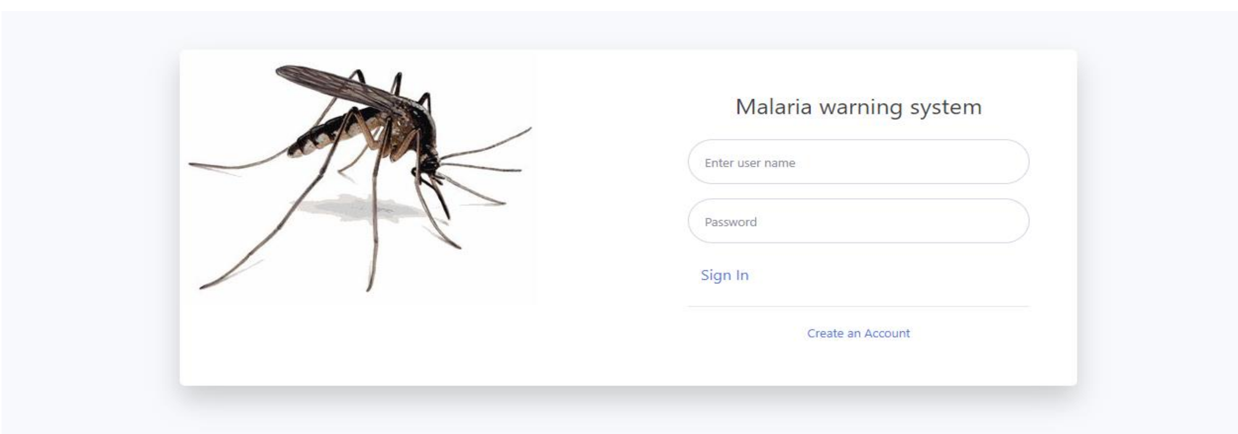


Figure 8.8 Administrators' login portal
Source: EWS screenshot

The administrators' portal it requires authentication to access the malaria warning system. When the administrator logs in, the home page is accessed. After performing tasks the admin can logout from the portal for security reasons. The administrators' main page is as shown in figure 8.9.

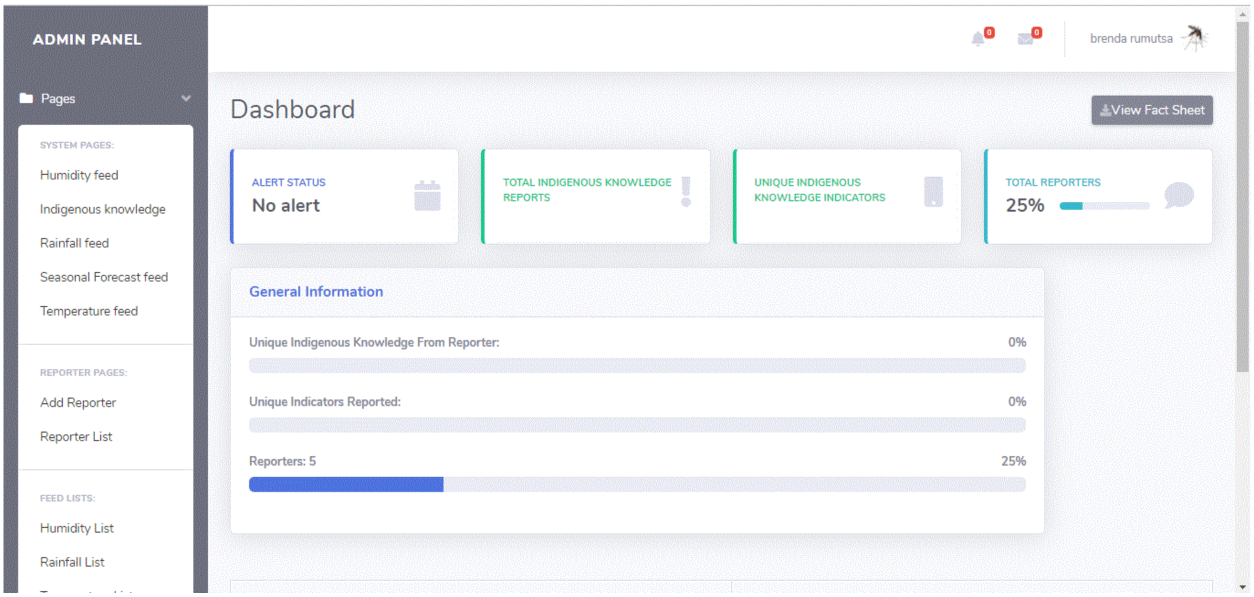


Figure 8.9 Administrators' main portal
Source: EWS Screenshot

The administrators' portal allows a person to view a fact sheet or helper file for IK. Administrators are required to feed in the scientific data, such as rainfall, temperature, and seasonal forecasts into the database. The administrators are the only ones who can able to view information posted by community members (reporters). They also have a task to add or remove users in the system or reset their password. The following figure 8.10 shows the reporter information that the administrators have access to.

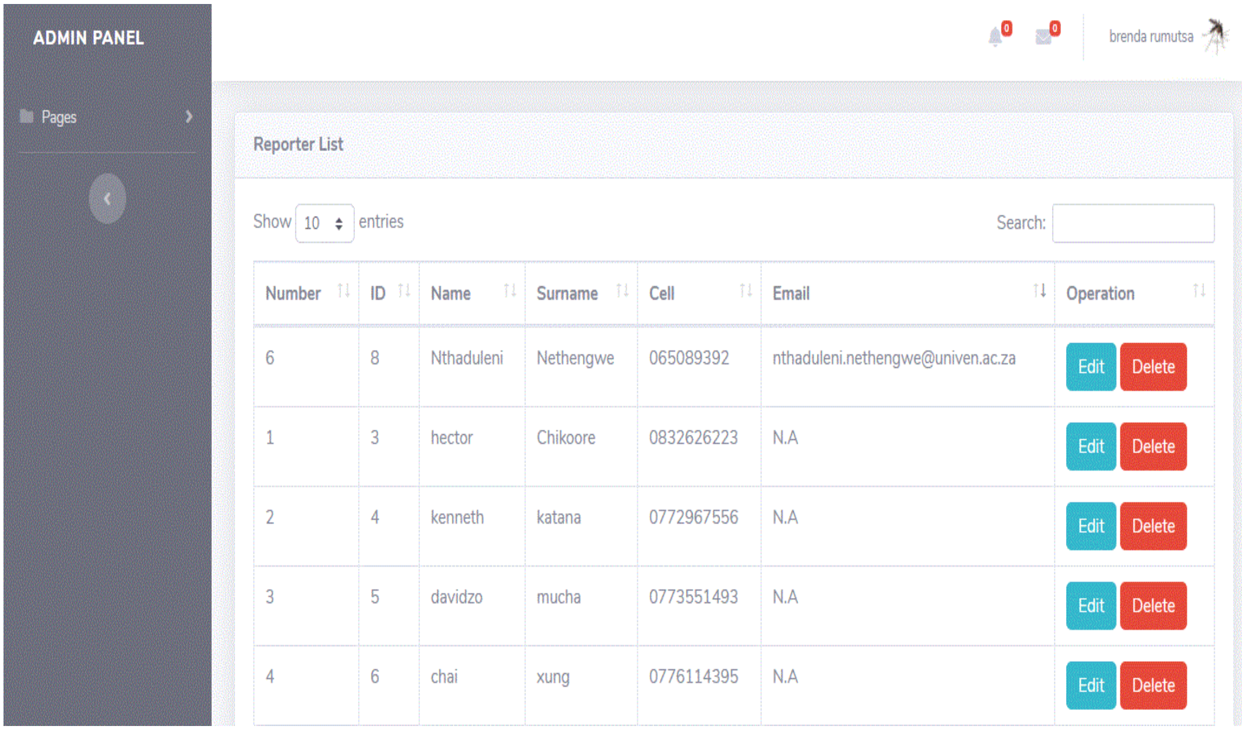


Figure 8.10 Administrators' reporter information
Source: Database screenshot.

8.6 Rationale for use of rainfall as the main variable

The researcher gathered information regarding the phenomena under study in its real situation hence information grounded in data collected from the people's life experiences was considered in trying to come up with a solution for further mitigating malaria in the area. Several participants mentioned that the moment that they receive rainfall in the area that is when the problem of malaria begins hence this was taken as the main variable.

Specifically one of the participants stated that:

> *When it rains that's when we will have a problem with mosquitoes and that's when malaria becomes a problem.* **P10**

However, even though rainfall was taken as the main variable the researcher decided to leave out the rainfall ranges in determining the threshold of the EWS. The researcher intended to develop a tool that enhances proactiveness since the moment it rains that demarcates the end of the embryonic stage of the hazard into a growth stage. Failure to handle the emergency at this stage can result in morbidity and mortality (refer to section 3.5.3 in chapter 3) hence it is important to prioritise measures on the pre-disaster phase thus prevention, mitigation and preparedness. Prevention can be enhanced through prediction, early warning and planning of relevant stakeholder coordination. Instead of rainfall being used in the EWS for monitoring the hazard, the developed EWS forecasts it instead.

8.7 Systems threshold determinants

An EWS is important as it helps in the detection, forecasting, and issuing of alerts in the event of hazard risk (Siddhartha, 2017). Precursors for monitoring and predicting an event can be automated with the aid of human decisions (ibid) hence the researcher decided on the thresholds of the EWS. The thresholds help in determining the raising of an alert. Some logic combinations were established using both forms of knowledge (IK and SK). These were decided after reviewing the literature and consulting expert. The optimum temperature range for the malaria vector was considered to be between 16-36ºC as determined by (Alemu *et al.*, 2011). The systems threshold determinants are summarised in the following table 8.3.

Table 8.3 Systems threshold determinants

Group	Portal	Variables	Thresholds	
Community members	Reporter	IK indicators	- 40% of reporters - 40% of total IK indicators	
Experts	Admin	Temperature	Minimum	> 15
			Maximum	< 36
		Rainfall	To be predicted	

Feeding of more than 40% indigenous knowledge-based indicators by 40% reporters as well as the conducive temperature range (minimum of 15 and maximum of 36) into the system triggers an alert.

8.8 The value of IK in the developed EWS

The blending of IK with scientific knowledge and advanced technology could improve DRR and encourage community participation (International Organisation for Migration, 2015). Contemporary MEWS are depending on prediction information from sophisticated models which is not understood by the general people in the communities. These are based on either alert centered on the set thresholds or detection of actual disease occurrence (Sewe 2017). Most of the malaria EWS models use exclusively scientific-based knowledge to predict malaria leaving out indigenous knowledge prediction measures. This has led to the dominance of top-down command and control strategies in malaria risk reduction (MRR) as communities' contributions are dismissed (Gaillard and Mercer, 2013; Lunga, 2015). There is therefore a need to bridge the gap to allow communities to participate in malaria risk reduction (MRR). Bringing in the communities IK and practices as advocated by the developed EWS in this study will make it easy to involve them and include some important components of DRR by adopting a multi-dimensional approach to malaria control and management. Making communities' passive recipients in handling the health hazard could be leading to a failure in preventing malaria outbreaks hence this makes IK a vital element of the EWS that was developed in this study.

8.9 Validation of the indigenous knowledge-based indicators for the EWS

The development of the EWS followed the process of the adapted heuristic for the integration of modern scientific and IK for appropriate technology development and implementation by Aluma (2004) (refer to figure 3.1 in chapter 3) as well as the elements of an effective early warning system by ISDR (2006). The process stipulates that there is a need for validating the indigenous knowledge before it can be integrated with scientific knowledge so that it is used in improving or developing appropriate technologies. This is also consistent with (Briggs 2013) who mentions that when it has been validated, that is, when it can be taken seriously otherwise devaluing IK as a knowledge system on its own has contributed to its dismissal in DRR and development. It is important to note that IK is a knowledge system that is complete with its own concepts of epistemology and its own way of validation (Battiste, 2002). In similar studies carried out by Hiwasaki *et al.*, (2014) and Macherera et al., (2015) the process of validating important indigenous knowledge-based indicators involved the communities and scientists. Specifically in the study by Hiwasaki *et al.*, (2014) FGDs were organized for community validation of the local indigenous knowledge.

The researcher applied the same process in this study and the indicators grounded in data collected from in-depth interviews and the survey were validated in a focus group discussion. Priority indicators were noted and validated for the practical IK based malaria EWS and research expert consultations were engaged. These indigenous knowledge-based indicators that were agreed upon in the focus group discussion were then used to determine in the EWS. The following indicators in tables 8.4-8.7 were compiled and the list was attached in the developed EWS to serve as a fact sheet to serve as a guiding fact sheet for constant referral by the administrators and reporters. The compiled fact sheet excludes some of the indicators that could not be quantified for example the birth of many baby boys signals good rains and the abundance of fruits.

Table 8.4 Rainfall indicators among Mopani District people

Category	Local name	Scientific name	Sign	Time of occurrence	Indicator of
Plant Phenology	Mvumayila	*Kirkia acuminata*	New foliage	Starting October	Imminent rainfall
	Xikukutsu/Mpotsa	*Combretum apiculatum*	Flowering	Starting September	Imminent rainfall
	Mango	*Mangifera indica*	Fruit ripening	Starts ripening in November	High malaria hazard risk period
	Mukanyi	*Scelerocarya birrea*	New foliage	September/October	Change of season
			Ripening of fruits	Start ripening in December	High malaria hazard risk period
	Nkuwa	*Ficus sycomorus*	Shading off leaves	October	Change of season
	Nxanatsi	*Colophospermum mopane*	Emerging of new leaves	October	Expected first rains
	Ntoma	*Diospyros Mespiliformis*	Smooth reddish new leaves especially in young plants	Starting September end	Indication of spring, the beginning of the warm season

Table 8.5 Rainfall indicators among Mopani District people

Category	Local name	English name	Sign	Indicator of
Birds	N'wharhi	Partridge	Unusual chirping and flying up	Imminent rainfall
	Gongoswani	Woodpecker	Excavating tree trunks	Imminent rainfall
	Tihunyi	Jacobin Cuckoo/ levaillants Cuckooo	Makes unusual sound	Imminent rainfall
	Gumba	Stock	Flying at a high altitude	Imminent rainfall
	Mbewulani	Swallow	A big flock of swallows flying high	Imminent rainfall

Table 8.6 Rainfall indicators among Mopani District people

Category	Sign	Time	Indicator
Meteorological Indicators	Solar radiant making the sky reddish	Morning and evening in winter	Good rain season
	Increased temperature	During the day and night in summer	Promise of rain
	Dew	Winter mornings	Good rains in summer
Celestial bodies	Full moon with dark circle	October/ November	Good rains
	Big star (Nyeleti)	August - November	Good rains

Table 8.7 Rainfall indicators among Mopani District people

Category	Local name	English name	Sign	Indicator of
Insects	Tinsuna	Mosquitoes	Many biting mosquitoes	Malaria hazard risk period
	Jenjhe	Termites	Gathering and storing food	Imminent rainfall
	Swicherere	Cicadas	Singing	Beginning of rain season
Other indicators	Chela	Frogs	Croaking	Near rainfall offset
	Dewulana	Bats	Flying in large swarms	Good rainy season

Source; primary

8.10 Validation of the developed EWS and Utility function of the system

The researcher did an evaluation and validation of the MEWS model performance. This was done using the indigenous knowledge-based indicators from the study area and sample data for temperature thresholds that had been determined. The criterion for raising an alert is based on the thresholds that were determined in section 8.7. In the demonstration 9 reporters and 2 administrators were involved in the evaluation and validation process. The group was comprised of 3 experts and 8 community members from the study area and the process was done online hosted by a free server. The evaluation and validation that was done was a success and this helped in fine-tuning the EWS as some suggestions were given by the reporters. One of the suggestions was that the downloading of the cellphone application should not be a long process and should be simple and understandable. This demonstration that was done for system validation mirrors the real life practice. Using the model, results show that the developed EWS can be a very useful tool when implemented in the area of study. To issue out probabilistic malaria early warning for pre-defined 'alert' thresholds an alert was raised when all the threshold set had been reached, for determined thresholds refer to section 8.6 in this chapter. Below (figure 8.11) is a cellphone screenshot of the reporters' portal showing the triggered alert as an output of the system.

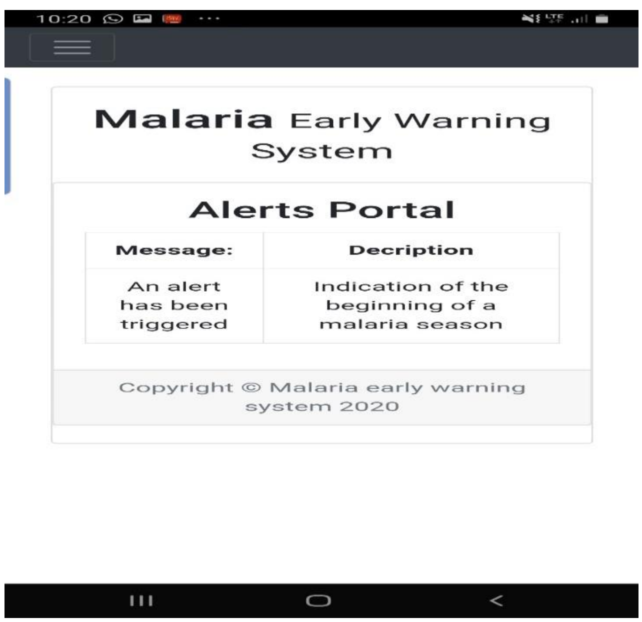


Figure 8.11 Community responders' mobile application showing an alert message
Source: Mobile screenshot

The following figure 8.12 also shows a screenshot for the admin portals' side, displaying the triggered alert.

Figure 8.12 Admin portal malaria season onset alert
Source; Mobile screenshot

8.11 System performance in relation to elements of an effective EWS

As evidenced by the screenshots (Figure 8.11 and 8.12) the evaluation and validation process, was a success in terms of two elements of an effective EWS which are monitoring (element 1) and warning services (elements 2). When an alert message has been issued, the reporters are supposed to relay the information to other community members (thus dissemination- element 3). The communities have a role to play by responding when an alert has been issued (it is also important to note that response is the fourth element of an effective EWS) hence all elements of an effective EWS are presented in the tool. The community members will have to consider both scientific and indigenous knowledge-based prevention measures to mitigate malaria transmissions (refer to table 9.1 for the list of prevention measures to be adopted for response).

The following figure 8.13 shows an illustration of what is involved in the system at different phases of the early warning system. The process was derived from ISDR elements of an integrated EWS and the process is as shown in the following figure.

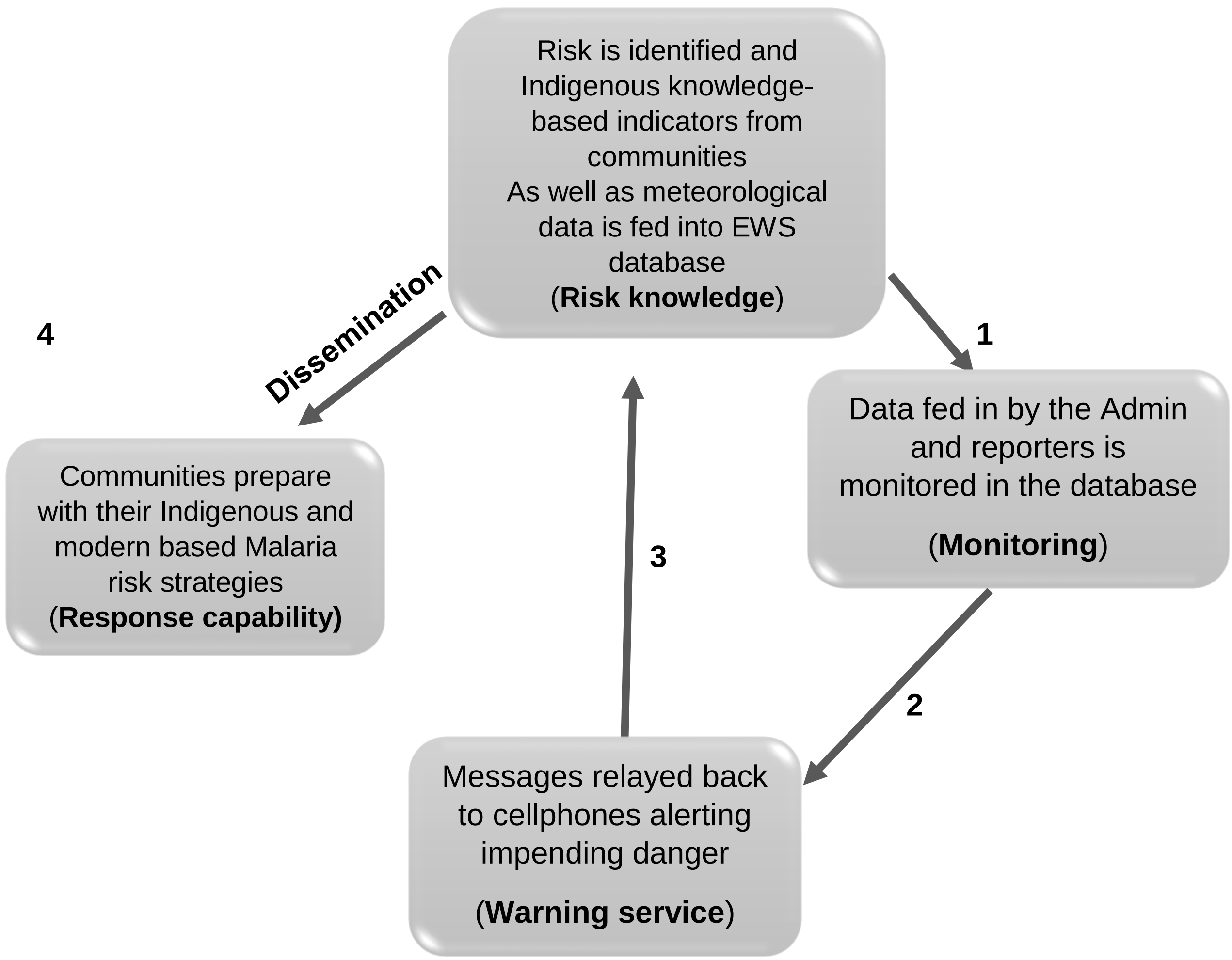


Figure 8.13 Process of relaying information in relation to elements of an effective EWS
Source: Authors work

Firstly the messages are sent from cell phones to the database (phase 1) by the community reporters and the experts (administrators of the system). The messages are received in the database and the database does the monitoring automatically (phase 2).

When a threshold is reached an alert is then raised. The alert is messages are then sent to the reporters' phones automatically. Upon receiving the alert message people have to prepare and respond using their indigenous knowledge for prevention.

8.12 Utility function of the EWS

The reporter's portal which is to be fed by the communities proved to be user friendly. The reporters only have a few tasks which are to feed the observed indicators. This is done by just clicking the category of indicator and selecting the specific listed indicators. The reporters can also make suggestions that can improve the EWS as well as advice on other indicators to be added. Although it was easy for the participants to feed the indicators into the database there were some challenges in downloading the application as it was a long process with a lot of icons to click.

The administrator of the system and community reporters are also required to enter data (temperature and rainfall readings). If data is not fed into the system by communities or by the administrators an alert cannot be raised hence community participation is important. The communities feed-in indigenous knowledge while the administrators feed-in scientific knowledge hence the two forms of knowledge are integrated in the system. This means that alerts are triggered as a result of the data entered by both the community and the administrator and no one between the two groups has the power to influence the triggering of a warning as the system does the monitoring on its own. When 40% of all the IK based indicators have been reported, a flag is stored as a potential event has been registered. However, this system threshold does not work alone as the other determinant (temperature) plays a role too. The following were the challenges noted during the development and testing of the EWS.

8.13 Challenges encountered during the development of the early warning system

The main challenge that was encountered during the development of the early system was financial resources. The actual EWS could have been developed for a macro-level project however the researcher ended up developing a system that can be emulated and perfected in the future. In this case, the researcher opted for a free server however this had limitations as the number of participants were limited because of its capacity. This was mainly used in the demonstration for the sake of evaluating and validating the developed EWS model. Determining the threshold for indigenous knowledge indicators was very difficult as some of the indicators could not be quantified. Those that could not be quantified for example the birth of many baby boys as a signal for a good rain season were excluded in the developed EWS as well as the fact sheet.

8.14 System performance in relation to the South African weather Services (SWS).

Contemporarily in South Africa, the EWS for malaria is expertly driven as evidenced by empirical results of this study (see section 6.2.2 in chapter 6). The malaria management and control stakeholders are focusing on detecting malaria cases thresholds (hospital, sub-district, and district thresholds) as well as sophisticated meteorological data and modeling. As an example, if Tshilidzini Hospital reports 50 cases in a week it is regarded that the surrounding areas are experiencing a malaria outbreak. In that case a team is activated and it will be comprised of the surveillance teams, pharmaceuticals office, health promotion, and the infection control teams, etc. The source of malaria cases is investigated at the village level and malaria education is conducted (dissemination EWS element) and surveillance teams do rapid tests in the villages. The teams work on a contract basis only for 6 months then they stop waiting for financial resources from global fund however the health department specifically the health promotion unit and community health workers are employed permanently and they do door to door campaigns. The people are made to be aware of the malaria hazard and are encouraged to go to the nearest health facility for testing and treatment once they notice malaria symptoms.

In the present discourse, there is a widespread promotion of the development of EWS to establish a risk prevention culture among communities. Prevention is stopping something bad from happening (Oxford English Dictionary 2015) and hence detection of malaria cases cannot be considered as a part of prevention. In the case of preventing malaria outbreaks, the SWS system should attempt to forecast and predict the hazard in advance and not work with malaria case thresholds. The hazard is supposed to be predicted in its embryonic stage, thus malaria vector breeding should be predicted before it poses risk to people. A proactive measure such as complementing the existing efforts by using the developed tool that also considers IK based indicators in forecasting rainfall may assist in mitigating the evolution of the hazard. This could help in maintaining it at the embryonic stage and preventing it from developing into a growth stage. Failure to manage the emergencies (growth stage) can consequently culminate into a mature stage whereby the SWS thresholds are exceeded and this may result in mortality leading to a disaster. It is important to note that according to the UN's International Strategy for Disaster Reduction (ISDR), for an event to be considered a disaster at least 10 people would have been killed or 100 people would have been affected by a hazard.

An effective EWS must be should be relevant to the communities that they should serve (Baudoin *et al.*, 2016; Macherera and Chimbari 2016) and it is important to note that EWSs cannot be implemented uniformly across communities. They have to be tailor-made and localized according to the particular needs of each group and the SWS system should consider that. It is important that an EWS is also driven by the communities at risk, facilitating the delivery of services tailored for each community's needs and possibly reducing implementation costs (Baudoin *et al.,* 2016). The process of the SWS system is not formally prescribing IK as a form of knowledge that could help in further alleviating malaria risk even though SK on its own is proving to be inadequate in helping communities single-handedly evidenced by continuous malaria outbreaks. The developed EWS system in this study therefore coming in to bridge those gaps to allow communities to participate in malaria risk reduction (MRR) with their IK and practices.

There is a need for establishing a new social contract between experts driving the current EWS (scientists) and the society (communities) to move away from a system that just gives facts towards a deeper engagement supporting policies for hands-on application in terms of community involvement. On another note there is also a need to overcome the governance trap which promotes dependency of communities whereby people expect the government to act while not taking precautionary measures towards the malaria hand. DRR advocates for collective action. Involving communities with their K and practices enables a multi-dimensional approach to malaria control and management. Taking the communities as passive recipients in handling the health hazard could be contributing to a failure in preventing malaria outbreaks.

8.15 Summary

The chapter outlined the steps that were involved in the development of a practical malaria early warning system. Information and Communication Technologies (ICT) was used as a platform to integrate the two forms of knowledge. Apache Cordova, JDK 1.8, Node JS, and XAMPP (Apache and MySQL) are the main software's that were used in developing the EWS. The thresholds for the EWS were determined by coming up with well thought out logic combinations from indicator results that came up in chapter 7. These were set for the system to be able to raise a warning. The next chapter provides a summary of the findings, a discussion of the data, the conclusion, and some recommendations on the way forward.

CHAPTER NINE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

9.1 Introduction

This chapter aims to present a summary of the major findings, recommendations, and conclusions in relation to the findings of the study. This research was focusing on integrating indigenous and scientific knowledge in community-based early warning system development for climate-related malaria risk reduction in Mopani District. IK is considered to be the knowledge that exists in local people and has been acquired through experiences and is passed through generations (Fernando 2003). On the other hand, scientific knowledge is a set of analyzed data or instrumental records with independent or dependent variables that can be empirically measured and demonstrate acceptable levels of reliability and validity (Alexander *et al*., 2011). This research was done in Mopani District which is located in Limpopo Province from 4 municipalities of the district. The municipalities that were involved are, Maruleng, Greater Tzaneen, Greater Letaba, and Ba-Phalaborwa. Data was collected from 381 selected participants through in-depth interviews, questionnaires and focus group discussions.

The study was underpinned by the constructivist grounded theory and the pragmatism epistemologies. These research philosophies integrated both quantitative and qualitative methods, processes and perspectives in the quest to find a solution for malaria risk reduction. The paradigms employed what works allowing the use of subjective and objective philosophical variables and enabling the researcher to achieve a practical outcome (Goduka 2012). The study was hinged on the systems theory for disaster management as well as the framework for elements of an effective early warning system (adapted from ISDR 2006). These were integrated to understand how an integrated early warning system can be developed. A multiphase design was the used and data was collected through in-depth interviews, questionnaires, and a focus group discussion. The data that was collected was analysed using SPSS version 23 for quantitative data while qualitative data was analysed using constructivist grounded theory. The conclusion drawn from the findings of the study enabled the researcher to make recommendations and suggestions for future studies.

9.2 Summary of key findings

The study was guided by the purpose of this study which was to come up with a solution for malaria transmissions in Mopani District and the aim was to develop an early warning system that integrates indigenous and scientific knowledge. In the following sections, the findings are summarised on each topic derived from the objectives of the study.

Factors that influence malaria transmission in Mopani District

The factors that influence malaria in the study area were identified. Findings reveal that malaria in Mopani District involves many interlinked factors. This converges with Kumar *et al.,* (2014) who reveals that the transmission of malaria is a dynamic process and involves many interlinked factors. These range from uncontrollable natural environmental conditions to man-made disturbances (ibid). The researcher categorized the factors influencing malaria transmissions in Mopani District. Categories from the findings are meteorological factors, socio-economic factors, anthropogenic and environmental factors. Meteorological factors were of greater interest as they assisted in determining the variables to be used for determining thresholds of the EWS that was developed so that an alert can be triggered. This was consistent with the findings of several authors who mention that malaria occurrence can be predicted using climatic factors that include temperature and rainfall (Tonnang *et al.,* 2014; Macherera *et al.,* 2017). Based on the findings, it was concluded that rainfall and minimum temperature have an influence on malaria cases in the study area, hence the two were adopted for determining thresholds for the developed early warning system

Existing malaria early warning system in Mopani District

The nature of the existing malaria early warning system in Mopani District was mainly guided by the systems approach for disaster management and the framework for elements of an integrated EWS by the International strategy for disaster reduction (2006). Inconsistent with the systems approach to managing disasters, an analysis of all possible sources of problems within the existing system was done by examining each individual element (Simonovic´2010). The theory brings out that an integrated system can be more effective than unconnected elements operating autonomously. The elements that make up a comprehensive integrated early warning system were identified and these are risk knowledge, monitoring and warning services, dissemination and communication and response capability as laid out by the international strategies for disaster risk reduction (ISDR 2006). This also gave the researcher a picture of what the early warning system that was developed should entail. From the empirical results, it was found out that even though all the elements of an early warning system were present in the system in Mopani District, there were some loopholes in it. By nature, the existing system emphasizes monitoring the number of malaria cases detected. According to Macherera and Chimbari (2016), the repercussions of prioritizing one element similar to what is being done in Mopani District leave people exposed to risks associated with a hazard. More so detection of a rise in malaria cases cannot be part of prevention as people would have already been affected. It was also noted from the results of the study that communities have a minimum role in the malaria control program. Experts in the malaria control program are assisting communities without discussing anything with them as they simply expect members to follow the given instructions and orders. The prevention measures that were being advocated for by the experts were scientific knowledge-based. In conclusion, the initiatives for malaria control in Mopani District are more reactionary and not proactive by nature.

Indigenous knowledge-based prediction indicators and prevention measures against malaria in Mopani District

The results also reveal that people in Mopani District have indicators for the malaria season onset based on rainfall. Several rainfall based indicators mentioned by the study participants were then used to develop a functional early warning system. This was consistent with Macherera *et al.,* (2017) who mentions that local communities can predict weather conditions using indigenous knowledge and it is possible to utilize the knowledge for developing an early warning system. With the proxy indictors, it was feasible to develop a functional malaria early warning system that integrated indigenous and scientific knowledge. The indicators mentioned by the participant from in-depth interviews and the survey were validated in a focus group discussion. These were used to determine thresholds in the early warning system. The indicators were compiled and the list was attached in the developed early warning system to serve as a fact sheet (see section 8.9 in chapter 8)

Summary of malaria prevention measures being employed

The results of the study also show that several products are used to repel mosquitoes for malaria prevention. The burning of various items was identified as one of the major traditional methods for vector control. The following is a table summarises the malaria prevention measures being employed by people in Mopani District.

Table 9.1 Malaria prevention measures

Malaria prevention measures in the area of study	
Category 1 – *IK based*	• *Cow dung* • *Donkey dung* • *Goat droppings* • *Pig waste* • *Epaltes gariepina* • *Dodonea viscosa* • *Lantana camara* • *Lippa javanica* • *Paw Paw leaves* • *Agave sisalana Perrine*
Category 2 – *MSK based*	• *Aerosols* • *Coils* • *Nets* • *Repellants* • *Anti-malarial injection* • *Anti-malaria pills*
Category 3- *Other*	• *Tissue paper* • *Egg crates* • *Fan*

Developing an integrated scientific and indigenous knowledge-based early warning system for climate-related malaria risk reduction for Mopani District.

The stages of the integrated early warning system were specifically developed from all the preceding chapters. This includes empirical evidence of the work conducted in this study. Each chapter of the study had a steering role in the development of a functional early warning system. This includes the literature review and empirical evidence of the work conducted in the study. Information and Communication Technologies (ICT) was used as a platform to integrate the two forms of knowledge. This converges with Lodhi and Mikulecky (2011), who reveal that ICT enhances the blending of indigenous, scientific, and technical knowledge. Karanath *et al.,* (2014) also supports Lodhi and Mikulecky, (2011) and reveals that ICT can be used as the basic foundation of networking arrangements that assist immensely in meeting the desired objectives of an EWS. The researcher developed a cell phone and desktop application to accommodate the feeding of scientific and indigenous knowledge-based data that is required in the EWS. Arpache Cordova, JDK 1.8, Node JS, and XAMPP (Apache and MySQL) are the main software's that were used in developing the EWS. The EWS was successfully tested at the micro-level.

9.3 Conclusion

Developing an integrated early warning system can be a solution for malaria risk reduction. Information and communication technology can be adopted in the integration of indigenous and scientific knowledge science the world is advancing technologically. This study, therefore, concludes that it is feasible to develop a tailor-made early warning system that integrates indigenous and scientific knowledge using Information communication and technology as a platform for the integration.

9.4 Limitation of the study

The researcher expected to obtain more information on indigenous knowledge from the traditional healers, unfortunately, they did not reveal much. This could have partly been affected by their work ethics. To address this the grounded theory that was adopted gave the researcher an advantage as data was collected from other participants until a saturation point was reached. Furthermore, the researcher was not conversant with the languages of the study area and employed interpreters as some participants preferred giving information in their local languages. Since the researcher was not conversant with the languages of the study area so an expert translator was engaged however the researcher acknowledges that some meanings of words and phrases could have been distorted after they were translated into English. The researcher also accepts that by adopting the constructivist perspective there was no one accurate translation of statements as one is influenced by his or her own experiences hence there are multiple meanings. The other limitation was that most participants had forgotten most of the indigenous knowledge-based prevention measures and indicators as they were no longer practising it. The grounded theory that was adopted by the researcher enabled the collection of data until a saturated. Also, the study the participants did not know the English or scientific names for some rainfall indicators, and identifying them was a challenge in this case experts were consulted. Quantification of other IK based rainfall indicators such as an abundance of certain fruits or birth of many boys is objective and there is no marker for abundant or less abundant. Such indicators were excluded in the developed EWS since they were not useful.

9.5 Contributions to the body of knowledge – A model

- Having gone through the research process the researcher came up with the contribution to knowledge for Disaster Risk Reduction. The contribution of the researcher is a model for the development of malaria early warning systems. This was an outcome of conceptualization, literature review, and data analysis using the grounded theory. The same model was used to develop an early warning system in this study and it can help to bring up tailor-made early warning systems for other communities facing the same challenge.

  The developed EWS enable and prepare communities to act in sufficient time to reduce the possibility of harm or loss using their indigenous knowledge and local resources. With this model the researcher, therefore, calls for the consideration of complementing the existing science knowledge-based malaria risk reduction interventions with indigenous knowledge in the development of an integrated early warning system.

- The study also contributes to the promotion of resiliency in communities through the integration of indigenous and scientific knowledge as it will increase community capacities to deal with the problem of malaria such that even when there is no external assistance or if the initiatives that are in place fail the communities will remain resilient to the disease, for example, in case DDT is banned.

9.6 Recommendations of the study

This study recommends the following:

To malaria management and control key stakeholders the researcher recommends that:

- The malaria management and control key stakeholders may consider adopting the practical Malaria Early Warning System (MEWS) that was developed in this study to complement the existing malaria control initiatives. This tool is functional and will enhance proactiveness, and early forecasting of the malaria season, that is, 3 months or more before the time when outbreaks occur. The MEWS was specifically developed considering the existing challenge of persistent malaria transmissions in Mopani District. It will help the communities to prepare and act in sufficient time to reduce the possibility of harm or loss.

- There is a need for malaria management and control key stakeholders to focus on more pro-active malaria risk reduction oriented approaches instead of concentrating on reactionary responses. Proactive actions on prevention, mitigation, and preparedness planning require a comprehensive approach that encompasses a multi-sectorial approach as well as prioritizing all the elements of an integrated early warning system. The line management sector should not dominate the program but encourage other related organizations to be active participants as well. As an example, there could be an orchestration of activities that includes the department of roads and waterworks such as cutting grass, removing drainage blockages, dredging of rivers and streams can be orchestrated at the same time when the spraying programme starts to make sure that mosquito habitats are eliminated.

- A plan with well laid out coordination structures should be in place to improve coordination effectiveness. The researcher recommends the laid out Organizational framework of a designed humanitarian project by De Paula (2017) as it minimizes uncoordinated activities in case of an emergency or disaster, in this case, the malaria outbreak. This assists with a layout of coordination between various DRR stakeholders. It overcomes coordination and logistic challenges. Appendix 12 shows the structure of an organizational framework of a designed humanitarian project that is being recommended.

- The promotion and encouragement of indigenous knowledge malaria season indicators and prevention measures in malaria risk reduction as this removes the stigma attached to it. Promoting indigenous knowledge gives the communities the confidence to express and develop their adaptation strategies using the local capacities that have worked for them for generations.

To the communities, it is recommended that they;

- Consider using IK and local resources for malaria seasonal forecasting and prevention measures. This implies that they should not view scientific knowledge more superior than their Indigenous knowledge.

- Promote sustainable strategies of utilizing the local resources used for malaria prevention so that the future generations are not compromised.

- Transmit the indigenous body of knowledge and skills to younger generations to provide survival strategies, improve the initiatives, and ensure that it is preserved.

9.7 Indications for further studies

There is a need for further studies on:

- Finding out if the same developed early warning system can be replicated in other communities facing a similar challenge using the same methodology as used by the researcher in this study.

- The effects of climate change on indigenous knowledge-based indicators used for forecasting the malaria season.

- Finding out the factors that may affect the use of indigenous knowledge as well as to analyze the acceptance and adoption of the developed early warning system in addressing the hazard by different stakeholders.

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Appendix 1 Ethical Clearance

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:
Mrs BN Rumutsa

Student No:
16023638

PROJECT TITLE: **Integration of scientific and indigenous knowledge in an early warning system for climate sensitive malaria risk reduction, in Mopani District.**

PROJECT NO: **SES/19/GGIS/02/2503**

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Dr NS Nethengwe	University of Venda	Promoter
Dr H Chikoore	University of Venda	Co - Promoter
Mrs BN Rumutsa	University of Venda	Investigator – Student

ISSUED BY:
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE

Date Considered: March 2019
Decision by Ethical Clearance Committee Granted
Signature of Chairperson of the Committee: ....
Name of the Chairperson of the Committee: Senior Prof. G.E. Ekosse

UNIVERSITY OF VENDA
DIRECTOR
RESEARCH AND INNOVATION
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"A quality driven financially sustainable, rural-based Comprehensive University"

Appendix 2 Consent form

Consent form for interviews

I am Brenda Nyeverwai Rumutsa, and currently doing PhD at the University of Venda, research topic entitled "Integration of modern scientific and indigenous knowledge in an early warning system for climate sensitive malaria risk reduction in Mopani District.

I would like you to participate in my research. Any information obtained from you is confidential and your name remains anonymous. Several steps will be taken to protect your anonymity and identity. Interviews will not mention your name, and any identifying information will be removed. Your participation in this study is voluntary and you are free to pull out of this project at any time. Your decision to participate in this project will not have any negative impact on your health or life. A tape recorder will be used to record this interview. Photographs will be taken if you do not mind.

This interview will require about 45 minute to 2 hours of your time. The results from this interview will be used to write up my thesis and also to publish journal articles. The outcome of the study will be presented to you and the rest of the participants so that you access the new knowledge generated. The policy recommendations will be disseminated to relevant institutions through a policy brief. However at all these stages, names the study participants will not be mentioned.

Researcher's signature__________________________________ Date____________

I have read through the consent form and hereby voluntarily consent to participate in this study.

____ (Printed Name)

____ (Signature)

____ (Date And Time)

Appendix 3 Interview guide for community members

In-depth interview guide.

Section A (Changes in Malaria Risk areas)

1. What are the most common diseases in this community?
2. Is malaria a problem in this area?
3. How long has it been a problem?
4. What are the reasons for repeated outbreaks of malaria in the area?
5. Are there any changes (is it getting better or worse) in malaria over the past years?
6. What could be the contributing factor on the part of the community?
7. What are the interventions being employed by the malaria controlling organizations?
8. On the part of the organizations involved in the controlling of malaria

Section B (Nature of existing EWS)

1. Do you receive timely alerts for the approach of the malaria season?
2. From which organizations does the alerts come from?
3. What media is used to alert you?
4. Is thee ay early warning system that you know of?
5. Do you participate in any way?
6. What household adjustments do you make upon receiving alerts?
7. Is early warning respected in your household?

Section C (prediction measures using traditional knowledge)

1. How do you predict rain using traditional knowledge?
2. Is the method effective?
3. What is the challenge of using traditional knowledge in predicting rainfall?

Section D (prevention measures)

1. What do you use to prevent malaria using modern resources?

2. Any challenges?

3. How can you prevent malaria using traditional knowledge?

4. Do you still apply traditional knowledge in malaria prevention?

5. Is it effective?

6. What are the challenges of using traditional methods stated in malaria prevention?

Section E (Climate change)

1. Have you noted any weather pattern changes in your area?

2. What is the evidence for change in climate?

3. Have you heard about climate change?

4 Is it affecting you at community level?

5. If yes explain how it is affecting you

Appendix 4 Example of Transcribed data

 # In-depth 2 Pseudo name: Mr Uticha

Area: Tzaneen rural 63 Occupation: Teacher

Sex Male Culture: Xi-Tsonga

Question: What are the most common diseases in this area?

Response: Because I am an educator we normally hear or find learners or their parents being affected by Malaria, I have heard of such cases.

Question: Which area are you from?

Response: I am staying here in Nkoankoa but I work in Mwamitwa.

Question: So it’s just malaria?

Response: For now, to be honest, I've never heard any outbreak besides malaria. It is the only disease that I find learners and their parents being affected with. Other diseases I don't know.

Question: What do you call malaria in your native language?

Response: We just call it malaria

Question: What about mosquitoes?

Response: Tinsuna (plural) nsuna (singular term)

Question for how long has it been in this area?

Response: Malaria has been there for more than a decade now but some years ago, it was severe but because the government is controlling you will find cases here and there.

Question What do you think are the reasons for repeated outbreaks of malaria in this area?

Response: I think it might be one or two things, one it might the ignorance of the people the government is trying to highlight that during the evening you should close your windows and wear long-sleeved clothes to protect yourself from mosquito bites.

One more other thing is that on the side of the government is reluctant to spray. They only start spray when there is an outbreak they should spray all the time, particularly in summer. I think if they know how long the chemical lasts they can follow that. They should follow that progamme to combat malaria.

Question Are there any changes in malaria over the past years? (is it getting better or worse)

Response; particularly in Tzaneen it is no longer severe because the government is controlling, unfortunately, I am an educator but if I was a doctor or a nurse I would know better than what I am telling you.

Question Do you receive timely alerts for the approach of the malaria season?

Response – yes, sometimes. Actually, when we are alerted that when people start dying prevention is rare, they are not preventing as they should they wait until people start dying then they start trying to contain the problem that's what I have noted.

"They wait until there is an outbreak then they start saying hee heheee be careful there is malaria you must do this you must not do this, but now its winter, according to me the programme should have started since its winter and we are getting into summer in no time. They must highlight to us and send awareness messages that the season is coming, that season of malaria, you should do this and this so that it must be in our mind all the time and malaria kills, that's what they must tell us.

Question: Do you get any assistance from any organization to prepare for a malaria season?

Response: No, what I know is that when you go to other countries like Mozambique that is when they warn you that when you are going there you must take some antimalarial drug before you go or inject yourself but as citizens or society there is nothing. Until maybe there is an outbreak that when they will come up with their method of spraying otherwise they take time. I remember in Nkowankowa I haven't seen them close to 25 years staying there haven't seen them at my house. If you feel your financial muscles are strong enough then you can go and buy something to protect yourself with. People do not think of buying that, with the little they have they think of buying food. For my household, I am buying nets and pills.

Question What media is used to alert you on the approach of a malaria season?

Response: They normally use SABC in native languages also radio Phalafala

Question. Is there any early warning system that you know of?

Response: that's why I am saying the government wait until something outbreaks, for example, there is diarrhoea which has been caused by maybe dirty water or contaminated water that's when they will say don't drink water that water because we have discovered that people are dying because of this water. Wait until we do one, two three. They just don't make a sort of awareness, they first wait for something to happen then they will help after people have died.

Question: When you are approaching the malaria season what household adjustments do you make upon receiving alerts?

Response; to be honest I just live like any other day I don't even think that there is even such a thing

Question: So do you practice what the government tells you to do?

Response: not for malaria, we just close windows in the evening. Isn't it that in the morning we open for fresh air? in the evening we also think of mosquitoes because they bite not particularly malaria, we don't think about malaria but annoying mosquitoes, that one we are doing, however by so doing we are also preventing ourselves from malaria, is it that a mosquito is a mosquito, you will never know which one is for malaria and which one is not. In the evening you close the window because there are a lot of things that might enter e.g. snakes and insects

Question How you know you are approaching the malaria season using indigenous knowledge?

Response: no, I don't know, maybe others. There is no such thing. I check the weather forecast on TV or phone

Question; what indigenous knowledge do you use to prevent yourself from malaria?

Response: That was used in the past during the time of our forefathers' maybe, but now for your information what we protect yourself with is wearing long clothing, what we were told to do. We are no longer applying indigenous knowledge.

Question: is it that it is no longer effective?

Response; applying indigenous knowledge and such stuff is only when you are troubled by certain things. That is when you must come up with new things. But the fact is that in our area people have relaxed though there have been some cases of malaria and even some have died.

Question: Is it still raining like it used to?

Response: because of that global warming there has been a lot of changes. Normally, we expect rain summer particularly in September but nowadays now rains can even come in December. Not because of drought but because of seasonal rainfall pattern changes.

Question Is it affecting the communities?

Response. Some people are still surviving on rain-fed agriculture they grow peanuts, mealies but it has now been affected.

Appendix 5 Interview guide for Key informants

Guided Interview (organizations)

Section A (Interviewee details)

1. Municipality ________________Recording number _________________________
2. Institution/organization/department ______________________________________
3. Name of organization____________________Cell number___________________
4. Designation____

Section B (Extent of changes in Malaria risk areas)

1. Which are the high malaria risk areas of Mopani District?
2. If it possible may you rank the municipalities according to risk.
   Maruleng, Phalaborwa, Tzaneen, and Letaba
3. What do you think is the reason for the worst affected area in Mopani District?
4. Has the risk areas changed over the past years?
5. What are the changes?
6. What do you think are the reasons for the change?
7. Are there any new areas newly affected by malaria?
8. If there are new areas, what do you think are the reasons for the spread of malaria in new areas?
9. Which areas used to be high malaria risk areas but now low risk areas?
10. What do you think are the reasons?

Section C (Nature of the existing malaria early warning system)

1. For which hazards do you have early warning systems in this district?
2. Is there any malaria early warning system or contingency plan for malaria emergencies in place?
3. Do you get timely alerts for malaria season?
4. How is your organization involved in the Early Warning System?
5. What type of service is it (*check framework for organization of humanitarian projects*)?
6. Who gives the Institution/organization/department orders on how to react when there is a malaria outbreak? i) Internal ii) External
7. Does your organization also give orders or assign responsibilities to other organizations?
8. If yes, which are the organizations?
9. For which activities do you give orders?
10. Are there any challenges that you experience during an emergency, in partnering with other organisations?
11. Do your activities overlap with other organizations in dealing with malaria?
12. If yes what are the activities in which you overlap?
13. Mention the other organizations that you overlap with?

14. How are activities carried out in case of a malaria outbreak to prevent more people from being affected?
15. What is the nature of the malaria early warning system (How it is organized)? (*Refer to the framework for organizational structure of humanitarian projects*)

Section D (Nature of the existing malaria early warning system)

1. What do you think are the challenges faced in the actioning of this MEWS or contingency plan?
2. Do the communities know how to react after alert has been raised?
3. How does the community respond when there is an outbreak of malaria?
4. Do the communities participate in the early warning system?
5. How do they participate?
6. Do communities know their hazards and vulnerabilities?
7. Are the malaria hazard parameters that being monitored?
8. Are accurate and timely warnings generated?
9. Do communities understand their risks?
10. Do they respect the warning services?
11. Do they know how to react?
12. Are plans always updated and practiced?
13. What is the pattern and trend of malaria outbreaks?
14. Are maps and data widely available?
15. Do warnings reach those at risk?
16. Do people understand the warnings?
17. What Media is mostly used to alert communities of an impending danger?
18. What do people do when they are not assisted in malaria control or when they don't receive assistance in time?

Section E (Existing prediction and malaria risk reduction measures)

1. How do you know you are approaching the malaria season (what are your indicators)?
    i. Using Scientific Knowledge
    ii. Using indigenous knowledge
2. How do the communities know they are approaching the malaria season? (their indicators)
    i. Using Scientific Knowledge
    ii. Using indigenous knowledge
3. Are the methods of malaria prediction effective?
4. What challenges faced in predicting the malaria season, using the method(s) mentioned?

Appendix 6 Questionnaire

Questionnaire (*Put a tick where appropriate*)

Section A (Biographical data)

1. Municipality ____________________
2. Geographic co-ordinates of dwelling ____
3. What is the type of dwelling,
   Very formal ☐ Formal ☐ Informal ☐ Traditional ☐ Other ☐
4. Town/Village____
5. Language____
6. Municipality of origin____
7. How long have you stayed in this area? in Years ☐
8. Gender: Male ☐ Female ☐
9. Age ☐ 16-20 ☐ 21-29 ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60-69 ☐ Above 70
10. Are you the household head? Yes ☐ No ☐
11. What is your highest education qualification?
    No formal education ☐ secondary -Level ☐ Primary-Level ☐
    Vocational Training ☐ Degree ☐ Post Graduate ☐
12. Occupation: Formal ☐ Informal ☐ None ☐
13. Size of household (*excluding visitors*) ☐

Section B (Communication)

1. Do you have a mobile phone? Yes ☐ No ☐
2. What type of mobile phone is it? Basic ☐ Feature ☐ Smart ☐
3. Do you have a TV ☐ Radio ☐ Do you buy Newspapers? ☐
4. Have you ever received or seen any malaria alert messages?
   No ☐ Yes ☐
5. If yes, how did (do) you receive the alert/s? ____

Section C (changes in malaria risk areas)

1. Is this area at risk of malaria? Yes ☐ No ☐ No Idea ☐
2. In which months are mosquitoes a nuisance? ____
3. Which months do your community usually experience malaria outbreaks?______________________
4. From the previous years, are the outbreaks still occurring in the same months?
   Yes ☐ No ☐ No idea ☐
5. What do you think contributes to the problem of mosquitoes in this area?
   ____

Section D (Nature of a malaria early warning system)

1. Are there any early warning systems that you know of in Mopani district?
   Yes ☐ No ☐ No idea ☐
2. For which natural hazard?____
3. Do you make any adjustments upon receiving alerts? Yes ☐ No ☐
   If no state the reason:
   ____
4. Do you get any assistance for malaria prevention? Yes ☐ No ☐
5. From which organizations or institutions do you get assistance from?
   i. Name of organization/institution ____

Type of assistance ____

ii. Name of organization/institution ____

Type of assistance ____

Section E (Prediction indicators and malaria risk reduction measures)

1. Which of the following malaria risk reduction measures are you employing?
   Modern Scientific knowledge ☐ Indigenous knowledge ☐ Both ☐ None ☐
2. Describe malaria risk reduction measures chosen in 1.
   Modern Scientific____
   ____
   Indigenous Knowledge____
   ____
3. Which methods would you consider in predicting the approach of malaria season?
   Modern scientific knowledge ☐ Indigenous knowledge ☐ Both ☐ None ☐
4. Describe the malaria prediction indicators (signs) for the chosen method in 3.
   ____
   ____
5. Are the methods effective? Yes ☐ No ☐
6. What are the challenges of using the methods of prediction stated?
   ____
7. How many family members have had malaria in the past 2 years? _________________________
8. Has any family member travelled to a malaria endemic area in the past 2 years?_____________
9. What would you do if you fail to get timeous external assistance of bed nets, spraying and anti-malarial drugs? i) Simply wait for the assistance ☐ ii) Buy items for yourself ☐
   iii) Use indigenous knowledge and local resources ☐

Section F (Climate change)

1. Have you noted any weather pattern changes in your area? Yes ☐ No ☐
2. What are the changes noted?____
3. Have you heard about climate change? Yes ☐ No ☐
4. If yes, is it affecting you at community level? Yes ☐ No idea ☐

If yes explain how it is affecting you____

Appendix 7 Approval to carry out a research in Greater Letaba Municipality

GREATER LETABA MUNICIPALITY

P.O Box 36, Modjadjiskloof, 0835, Tel (015) 309 9246/7/8,
Fax (015) 309 9419, Email:greaterletaba@glm.gov.za

Enq: Mr Malola MP
Date: 05 September 2019

Mrs Rumutsa B.N (Student No. 16023638)
University of Venda
P/Bag X5050
Thohoyandou
0950

SUBJECT: APPROVAL FOR THE APPLICATION TO CONDUCT ACADEMIC RESEARCH: YOURSELF

1. The above matter bears reference.
2. It is with great enthusiasm to inform you that Greater Letaba Municipality has approved your application to conduct PhD research study within its jurisdiction.
3. You are requested to ensure that participants partaking in the research are protected and information collected is treated with confidentiality.
4. You are further requested to ensure that during the process of collecting data you do not interfere with normal operations of the institution.
5. Trusting that you will find the research rewarding

Kind regards,

Dr SIROVHA K I
MUNICIPAL MANAGER

44 Botha Street, Civic Centre Modjadjiskloof, Limpopo Province, Republic of South Africa
"To be the leading municipality in the delivery of quality services for the promotion of socio-economic development"

Appendix 8 Approval to carry out a research in Greater Tzaneen Municipality

GREATER TZANEEN MUNICIPALITY
GROTER TZANEEN MUNISIPALITEIT
MASIPALA WA TZANEEN
MASEPALA WA TZANEEN

FROM NATURE

P.O. BOX 24
TZANEEN
0850

TEL: 015 307 8000
FAX: 015 307 8049

www.tzaneen.gov.za

17 September 2019

Ref.: 4/4/R
TG Hlangwane

University of Venda
Directorate: Research and Innovation
Private Bag x5050
Thohoyandou
0950

Sir/Madam

PERMISSION TO CONDUCT RESEARCH: MRS. BRENDA N RUMUTSA -16023638

1. Your letter dated 21 August 2019 has reference.
2. Kindly note that permission has been granted to conduct research at the Greater Tzaneen Municipality on the topic "Integration of western and indigenous knowledge in an early warning system for climate change sensitive malaria risk reduction in Mopani District".
3. The student is welcome to conduct a research according to a structured questionnaire/ and or conduct face to face interview. However the student must undertake the responsibility to provide this Municipality with a copy of the final report.
4. The student is welcome to liaise for further assistance with the Training Officer, MS. Glacia Hlangwane on tel.no. (015) 307 8378 or by e-mail: glacia@tzaneen.gov.za

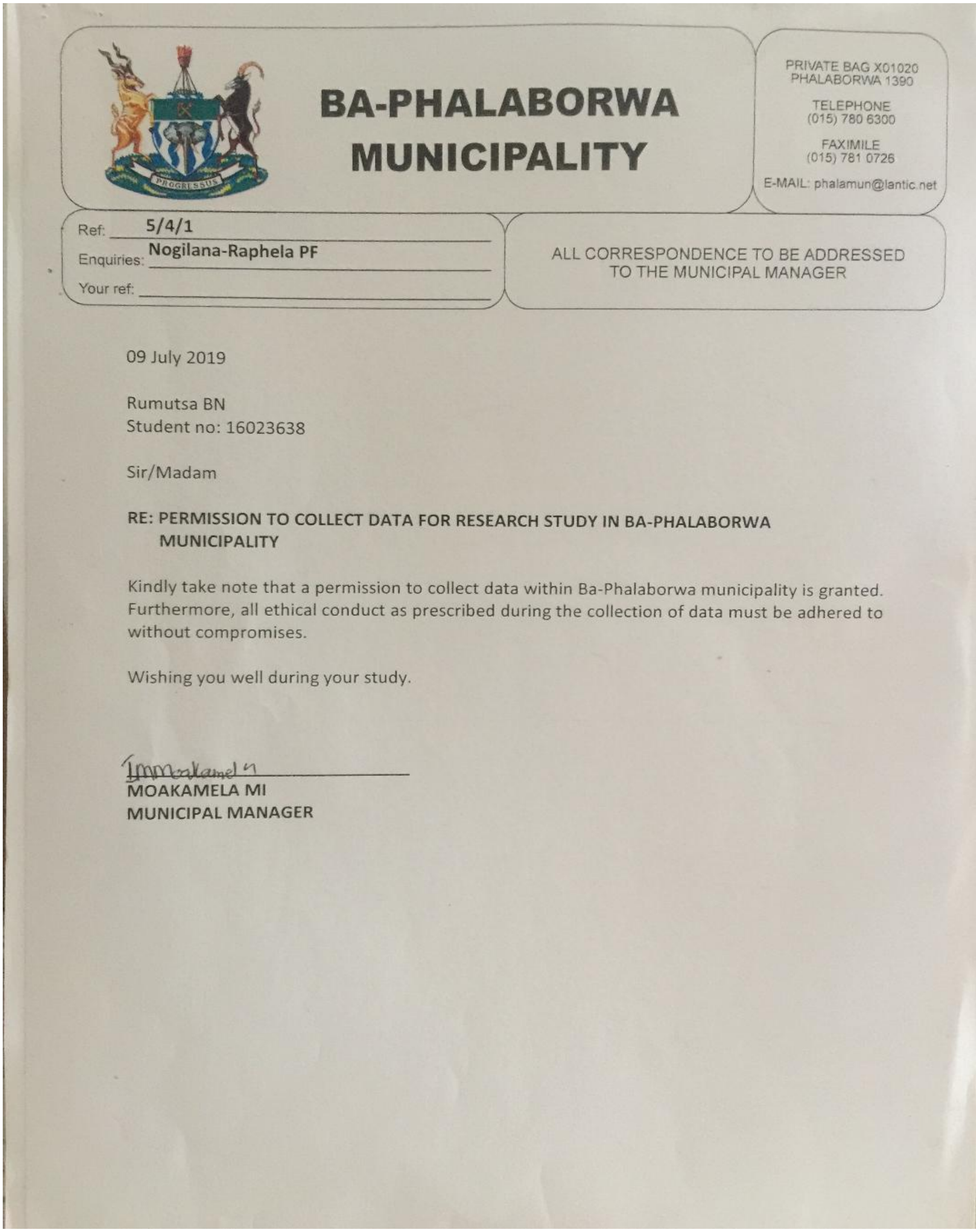
It is trusted that you will find this matter in order

Yours faithfully

BS Matlala
Municipal Manager

A Green, Prosperous and United Municipality that Provides Quality Services to All

Appendix 9 Approval to carry out a research in Ba-phalaborwa Municipality



BA-PHALABORWA MUNICIPALITY

PRIVATE BAG X01020
PHALABORWA 1390
TELEPHONE
(015) 780 6300
FAXIMILE
(015) 781 0726
E-MAIL: phalamun@lantic.net

Ref: 5/4/1
Enquiries: Nogilana-Raphela PF
Your ref:

ALL CORRESPONDENCE TO BE ADDRESSED TO THE MUNICIPAL MANAGER

09 July 2019

Rumutsa BN
Student no: 16023638

Sir/Madam

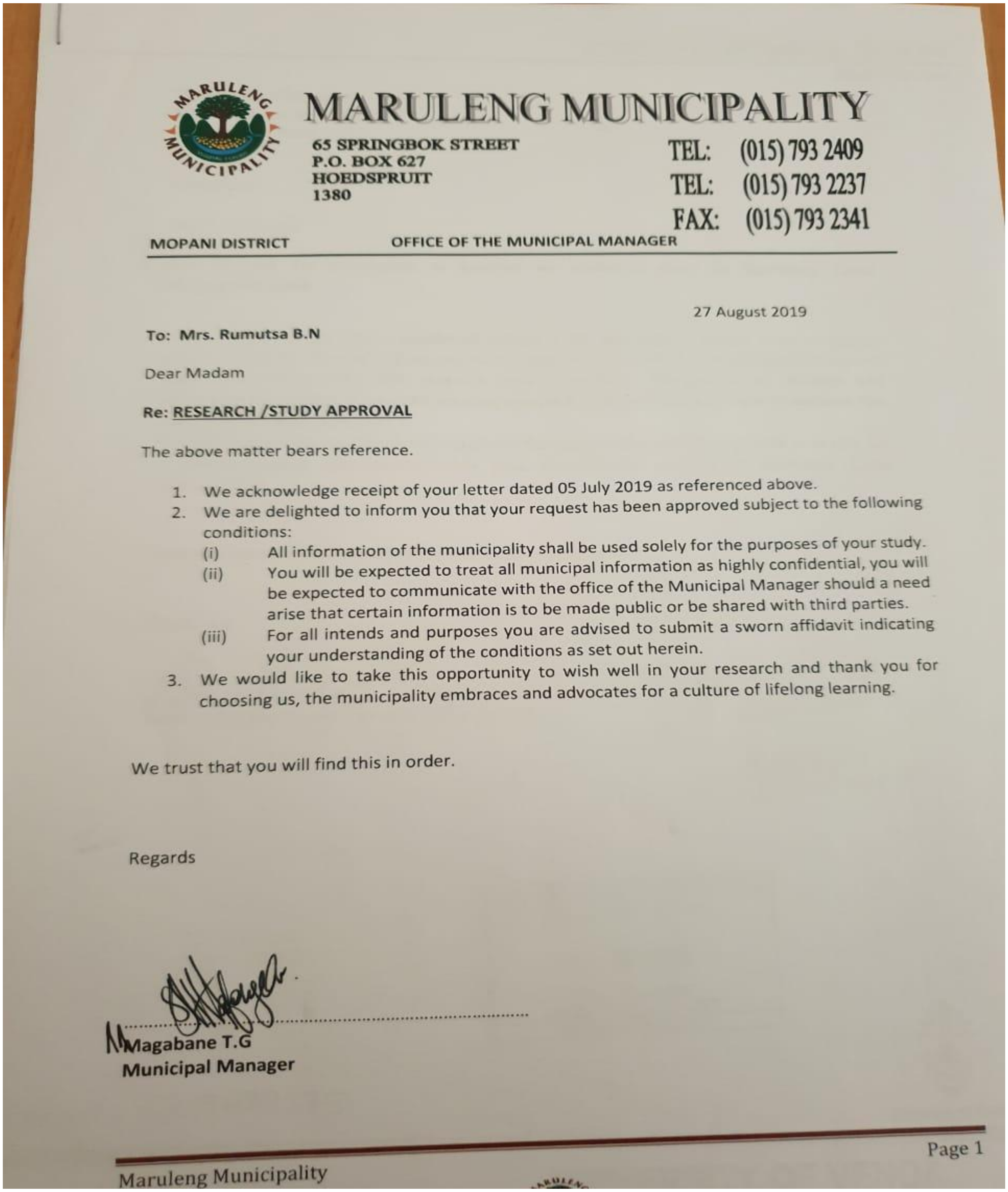
RE: PERMISSION TO COLLECT DATA FOR RESEARCH STUDY IN BA-PHALABORWA MUNICIPALITY

Kindly take note that a permission to collect data within Ba-Phalaborwa municipality is granted. Furthermore, all ethical conduct as prescribed during the collection of data must be adhered to without compromises.

Wishing you well during your study.

MOAKAMELA MI
MUNICIPAL MANAGER

Appendix 10 Approval to carry out a research in Maruleng Municipality



MARULENG MUNICIPALITY

65 SPRINGBOK STREET
P.O. BOX 627
HOEDSPRUIT
1380

TEL: (015) 793 2409
TEL: (015) 793 2237
FAX: (015) 793 2341

MOPANI DISTRICT — OFFICE OF THE MUNICIPAL MANAGER

27 August 2019

To: **Mrs. Rumutsa B.N**

Dear Madam

Re: RESEARCH /STUDY APPROVAL

The above matter bears reference.

1. We acknowledge receipt of your letter dated 05 July 2019 as referenced above.
2. We are delighted to inform you that your request has been approved subject to the following conditions:
   (i) All information of the municipality shall be used solely for the purposes of your study.
   (ii) You will be expected to treat all municipal information as highly confidential, you will be expected to communicate with the office of the Municipal Manager should a need arise that certain information is to be made public or be shared with third parties.
   (iii) For all intends and purposes you are advised to submit a sworn affidavit indicating your understanding of the conditions as set out herein.
3. We would like to take this opportunity to wish well in your research and thank you for choosing us, the municipality embraces and advocates for a culture of lifelong learning.

We trust that you will find this in order.

Regards

Magabane T.G
Municipal Manager

Maruleng Municipality — Page 1

Appendix 11 Approval to use the South African Weather Service Data

South African Weather Service

Private Bag X097, Pretoria, 0001 • Tel: + 27 (0) 12 367 6000 • **www.weathersa.co.za** • **USSD: *120*7297#**

DISCLOSURE STATEMENT

The provision of the data is subject to the User providing the South African Weather Service (SAWS) with a detailed and complete disclosure, in writing and in line with the requirements of clauses 1.1 to 2.4 (below), of the purpose for which the specified data is to be used. The statement is to be attached to this document as Schedule 1.

1 **Should the User intend using the specified data for commercial gain then the disclosure should include the following**:

1.1 the commercial nature of the project/funded research project in connection with which the User intends to use the specified data;

1.2 the names and fields of expertise of any participants in the project/funded research project for which the specified data is intended; and

1.3 the projected commercial gains to the User as a result of the intended use of the specified data for the project/funded research project.

2 **Should the User intend using the specified data for the purposes of conducting research, then the disclosure should include the following**:

2.1 the title of the research paper or project for which the specified data is to be used;

2.2 the details of the institution and supervisory body or person(s) under the auspices of which the research is to be undertaken;

2.3 an undertaking to supply SAWS with a copy of the final results of the research in printed and/or electronic format; and

2.4 the assurance that no commercial gain will be received from the outcome from the research.

If the specified data is used in research with disclosure being provided in accordance with paragraph 2 and the User is given the opportunity to receive financial benefit from the research following the publication of the results, then additional disclosure in terms of paragraph 1 is required.

The condition of this disclosure statement is applicable to the purpose and data requirements of the transaction recorded in Schedule 1 on page 2.

SCHEDULE 1

Please note: The South African Weather Service will only act upon customer requirements noted on this disclosure statement and not from any other correspondence.

FULL PERSONAL DETAILS OF USER

Full Names	Brenda Nyeverwai Rumutsa
University/school/organisation	University of Venda
Student Number (if applicable)	1603638
Email address	brendarumucha@yahoo.com
Cellphone	0618689275
Supervisors	Dr N.S Nethengwe and Dr H Chikoore
Project/Thesis Title	*Integration of modern scientific and IK in an early warning system for climate sensitive malaria risk reduction in Mopani District.*
Current registered degree (e.g. BSc)	Ph.D Geography
Expected finalization date (MMYYYY)	15 august 2019

The South African Weather Service reserves the right to request, at any time, from the student proof of registration for the Degree at the University.

THE PURPOSE (*Please indicate a detailed description of the purpose for which the data will be used)*

The data will be strictly for research purposes. I would like to find out the Relationship between malaria and climate variables (Rainfall and Temperature) in Mopani district from 1988-2018 and also to see the trends, where exactly the outbreaks occur in relation to weather.

DATA REQUIRED *(Indicate weather elements (e.g. rain, temp), place/s, time period and resolution (e.g. daily, hourly)*

Weather elements – Monthly rainfall and temperatures for Mopani District. Monthly rainfall amounts (maximum and minimum) as well as maximum and minimum temperatures from 1988-2018.

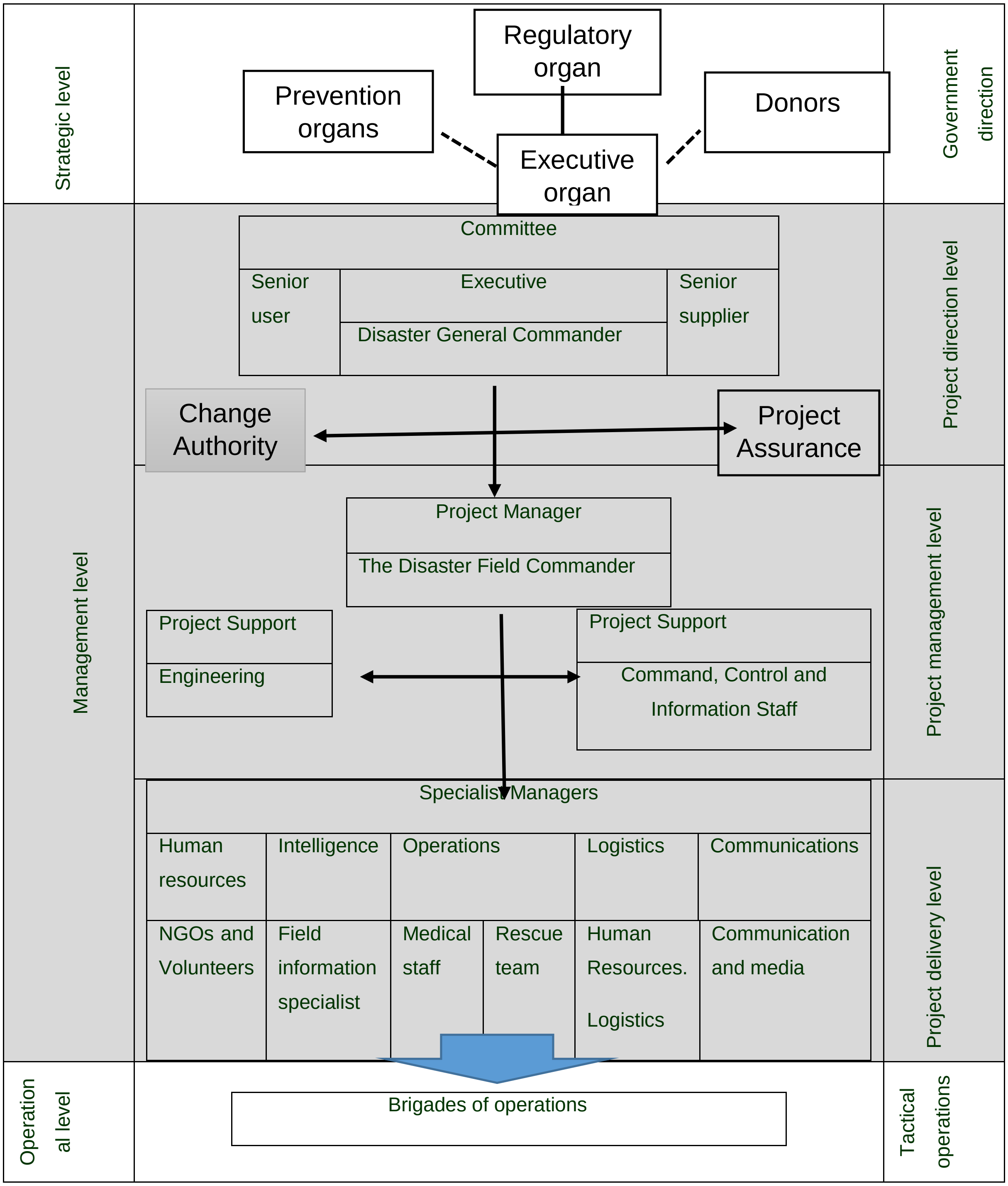
I hereby accept that:

- SAWS will be acknowledged in the resulting thesis/project or when published, for the data it provided.
- SAWS will be provided with a copy of the final results in printed or electronic format.
- The data received shall not be provided to any third party.

Signature of the User: Date: 23 July 2019

(*Please sign the document and do not type your name in as this is a legal document and requires a signature.*)

Appendix 12 Framework for organizational structure for disaster management projects



Source: Adapted from De Paula *et al*, (2017).

Appendix 13 Malaria risk reduction measures employed in Mopani District

Malaria risk reduction measures being employed					
		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	Scientific knowledge	191	55.0	55.0	55.0
	Indigenous knowledge	11	3.2	3.2	58.2
	Both	82	23.6	23.6	81.8
	None	63	18.2	18.2	100.0
	Total	347	100.0	100.0	

Source: primary