EFFECT OF ATMOSPHERIC TEMPERATURE AND RAINFALL ON MALARIA INCIDENCE RATES IN SELECTED DISTRICTS OF THE THREE ECOLOGICAL ZONES OF ZAMBIA, OVER A SEVEN- YEAR PERIOD: RETROSPECTIVE STUDY

BY

MWENYA SILOMBE

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DECLARATION

I, **Mwenya Silombe** hereby declare that this dissertation has been compiled by myself and that the sources of all the material referred to has been specifically acknowledged. This work has not previously been submitted for the degree at this University or any other.

Signature of Author: ……………………………………………………………..

Date: ……………………………………………………………………………….

APPROVAL

This dissertation of Mwenya Silombe is approved as partial fulfilling the requirements for the award of the degree of Master of Science in Ecological Public Health of the University of Zambia.

Examiner 1: ………………… ……………………………………………………….

Signature: ………………………………………

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Examiner 2: ………………………………………. …………………………………

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External Examiner: ……………………………….. …………………………………

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ABSTRACT

In 2020, it was estimated that 241 million malaria cases were recorded globally, increasing from 227 million in 2019, with African countries contributing most to the increase. Studies have indicated that malaria is influenced by climate. Climate factors such as temperature and rainfall affect malaria incidences through changes in the mosquito life cycle and duration or parasite behavior such as fertilization and breeding of mosquito's eggs. This study was conducted to determine the influence of atmospheric temperature and rainfall on confirmed malaria incidences in six selected districts of the three ecological zone of Zambia between the period of 2014 to 2020. Retrospective analytical comparative study design was used in this research. The first stage involved identifying the three ecological zones in Zambia; followed by randomly selecting two districts from each ecological zone. A total of six districts were selected and considered in the study. The second stage involved the collection of quantitative (secondary) data from the Ministry of Health and Meteorological Department both at district level. Confirmed malaria cases from 2014 to 2020 were used in this study. Microsoft® excel ® 2020 version was used to create graphs to show the annual trends of rainfall, atmospheric temperature and confirmed malaria incidences in six selected districts of the three ecological zones. Pearson's correlation analysis was used to measure the relationship between annual atmospheric temperature, rainfall (independent variables) and confirmed malaria incidences (dependent variable). The results showed a low positive Pearson correlation of statistical significance between annual rainfall and confirmed malaria incidences in the three ecological zones of Zambia from 2014 to 2020 ($r= 0.476$, $p < 0.001$). This entails that; annual confirmed malaria incidences and rainfall had a direct relationship. The Pearson correlation between annual atmospheric temperature and confirmed malaria was low negative relationship but statistically significant ($r= -0.451$, $p< 0.003$). This entails that; an increase in the independent variable (temperature) leads to a decrease in the dependent variable (malaria incidences). Districts of the ecological zone 3 received the highest amount of rainfall and also recorded the highest number of confirmed malaria incidences. The districts of the ecological zone 1 recorded the highest annual atmospheric temperature but lowest numbers of confirmed malaria incidences. This study conclusively reports that there was a direct relationship between annual rainfall and confirmed malaria in the three ecological zones. Further, there was an inverse relationship (low negative correlation) between annual atmospheric temperature and confirmed malaria incidences but this relationship was statistically significant. Future studies should consider increasing number of sampling districts from each ecological zone.

Key Words*: Malaria Prevalence, Mosquitoes breeding, Parasitic Diseases, Zambia Ecological Zones*

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DEDICATION

This dissertation is dedicated to my beloved daughters **Raye Mwenya Silombe**, **Ria Chanda Silombe** and my late parents **Mr. and Mrs. Silombe**.

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ABBREVIATIONS

ACEIDHA	Africa Centre of Excellence for Infectious Diseases of Humans and Animals
ANOVA	Analysis of Variance
CEEEZ	Centre for Energy, Environment and Engineering Ltd of Zambia
DRC	Democratic Republic of Congo
EZ1	Ecological Zone 1
GHGs	Green House Gases
IDSR	Integrated Disease Surveillance and Response
IRS	Indoor Residual Spraying
MoH	Ministry of Health
Mm	Millimeter
NASA	National Aeronautics and Space Administration
^{O}C	Degree Celsius
SDGs	Sustainable Development Goals
WHO	World Health Organization
ZMD	Zambia Metrological Department

CHAPTER ONE

INTRODUCTION

1.1 Background

Malaria is a serious disease in human beings which is caused by a protozoan parasite called Plasmodium. This parasite is transmitted through the bite of a female *Anopheles* mosquito. In 2020, it was estimated that 241 million malaria cases were recorded globally, increasing from 227 million in 2019, with African countries contributing most to the increase (WHO, 2021). Out of this world malaria cases, 96% is accounted for by twenty-nine countries and 55% of all malaria cases is accounted for by six countries; Nigeria (27%), Democratic Republic of Congo (12%), Uganda (5%), Mozambique (4%), Angola (3.4%) and Burkina Faso (3.4%) (WHO, 2021). Globally, malaria case incidence (i.e. cases per 1000 population at risk) reduced from 82 in 2000 to 57 in 2019, before increasing to 59 in 2020. There was no change in case incidence between 2020 and 2021 (WHO, 2022). Between the year 2000 and 2019, case incidence in the World Health Organization (WHO) African Region reduced from 373 to 225 per 1000 population at risk, but increased to 234 in 2020. The world malaria deaths reduced steadily over the period 2000–2019, from 897 000 in 2000 to 577 000 in 2015 and to 568 000 in 2019. In 2020, malaria deaths increased by 10% compared with 2019, to an estimated 625 000 (WHO, 2021). While there are four types of parasites that can cause malaria in humans, *Plasmodium falciparum* is by far the most deadly and common, particularly in Zambia and throughout sub-Saharan Africa. Though major achievements have been made in malaria control, the disease remains a significant cause of morbidity and mortality in Zambia, with one in five children under age five infected with malaria parasites, and other vulnerable population groups at risk (MoH, 2017). Zambia is among the 20 countries with the highest malaria incidence and mortality globally, and the country carries 1.4% of the global malaria cases and death burden, and 6% of the case burden in East and Southern Africa (WHO, 2019).

In Zambia, the country recorded about 2.6 million malaria cases and nearly 8000 malaria death in 2019 (WHO, 2021). Malaria incidence (per 1000 population at risk) in Zambia was 386 in 2013, 409 in 2014, and 335 in 2015, with a three-year average of 376 (Inambao *et al.*, 2013). Malaria and its effect have negative impact on the Zambian public health sector and this requires the government to be studying the malaria trends in the country time and again. The disease has also created significant economic burden among the population due to spending more resources on treatment, prevention measures and reducing human capital productivity (Sachs and Malaney, 2002, WHO, 2013). Considering the persistence of malaria in Zambia, it is important for National Health Organizations, Non-Governmental Organizations (NGOs) and ministries to consistently do retrospective reviews of trends and patterns in order to enhance response strategies and models of intervention development which may in turn, improve the effectiveness and responsiveness of health systems (Chasaya, Phiri and Ngomah, 2020).

Zambia is divided into three major agro-ecological zones (Zone 1, 2 and 3), which are primarily based on rainfall amount but also incorporate soils and other climatic characteristics (De Groote *et al.*, 2014). Semi-arid ecological zone 1 includes areas of southern, eastern and western Zambia: Zambia's valleys at 300- 800m altitude mostly lie in zone 1. Mean annual rainfall in zone I ranges below 800mm. Ecological zone 2 includes much of central Zambia, with most of Central, Southern, Eastern and Lusaka provinces. Annual rainfall in zone 2 averages 800-1000mm and distribution of rainfall is not as erratic as in zone 1, but dry spells are common. Average mean daily temperatures range from 23- 26°C in the hottest month October to 16-20°C in the coldest months of June and July. Ecological zone 3, the high-rainfall area, lies in a band across northern Zambia, including the Northern, Luapula, Copperbelt, Northwestern provinces and some parts of the Central province (De Groote *et al.*, 2014). This region receives over 1000mm of precipitation each year (Zulu, 2014). Each zone has unique characteristics, due to variations in temperature, rainfall, and humidity, that influence the malaria vector and parasite, and subsequent transmission (Kasali, 2008). Studies have indicated that malaria is affected by climate (Craig *et al*., 2004, Kim *et al*., 2012) . Climate factors such as temperature and rainfall affect malaria incidences through changes in the mosquito life cycle and duration or parasite behavior such as fertilization and breeding of mosquito’s eggs (Unep *et al*., 2008, Paaijmans *et al*., 2010, Parham and Michael, 2010, Jung *et al*., 2023).

1.2 Problem statements and Justification

In Zambia, Malaria is a major cause of morbidity and mortality especially in highly endemic areas and among vulnerable population (WHO, 2013). In 2019, the country recorded nearly 8000 malaria deaths despite the government effort in fighting malaria (MoH, 2020). North-western. Luapula, Northern and Muchinga provinces recorded the highest number of malaria cases (Nawa *et al*., 2019, MoH, 2020). These provinces are found in the northern parts of Zambia and receives the highest amount of rainfall of up to 1400mm annually, and fall in ecological zone 3 (Unep *et al*., 2008, Kajumba, 2018). Efforts to control and eliminate malaria in the country through the use of interventions have been scaled up by the government with the help of local and international partners although malaria incidences are still high (MoH, 2017).

Studies have shown that malaria is influenced by changes in climate (Kim *et al.*, 2012). Climate factors such as temperature, rainfall and humidity play a role in the incidences of malaria (Reiter, 2001). In recent years, Zambia has seen fluctuations in atmospheric temperature and rainfall amounts recorded which is considered climate variation and change (Kajumba, 2018). Human activities also influence malaria parasites population and its behavior (Ferguson *et al.*, 2010; Shah *et al.*, 2022). Therefore, it is important to determine the relationship between climate factors and malaria incidence rates in order to conduct more effective prevention and control programs. This research focused on measuring the relationship between atmospheric air temperature, rainfall and confirmed malaria incidence rates in six selected districts of the three ecological zones of Zambia.

1.3 Research Questions

In order to meet the objective of the study, the research questions set include the following;

1. What are the annual trends in confirmed malaria incidences in the three ecological zones?
2. What are the annual trends in atmospheric temperature and rainfall in the three ecological zones?
3. What is the relationship between the annual atmospheric temperature and confirmed malaria incidences?
4. What is the relationship between the annual rainfall and confirmed malaria incidences?

1.4 Objective

1.4.1 General objective

The general objective of this study was to determine the influence of annual atmospheric temperature and rainfall on confirmed malaria incidence rates in six selected districts of the three ecological zones of Zambia from 2014 to 2020.

1.4.2 Specific Objectives

To meet the stated overall objective, the study focused on the following specific objectives:

1. To establish annual trends in confirmed malaria incidences in three ecological zones,
2. To establish the annual trends in atmospheric temperature and rainfall in three ecological zone,
3. To determine the relationship between annual atmospheric temperature and confirmed malaria incidences, and

4. To determine the relationship between annual rainfall and confirmed malaria incidences.

1.5 Conceptual framework

The effects of atmospheric temperature and rainfall on malaria incidence have been conceptualized in Figure 1. Rainfall pattern and atmospheric air temperature increases the density of *Anopheles* mosquitoes resulting in a corresponding enhanced malaria cases and consequently morbidity and mortality. The conceptual framework will help in answering the research question and to address the specific objectives.

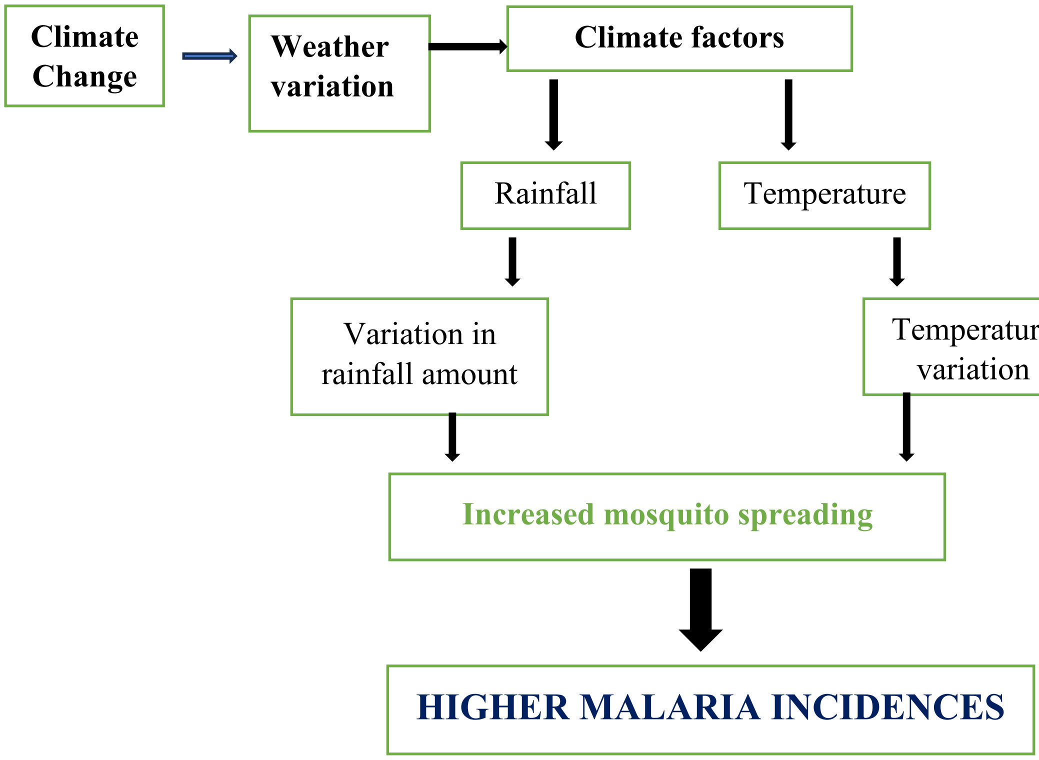

Figure 1: conceptual framework of the influence of climate factors on Malaria Incidences

CHAPTER TWO

LITERATURE REVIEW

2.1 Climate variability in Zambia

The physical processes that cause climate change are scientifically well documented: both human activities and natural variability are contributing to global and regional warming. Obviously, the natural factors are almost beyond human control. But the human factors are to a large extent under human control**.** According to the Intergovernmental Panel on Climate Change (IPCC), the global warming observed over the past 50 years is as the result of increased greenhouse gases generated by human activities (Field *et al.*, 2008)**.** Climate change is a broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth's atmosphere (Caminade *et al.*, 2014). Early on in human history our effect on the climate would have been quite small. However, as populations increased and increased human activities such as cutting of trees down in large numbers, burning of fossil fuel, charcoal burning, so our influence on the climate increased (Pourtois *et al.*, 2023; Trenberth, 2018). This is because trees take in carbon dioxide and produce oxygen therefore, reducing the amount of carbon dioxide in the atmosphere.

The Industrial Revolution, starting at the end of the 19th Century, has had a huge effect on climate. The burning of fossil fuels has increased the amount of carbon dioxide (a greenhouse gas) released in the atmosphere (Kweku *et al.*, 2018). Carbon dioxide, a major greenhouse gas, is increasing in the atmosphere faster than at any time measured in the past, having grown by about 35 percent since 1850 (Field *et al.*, 2008).Two other greenhouse gases, methane and nitrous oxide, are present in the atmosphere at much lower concentrations than carbon dioxide but have increased rapidly. Methane has increased by 150 percent; in addition, it is 25 times more effective per molecule at trapping heat than carbon dioxide. Nitrous oxide, nearly 300 times more effective, has increased by more than 20 percent (Kweku *et al.*, 2018).

Zambia's climate is influenced by the equatorial low and the Inter-Tropical Convergence Zone (ITCZ) as they move north and south over Africa in different months of the year. In January the ITCZ forms Z-shape over Africa and it is at this time that it controls rainfall over Zambia (Kasali, 2008). The major part of the country is classified as humid subtropical or tropical wet and dry, while the south-west of the country is semi- dry which receives less rainfall. The country is characterized into three distinct seasons; a cool dry season (May to mid- August), a hot and dry season (mid- August to Mid- November) and a wet rainy season (mid- November to April) (Bailey, 2021; Musonda, 2013). The annual rainfall ranges from 700mm in the extreme southwest to 1,400mm in the north and is 1,001mm on average (Musonda, 2013). On a seasonal basis, more than 90% of annual rainfall is concentrated in the rainy season from November to March. The 8% of the residual falls in October and April, while the remaining 2% occurs in September and May. On average, the monthly rainfall ranges from 100 to 250mm. Zambia have the average temperature of 21ºC and July is the coldest month with the range of 3.6- 12.0ºC. The hottest month is October with temperature range of 27.7–36.5ºC (Chipeta and Mumba, 2000; Musonda, 2013). Geographically, the actual levels of air temperature and rainfall pertaining to the seasons differ from location to location depending on the ecological zone of the country. The effect of climate varies with different ecological areas which experience different temperature and rainfall. Zambia has three ecological zones that is zone 1, 2 and 3. Zones 1 and 2 occupy 55.8% of Zambia's landmass and are located in the southern half of the country, while Zone 3 occupies the northern half (Kasali, 2008). These zones experience different climate for example Zone 1 receives less than 800mm, Zone 2 800-1000mm and Zone 3 above 1000mm rainfall annually.

2.2 Vector-borne diseases

Vectors are lifeforms that act as a medium for transmitting infectious germs from animals to humans and in some cases, between humans. These organisms first get infected by the disease-causing pathogens, and once infected, they can transmit the pathogen to humans throughout their life whenever they come in contact with a human host and caused a disease (Lo Iacono *et al.*, 2017; Martens *et al.*, 1999). Vector-borne diseases are caused by the bites of infected insect like mosquitoes, bacteria, protozoa, worm parasite and ticks which acts as a carrier. These pathogens spend part of their life cycle in a cold-blooded arthropod vector and therefore, they are influenced by environmental changes such as climate variation. The transmission of these diseases may, therefore, be affected by ambient temperature (Mubemba *et al.*, 2022). Malaria, dengue fever, plague, Japanese encephalitis and yellow fever are examples of vector-borne diseases. Diseases that are spread to humans through mosquitoes include Malaria, Dengue, West Nile virus, Zika virus, Yellow fever and Chikungunya. Mosquito borne diseases are major public health problem in most parts of the world (Teklehaimanot *et al.*, 2004). Among the types of mosquito- borne diseases, malaria is the most commonly known in the world, and close to 50% of the world's population live in areas at risk of infection (Ligsay *et al.*, 2021). In Zambia, numerous zoonotic pathogens have been reported in changed ecological landscapes and malaria disease is the one of the leading cause of deaths in the country (MoH, 2017; Mubemba *et al.*, 2022).

2.2.1 Mosquitoes and *plasmodium* life cycles

The life cycle of mosquitoes has four stages including; egg, larva, pupa, and adult (Figure *2*). The mating of most mosquitoes takes place when females enter swarms of flying males and it usually occurs at low light intensities especially in the evening and morning (Becker *et al*., 2010). Copulation requires a complex merging of the male and female reproductive structures and takes less than half a minute for the male to deposit the spermatozoa in the bursa copulatrix of the (Crans, 2004). Adult mated females take several blood meals, with each meal resulting in the laying of a batch of eggs, thereby resulting in hundreds of offspring. They lay between 50 and 500 eggs in 2–4 days (or longer in cool temperate climates) after taking a sufficient blood meal (Eckhoff, 2011). Females deposit their eggs onto the water surface in batches (*Culex*). Mosquitoes require aquatic habitats for their development, although *Aedes* and *Ochlerotatus* species can lay their eggs in moist soil. The hatching process is greatly affected by water temperature and in cold season premature hatching usually occurs, causing delays in the development of the mosquitoes (Becker *et al.*, 2010). After hatching, they pass through three stages; larval instars, pupal stage then transformation into an adult.

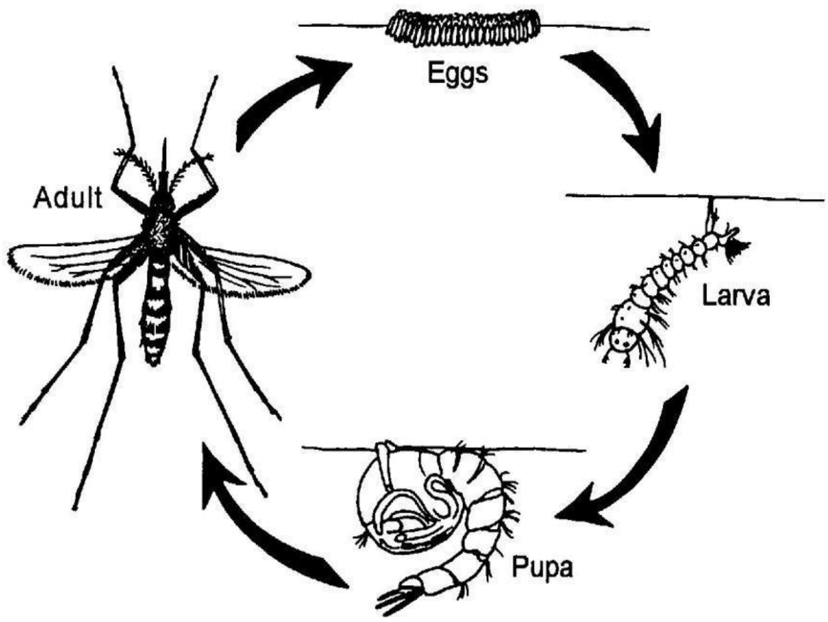

Figure 2: Mosquito life cycle (Source: Becker et al., 2010)

In humans, malaria infection is caused by the female Anopheles mosquitoes bite and injecting *Plasmodium* parasite in the form of sporozoites which grow and multiply first in the liver cells and then in the red blood cells over the next 7 to 10 days, causing no symptoms (Baer *et al.*, 2007). The parasites, in the form of merozoites are released from the liver cells in vesicles, journey through the heart, and arrive in the lungs, where they settle within lung capillaries. The merozoites invade red blood cells (erythrocytes) and multiply again until the cells burst as shown in Figure 3. This cycle is repeated, causing fever each time parasites break free and invade blood cells, and this called blood stage (Baer *et al.*, 2007). The merozoites in these cells develop into sexual forms of the parasite, called gametocytes. During blood feeding, when a mosquito bites an infected human, it ingests the gametocytes, which develop further into mature sex cells called gametes. The female gametes are fertilized by the male gametes resulting in the formation of a zygote which develops into an actively moving ookinetes that burrow through the mosquito's midgut wall and form oocysts on the exterior surface. Thousands of active sporozoites develop inside the oocyst. The oocyst eventually bursts, releasing sporozoites into the body cavity that travel to the mosquito's salivary glands. The cycle of human infection begins again when the mosquito bites another person (Crans, 2004).

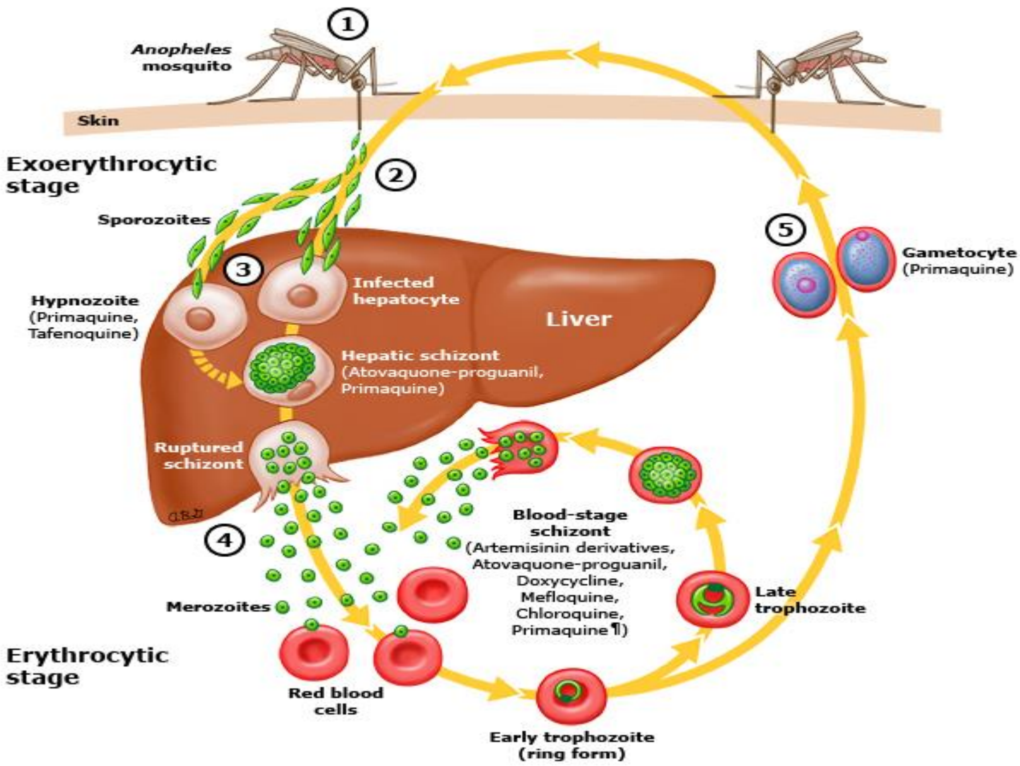

Figure 3: Anopheles life cycle (Source: Baer *et al*., 2007*)*

2.3 Malaria in Zambia

Zambia lie between the latitude 10° and 18° South, longitude 22° and 33° East in the Southern part of Africa and it is a landlocked country covering 752,612 square kilometers. It is bordered by eight countries: Tanzania and the Democratic Republic of Congo (DRC) to the north; Botswana and Namibia to the south; Malawi and Mozambique to the east; and Zimbabwe and Angola to the west (Figure 4). The majority of Zambians in urban areas live in informal settlements that lack basic services (Chiwele *et al*., 2022). Malaria disease is one of the major public heath importance although there has some reduction in malaria burden among children and women. In 2004, malaria infection accounted for 45% of hospitalizations and outpatient department visits. About 20% of children under five, mostly among the rural poor, tested positive for malaria parasites in 2006, and 13% suffered from severe anemia (Finn *et al.*, 2020). In order to reduce the burden of malaria, the Zambian government through the allied ministries and partners have come up with the National Health Strategic Plan (NHSP) and National Development Plan (NDP). The NHSP represent the compressive strategic framework and direction of the health sector in attending national and global health goals (MoH, 2021).

Figure 4:Map of Zambia and the surrounding countries (Source: UN Cartographic Section)

According to the Zambia's Ministry of Health, the common malaria parasite, *Plasmodium falciparum,* accounts for more than 95%, while *P. malariae* makes up 3% and *P. ovale* 2% (Chanda *et al.*, 2012; Keating *et al.*, 2009). In April 2017, the government through the Ministry of Health launched the National Malaria Elimination Strategy 2017-2021 and rebranded the National Malaria Control Centre to be the National Malaria Elimination Centre in Lusaka. (MoH, 2021; Steketee *et al.*, 2020). The goal of this strategy was to eliminate local malaria infections and disease by 2021 and also maintain free malaria status (MoH, 2017). The

Ministry of Health (MoH) set six objectives to be achieved in order to meet the overall goal of the strategy; Increase the implementation rate of interventions from 36 percent in 2015 to 95 percent by 2018, Reduce malaria incidence from 336 cases per 1,000 population in 2015 to less than 5 cases per 1,000 population by 2019, Increase the malaria-free health facility catchment areas (HFCAs) from 0.5 percent in 2015 to 100 percent in 2021, Reduce malaria deaths from 15.2 deaths per 100,000 in 2015 to less than 5 deaths per 100,000 population by 2021, Achieve 100 percent malaria-free status by 2021 and maintain 100 percent malaria-free status, following 2021 (MoH, 2017). The common key interventions the government is undertaking in malaria prevention, control and management involves;

1. Vector control using indoor residual spraying (IRS) and promotion of ownership and use of insecticide-treated nets (ITNs);
2. Malaria case management using effective diagnostics and lifesaving drugs-artemisinin-based combination therapy (ACTs);
3. Control of malaria in pregnancy through intermittent presumptive treatment strategy and;
4. Information, education, and communication (IEC)/ behavioral change communication (BCC) strategies.

Despite these strategies, the country has continued recording high malaria deaths and cases. In 2007 there were 4.4 million cases of malaria; incidence was down from 412 per 1,000 people in 2006 to 358 per 1,000 Malaria accounted for 20% of maternal mortality, 40% of infant mortality, 47% of the overall disease burden among pregnant women, and 50% of the disease burden among children under five years of age (Jumbam *et al.*, 2020). Studies have shown that Zambia's malaria incidence is at peak between the period of November and May which can be seen in Figure 5 which shows the number of confirmed malaria case country wide were at peak between march to May (Inambao *et al.*, 2013; Steketee *et al.*, 2020).

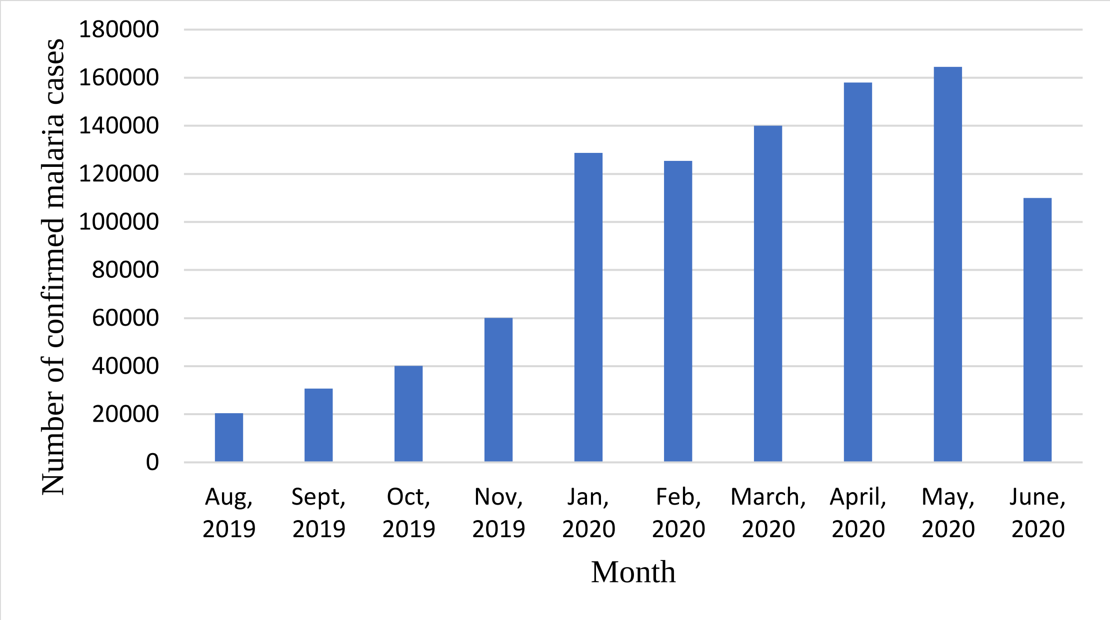

Figure 5: International Disease Surveillance and Response (IDSR) reported Confirmed Malaria cases in Zambia from August 2019 to June 2020 (Source: Chasava et al., 2020)

2.4 Influence of temperature on malaria

A study conducted by Ebi *et al*. (2005), reported that temperature changes could change the geographic distribution of malaria and make some regions suitable for malaria parasite which was previously not suitable for malaria parasite. Temperature plays an important role in the mosquito and parasite life cycle (Shapiro *et al.*, 2017). *Anopheles* mosquitoes go through four stages in their life cycle: egg, larva, pupa, and adult. The first three stages are aquatic and last 7-14 days to reach the adult stage, but this depends on the species and the ambient temperature because the increase in temperature increase the rate of development (Blanford *et al.*, 2013; Komen *et al.*, 2015). They showed that the malaria parasite is sensitive to temperature and Minimum threshold temperatures for parasite development of *Plasmodium falciparum and P. vivax* are 18ºC and 15ºC, respectively. Studies of diurnal temperature fluctuations show that fluctuations around low temperatures increased malaria risk while fluctuations around high temperatures decreased the risk. A study by Bi *et al*. (2003) reported the highest positive relationship between monthly incidence of malaria and monthly mean maximum of 30°C and minimum temperature of 16°C, with one-month lag in Shuchen, China. The results showed a greater correlation coefficient association between minimum temperature and malaria incidences than the maximum temperature. In a temperate region of China, the maximum and minimum temperature had the highest positive relationship with monthly incidence. The relationship showed a one-month lag and 1°C increase in minimum temperature resulted in 12 to 16% increase in incidence and minimum temperature of 10.99°C was more effective than maximum temperature of 25°C (Zhang *et al.*, 2008). When the temperature increase, particularly minimum temperature (18- 26°C) there is increase in the survival of *Plasmodiums* and *Anopheles* in winter and therefore results in faster transmission and distribution of malaria in populations (Pemola and Jauhari, 2006). The timing and intensity of blood feeding by mosquito parasite is also influenced by temperature(Githeko and Ndegwa, 2001). Female mosquitos have shown reduced blood-feeding frequency at lower temperature (15- 20°C), on the other under warmer temperature (30°C) there is high frequency of blood feeding (Afrane *et al*., 2005; Lardeux *et al*., 2008; Alonso, Bouma and Pascual, 2011). According to Githeko et al. (2005), the average lifespan of mosquitos which carry malaria is 21 days and at 25ºC, the malaria parasite only takes 19 days to mature while at 30ºC takes 8 days. This shows that temperature affect the period of malaria parasite development; at higher temperature they develop within a short period and this potentially leads higher malaria incidences.

2.5 Influence of rainfall on malaria

The rate of malaria incidences is influenced by change in climate factors such as temperature, humidity and rainfall. Rainfall amounts affects the incidences of malaria by offering a lot of sites suitable for mosquitoes to breed in such as pools of water (Mafwele and Lee, 2022). (Githeko and Ndegwa, 2001; Mafwele and Lee, 2022) found that malaria incidences were associated with increase in rainfall. Odongo-Aginya *et al*. (2005) study showed the rate of malaria incidences was at peak coinciding with the peak rainfall partner because rainfall provides vector breeding sites and also it prolongs the life span by increase of water availability. According to the study done by Mishra *et al*. (2023) which was on the trends of malaria incidence and its association with rainfall in Kalahandi District of Odisha, India**.** The results showed highest records of malaria incidences in the rainy season and months before the rainy season (October to November). Rainfall showed a low positive correlation with malaria incidences in the cold (r= 0.47). Mosquitoes need standing water in order to complete their lifecycle, they lay their eggs in still/ stagnant water and can go from egg to biting adult even 7-10 days (van Lieshout *et al.*, 2004). According to Jung *et al*. (2023) rainfall hoists the environmental humidity and brings about many temporary puddles, concurrently increasing the number of mosquitos breeding sites and which enhances mosquito survival. Though, excessive rainfall and build-up of surface water in complicated terrain would potentially destroy mosquito-breeding sites, thus reducing the mosquito density. A study done by Tian *et al*. (2008) also disclosed that when the rainfall is too much it rinses always the breeding sites, eggs and larva leading to lower rates of malaria transmission because it takes a long time for the mosquito to rebuild its lifecycle for an infection. Makame and Kangalawe (2018)) observed that the highest amount of rainfall of above 1600mm showed reduced malaria incidences by washing away the mosquito eggs and larva. Studies have shown that different *Anopheles* mosquitoes have preference to types of water to breed in. For example, *Aedes vexans* favored high humidity, intermediate degree days, and low precipitation. *Coquillettidia perturbans* and *Oc. Dorsalis* activity increased with high humidity and high rainfall, respectively (Odongo-Aginya, 2005; Baril *et al*., 2023). According to Kifle *et al*. (2019) rainfall influences malaria incidence in Eritrea, indicating a direct relationship between rainfall and malaria incidences. A study done Mzyece (2016) in Zambia, specified that malaria cases increased at the onset of the rain season and the highest numbers of cases were recorded in January, and they dropped at the onset of dry cold season April after the rains have gone. The variables exhibited a positive trend in the month of January clearly show the direct relationship monthly rainfall and monthly malaria cases in Zambia.

CHAPTER THREE

METHODOLOGY

3.1 Research Design

The study used Retrospective analytical comparative as the study design. This design is used to investigate the association/ relationship between two variables (independent and dependent) and is used after outcome of interest has already occurred at the time of study (Sena *et al.*, 2015). Atmospheric temperature, rainfall and confirmed malaria incidences for seven-year period was collected from 2014- 2020 for analysis.

3.2 Study Area

Zambia is classified into three ecological zones based on the amount of rainfall received annually. These ecological zones have varying climatic and other environmental conditions that are suitable for the propagation of *Anopheles* mosquitoes and malaria parasites**.** Research results from the district of a particular ecological zone can be applicable to other areas with similar ecological conditions. The ecological zones are classified as; Ecological zone 1 receives annual rainfall of less than 800mm and districts sampled were Livingstone and Sesheke. Ecological zone 2 receives annual rainfall of between 800- 1000mm and districts sampled were Chipata and Chongwe. Ecological zone 3 receives annual rainfall of between 1000-1400mm and districts sampled were Chililabombwe and Solwezi. The map in Figure 6 shows the three ecological zones and six selected districts.

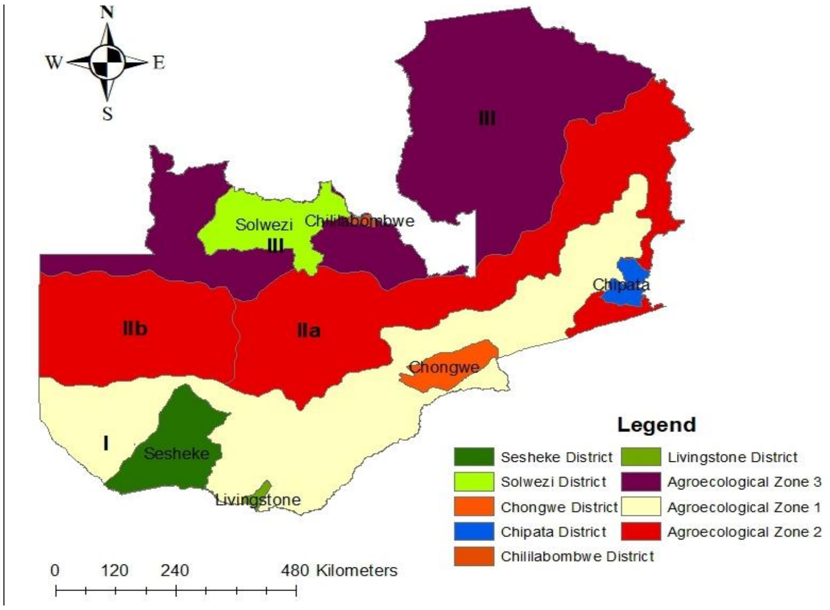

Figure 6: Map of Zambia showing the three ecological zones and six districts (Source: Smale and Asare-Marfo, 2014)

3.2.1 Sampled district in Ecological zone 1

The districts sampled from this ecological zone were Livingstone and Sesheke. Livingstone is a district found in Southern Province of Zambia, located at a Latitude of 17° 39' 59.99" S and Longitude 25° 49' 59.99" E. According to 2022 population statistics, the district has a total population of 177,393 inhabitants. Sesheke is a small border district and it is situated across Zambezi River from Nambia's Katima mulilo. It is located at latitude of 17°28'33.35"S and longitude 24°17'48.62″E, with a population size of 72, 655 inhabitants.

3.2.2 Sampled districts in Ecological Zone 2

Chipata and Chongwe districts were sampled from this ecological zone. Chipata is a district located at a Latitude 13°38'43.0"S and Longitude of 32°38'47.0"E. The district has a total population of 327, 059 people. Chongwe is a district located in Lusaka Province of Zambia, has a latitude of 15°19'44.98"S and longitude of 28°40'55.34"E. The district has the total population of 313, 389 according 2022 statistics by Zambia Statistics Agency.

3.2.3 Sampled districts in Ecological Zone 3

In this ecological zone, the sampled districts were Solwezi and Chililabombwe. Solwezi district is located on latitude 12°08'36.0"S and longitude 26°23'09.0"E. The district has a population of 332, 389 people as of 2022 census statistics. Chililabombwe is a district on the Copperbelt province of Zambia. The district has a latitude of 12° 21' 53.1" S and longitude of 27° 49' 22.3" E. The district has a population of 141, 899 inhabitants according to 2022 statistics by Zambia Statistics Agency.

3.3 Variables

3.3.1 Dependent Variable

The dependent variables are variables being tested and measure in an experiment and is 'dependent' on the independent variables. These variables are expected to change as a result of changes in independent variable and is presumed as the effect (Isaacs, 2014). Annual confirmed malaria incidences are the dependent variable.

3.4 Independent Variables

The independent variables that are expected to influence dependent variables and it is assumed to be a direct effect on the dependent variables (Isaacs, 2014). It's called "independent" because it's not influenced by malaria incidences in the study. Atmospheric air temperature and rainfall are the independent variables in this study. Table 1 shows the study variables and their operation measurements.

Table 1: Study variables, operation measurements and indicators

Variables	Definition of measurement	Scale of measurements		Indicators
Dependent Variable: Malaria incidence	Confirmed malaria cases recorded per year	Binary (Percentages %) Ordinal	1.	2. Number of new malaria cases per year 3. Number of Mortality case fatality per year 4. Parasite prevalence by type of parasite per year
Independent Variables:				
Atmospheric temperature	Degree Celsius (ºC)	Interval	1.	2. Humidity
Seasonal rainfall pattern	Millimeters (mm)	Ordinal	1.	2. Floods 3. A lot of Vegetation growth with high rainfall

3.5 Sampling method

Random Sampling

Random sampling is a method of choosing a sample of observations from a population to make assumptions about the population and each sample has the same probability as other samples to be selected to serve as a representation of an entire population (Cunningham *et al.*, 2019; Taherdoost, 2016). The study areas were randomly selected from each ecological zone. The districts of Zambia were listed according to their ecological zone in the excel spreadsheet and random numbers were assigned to each district (district ID). Two districts from each ecological zone were selected by randomization using Microsoft ® excel®. Livingstone and Sesheke districts were selected from ecological zone 1, using the same method Chipata and Chongwe districts were selected from ecological zone 2, Chililabombwe and Solwezi districts were selected from ecological zone 3.

3.6 Data Collection Method and Tools

3.6.1 Malaria data

Malaria data was obtained from the Ministry of Health at respective district offices. All confirmed malaria incidences data was extracted from the district data base from 2014 to 2020 for each district. The data collected was annual confirmed malaria incidences.

3.6.2 Climatic data

Atmospheric air temperature and rainfall data was obtained from the Zambia Meteorological Department (ZMD) offices at respective districts. Two district offices did not have officers at the station and data was collected from the headquarters in Lusaka. The annual data of atmospheric temperature and rainfall were collected for a period of seven years 2014- 2020.

3.7 Data analysis

Atmospheric temperature, rain and confirmed malaria incidences was extracted in Microsoft excel from Zambia Meteorological Department and Ministry of Health respectively. The data collected was cleaned and coded for analysis. Descriptive statistics of graphs was used to show the trends of climate factors and malaria in three ecological zones using Microsoft excel 2020 version. Pearson's correlation analysis was performed in statistical package for social scientists (SPSS) version 26.0 to show the influence of air temperature and rainfall (independent variables) on malaria incidences (independent variable).

3.8 Ethical Considerations

In this research, Appendix 1, Appendix 2 Appendix 3Appendix 4 were used to apply for ethical clearance. The ethical clearance was obtained from Excellence in Research Ethics and Science (ERES) Converge Institutional Research Board (IRB) to conduct the study, Ethical Clearance number- ERES Ref No. 2021-Aug-008 (Appendix 5). In addition to this, permission was obtained from the Director for Zambia at Meteorological Department for use to climate data and the Director at the Ministry of Health for malaria cases records (Appendix 6Appendix 7).

CHAPTER FOUR

RESULTS

4.1 Annual trends of atmospheric temperature, rainfall and confirmed malaria incidences in six selected districts of the three ecological zones

Annual trends of atmospheric temperature, rainfall and confirmed malaria incidences in six selected districts of the three ecological zones from 2014 to 2020 are shown in figures 7,8 and 9, respectively. The highest temperature was recorded in 2015 in districts of the ecological zone 1 and the lowest temperature was recorded in 2017 in districts of the ecological zone 2. Chililabombwe and Solwezi districts of the ecological zone 3 received the highest annual rainfall in 2017 and the lowest annual rainfall was recorded in the selected districts of the ecological zone 1 in 2019. The highest number of confirmed malaria incidences was recorded by districts of the ecological zone 3 in 2020. Chipata and Chongwe districts of the ecological zone 1 recorded the lowest number of confirmed malaria incidences in 2019.

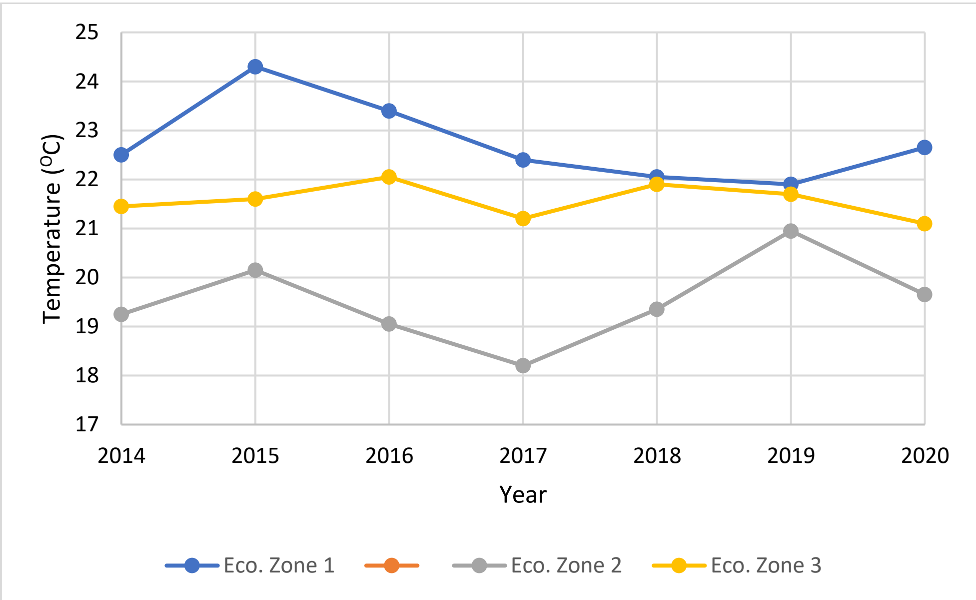

Figure 7: Annual trends of atmospheric temperature in six selected districts of the three ecological zones (2014- 2020)

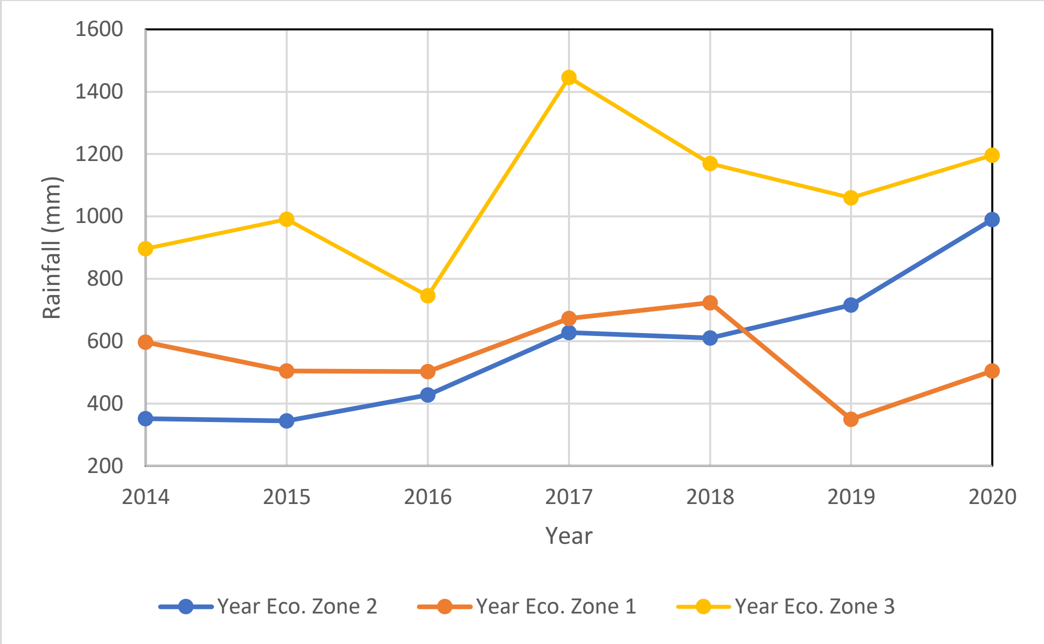

Figure 8: Annual trends of rainfall in six selected districts of the three ecological zones (2014- 2020)

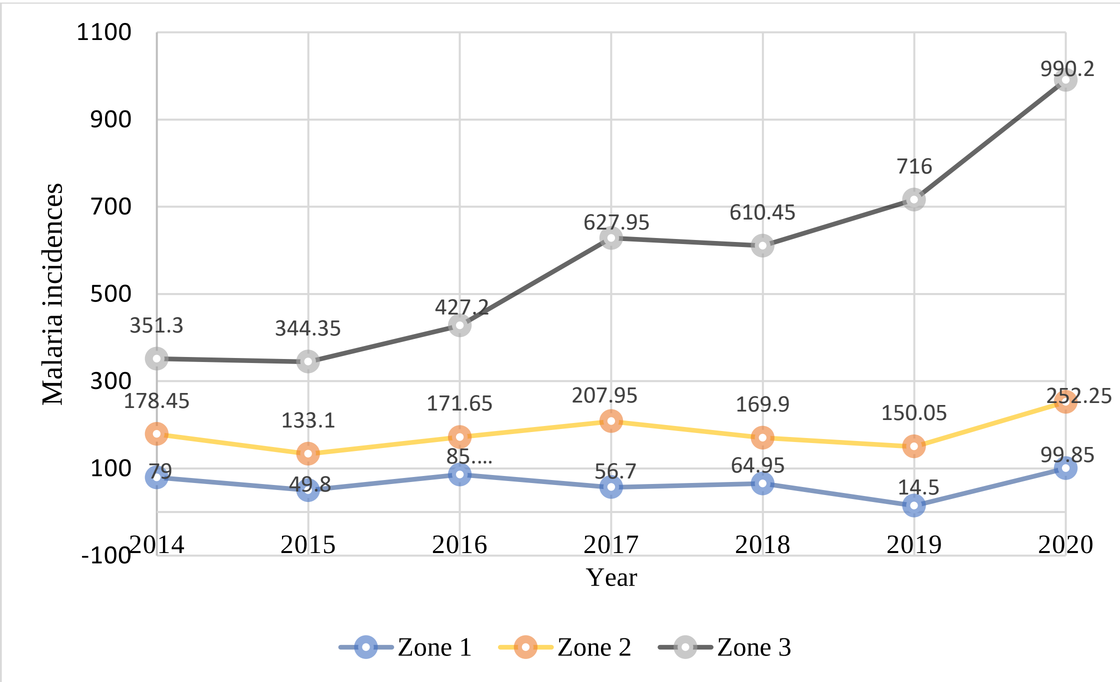

Figure 9: Annual trends of confirmed malaria incidences in six selected districts of the three ecological zones (2014- 2020)

4.2 Annual trends in the occurrences of confirmed malaria incidence and rainfall

Chililabombwe and Solwezi districts of the ecological zone 3 had the highest number of confirmed malaria incidences and received the height annual rainfall (Figure 10) followed by

Chipata and Chongwe districts of the ecological zone 2 (Figure 11) and then Livingstone and Sesheke districts in the ecological zone 1 (Figure 12). The number of confirmed malaria incidences and rainfall received in two districts of the three ecological zones varied from year to year, with some years showing increases and others showing decreases. The number of confirmed malaria incidences in two districts of the ecological zone 1 ranges from 3 to 10.2 which was the lowest compared to the other selected districts of ecological zone 2 and 3.

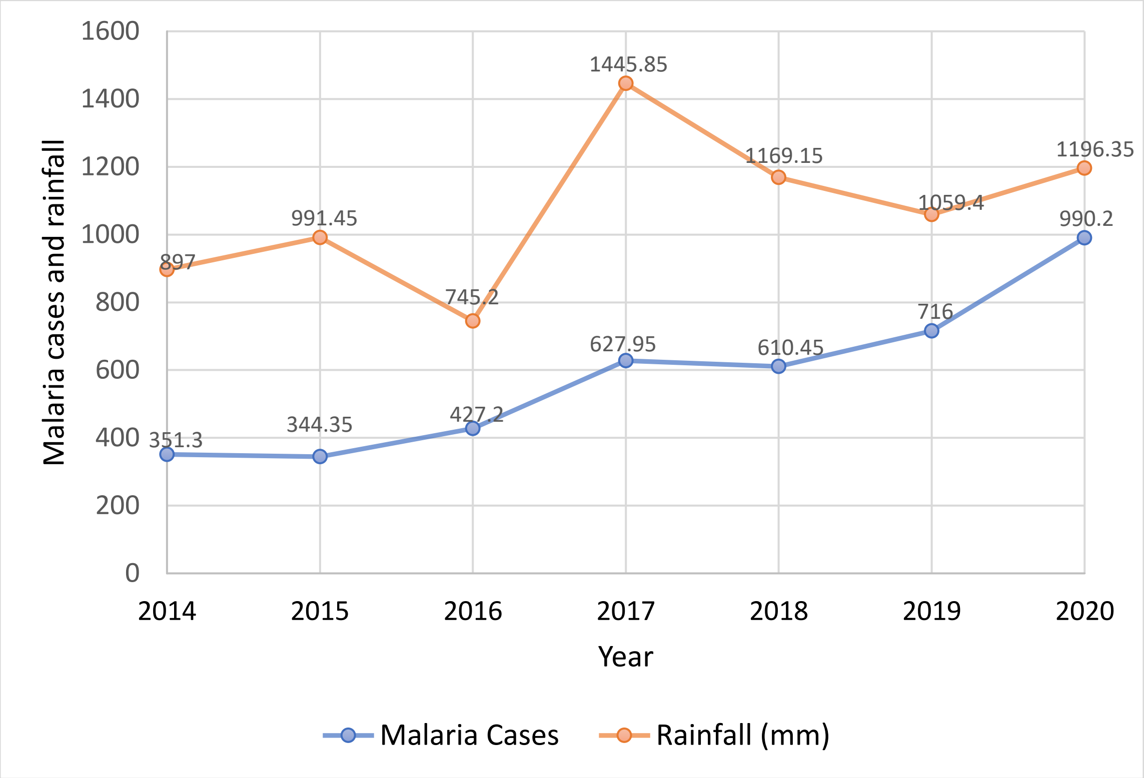

Figure 10: Annual trends of confirmed malaria cases and rainfall in two selected districts of the ecological zone 3

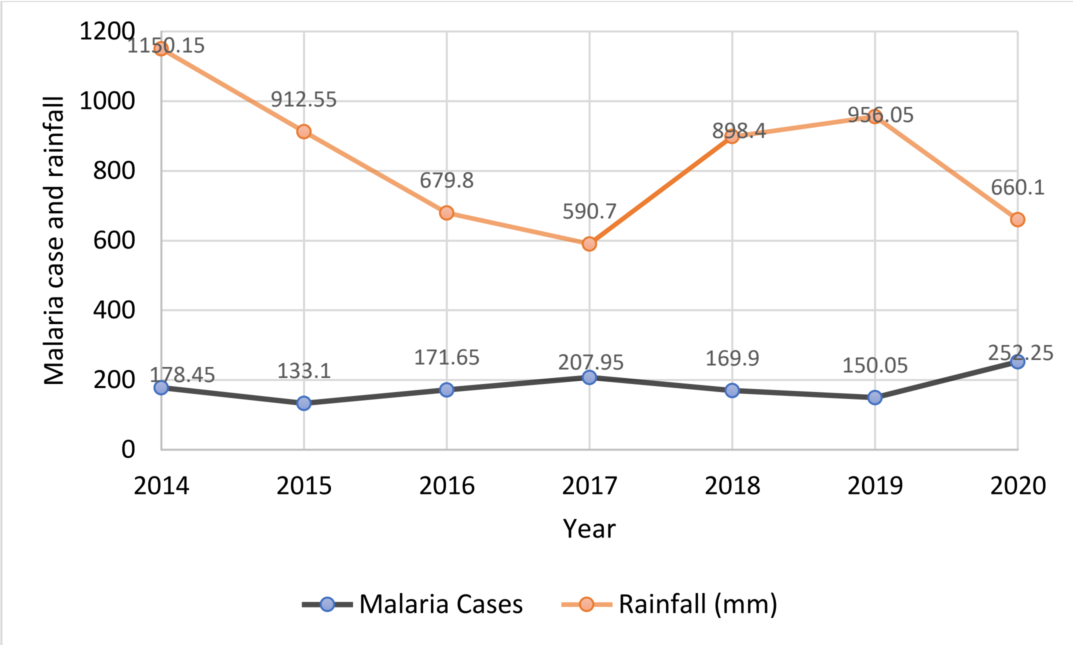

Figure 11: Annual trends of confirmed malaria incidences and rainfall trends in two selected districts of the ecological zone 2

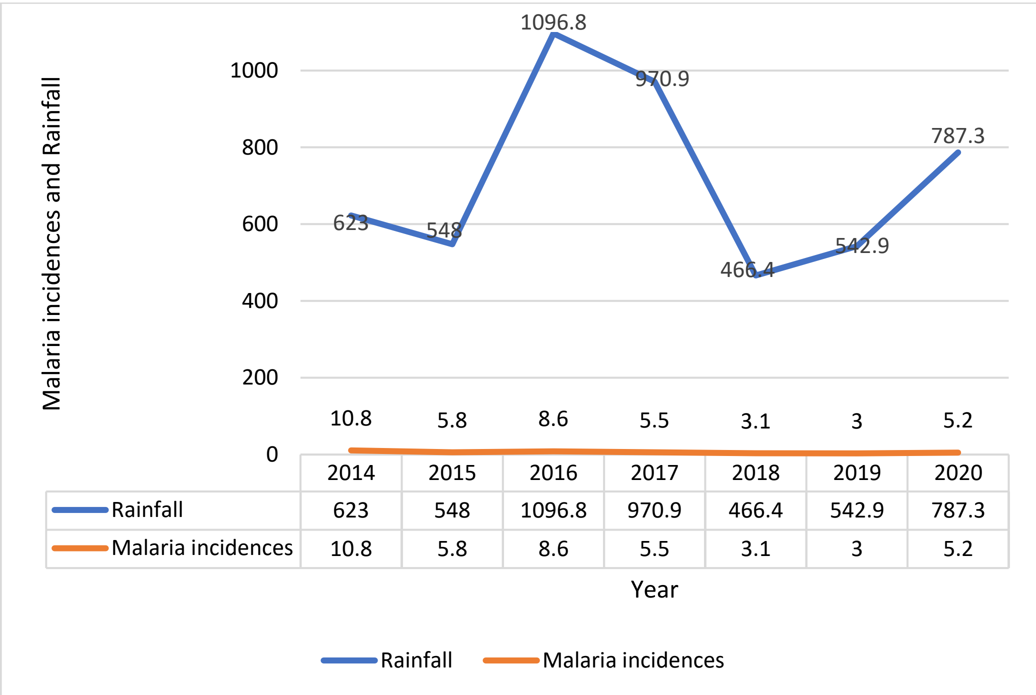

Figure 12: Annual trends of malaria incidence and rainfall trends in two selected districts of the ecological zone 1

4.3 Annual trends in the occurrences of confirmed malaria incidence and atmospheric temperature

The two selected districts (Livingstone and Sesheke) of the ecological zone 1 recorded highest atmospheric temperature of between 22.7 and 23.7ºC but recorded the lowest number of confirmed malaria incidences (Figure 13). The lowest atmospheric temperature was recorded in the two selected districts (Chipata and Chongwe) of ecological zone 2 between 18.2 to 20.15ºC (Figure 14). Atmospheric temperature for the two selected districts (Chililabombwe and Solwezi) of the ecological zone 3 ranges from 20.1 to 22.05ºC and these districts recorded the highest number of confirmed malaria incidences (Figure 15). Figure 16 show the aggregated data of annual atmospheric temperature and confirmed malaria incidences for the six selected districts of the three ecological zones. The atmospheric temperature recorded in all the six selected districts of the three ecological zones were below 30 ºC which is not associated with high mosquito activities. Studies have suggested that the optimal temperature for mosquito activity is between 30 and 33°C (Abdullahi and Abubakar, 2019; Ogega and Alobo, 2020).

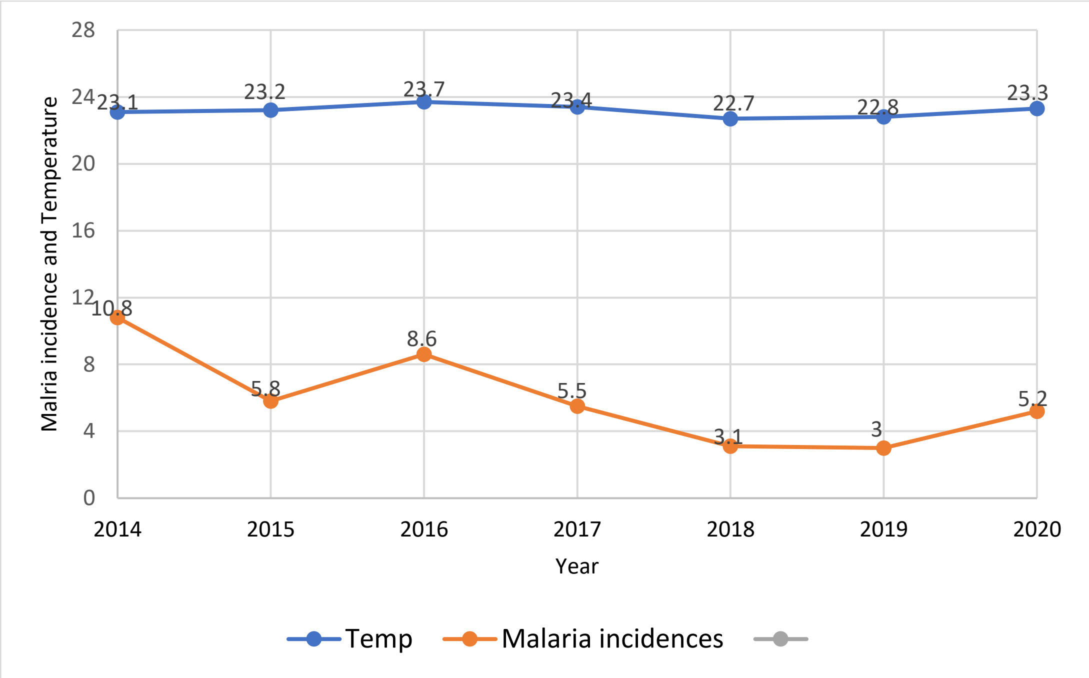

Figure 13: Annual trends in the occurrence of malaria incidences and atmospheric temperature in two districts of the ecological zone 1

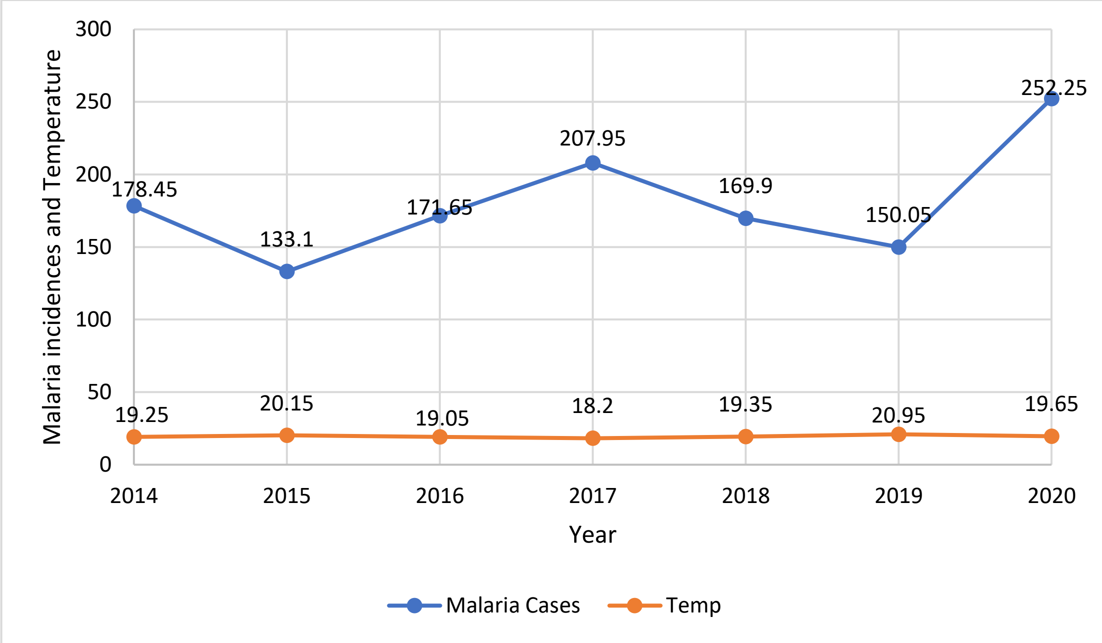

Figure 14: Annual trends in the occurrence of malaria incidences and atmospheric temperature in two selected districts of the ecological zone 2

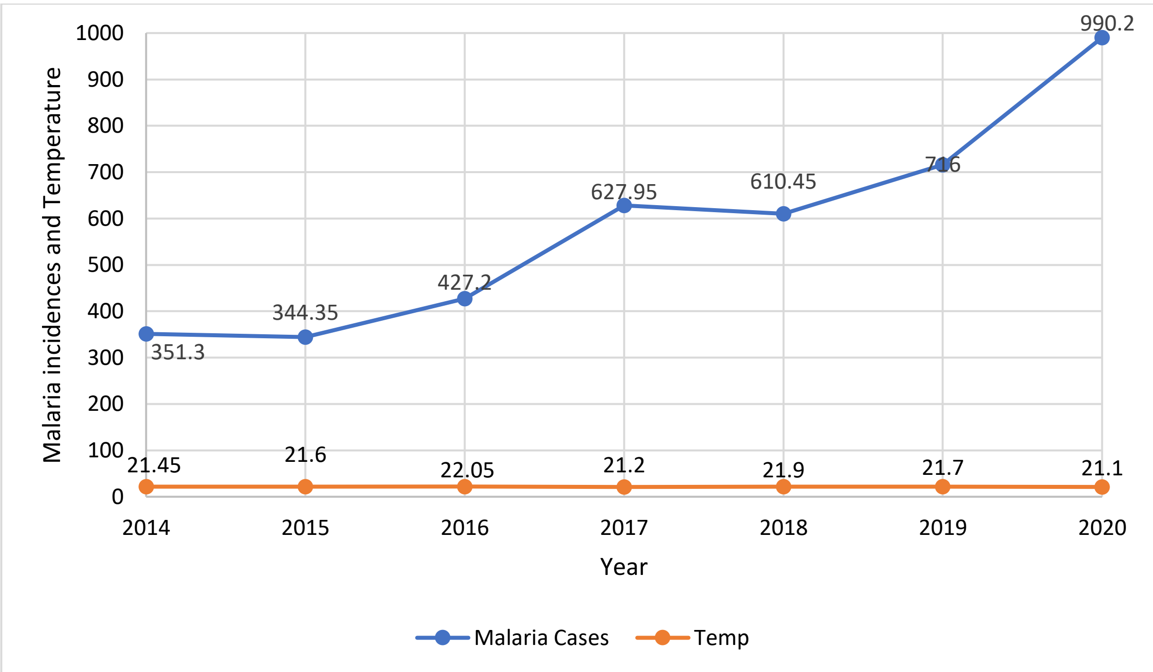

Figure 15: Annual trends in the occurrence of malaria incidences and atmospheric temperature in two selected districts of the ecological zone 3

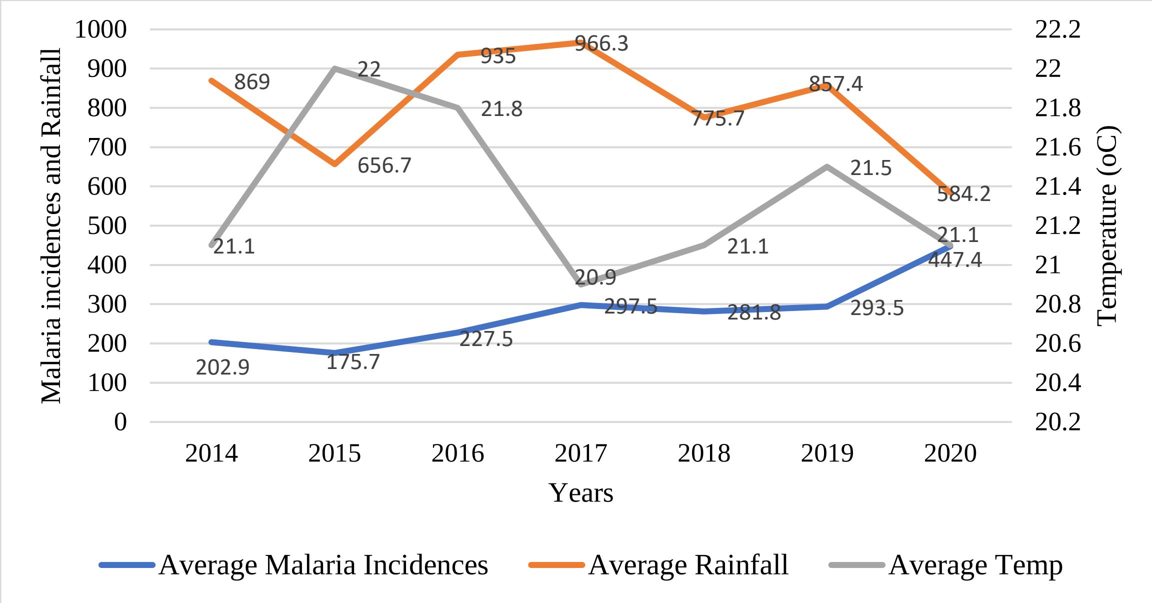

Figure 16: Annual trends in the occurrence of malaria incidences, rainfall pattern and atmospheric temperature in six selected districts of the three ecological zones

4.4 Relationship between atmospheric temperature, rainfall, and malaria incidence

Table 2: Pearson's correlation between annual rainfall, atmospheric temperature and malaria incidences

Climate & malaria variables	Statistics	Malaria incidences	Rainfall (mm)	Temp (ºC)
Malaria incidences	Pearson Correlation	1		
Rainfall (mm)	Pearson Correlation	.476**	1	
	Sig. (2-tailed)	.001		
Temp (ºC)	Pearson Correlation	-.451**	-.289	1
	Sig. (2-tailed)	.003	.063	

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

Rule of Thumb for Interpreting the Size of a Correlation Coefficient states; r ≥ 0.7 is high positive correlation, 0.5 to 0.7 is moderate positive correlation, 0.3 to 0.5 is low positive correlation, 0.1 to 0.3 is very low positive correlation, -0.1 to -0.3 is very low negative correlation, -0.3 to -0.5 is low negative correlation and -0.5 to -0.7 is moderate negative, 0.7≥ is high negative correlation (Mukaka, 2012). Table 2 illustrates the relationship between annual atmospheric temperature, rainfall and confirmed malaria incidences in six selected districts of the three ecological zones from 2014 to 2020. The results of the correlation coefficient between annual rainfall and confirmed malaria incidences was 0.476 which represented a low positive relationship and it was statistically significant with a P-value of 0.001. This shows that an increase in rainfall will lead to higher confirmed malaria incidences. Annual confirmed malaria incidences and rainfall had a direct relationship. The correlation coefficient between annual atmospheric temperature and confirmed malaria incidences was -0.451which represents a low negative relationship but it was statistically significant with a P- value of 0.003. Annual atmospheric temperature and confirmed malaria incidence had an inverse relationship. This entails that; an increase in the independent variable (temperature) leads to a decrease in the dependent variable (malaria incidences). Irrefutably an increase in annual atmospheric temperature exhibited a negative influence on the confirmed malaria incidences.

CHAPTER FIVE

DISCUSSION

5.1 The effect of seasonal rainfall on malaria incidences

The literature study carried out during the course of this study clearly showed that the interaction between climate factors is important in malaria incidences, as they are closely associated with vector abundance, survival and parasite maturation. This study explored the relationship between atmospheric temperature, rainfall associated with the six selected districts of the three ecological zones in Zambia on malaria incidences. The results of this study found a low positive correlation between annual rainfall and confirmed malaria incidences in the six selected districts of the three ecological zones from 2014 to 2020. This finding resonates well with Odongo-Aginya *et al*. (2005) whose study showed that the rate of malaria incidences was at peak; coinciding with the peak rainfall partner and further concluded that because the rainfall provides vector breeding sites and also it prolongs the life span of vectors by increasing water availability. Further, in their report; Brooker *et al.* (2009) explicated that higher *Anopheles* density and biting rates have been observed during the rainy seasons when compared with the dry season. Similarly, the findings from this study are consistent with other scholarly studies done by Ge *et al*. (2017); Ligsay *et al.* (2012); Mzyece (2016); Parham and Micheal (2010b). From the trends in Figure 10, the high number of confirmed malaria incidences were registered in areas that recorded more annual rainfall amounts. This can be explained by the fact that rainfall influences malaria incidences by creating more mosquito breeding sites through increase of stagnate water pools, floods and vegetation growth like grass not controlled by man. This elucidation was equally shared by Thomson *et al.* (20005) who in their study investigated the influence of rainfall on malaria incidences and they found that malaria is positively correlated with rainfall; which favours the malaria parasite breeding and feeding blood. In the Zambian context, regions in ecological zone 3 and 2, predominantly have higher rainfall coupled with poor drainage, resulting in water stagnation. This situation enables female mosquitoes to lay more eggs which in turn leads to high population of malaria parasites and therefore rapid spread of malaria incidences. An alternative concept was reported by Jaenisch *et al.* (2010), who stated that the relationship between rainfall is positive correlation but implicitly assumed a linear relationship. This is because too much rainfall washes the breeding sites for malaria parasites which includes the eggs, larva and mature malaria parasites. However, Zambian ecological zones record lower annual rainfall and distribution compared to their research study area (Pemba Island) which receives up to 2000mm rainfall per year (Walsh, 2009, as cited by Makame and Kangalawe, 2018).

5.2 The effect of temperature on malaria incidences

The results showed that annual atmospheric temperature and confirmed malaria incidence had an inverse relationship but statistically significant, and these results are consistent with the findings reported by Darkoh *et al.* (2017) and Arab *et al.* (2014). A study done by Darkoh *et al.* (2017), in Ghana, reported a negative correlation between temperature and malaria incidences. The negative correlation found was associated to the fact that temperature plays a critical role in the regulation of growth, development, and survivor-ship of mosquito and malaria parasite, and also determines the period of the gonotrophic cycle. Gonotrophic cycle length is an indicator of mosquito abundance and contact frequency between the host and the mosquito vectors. The shorter the gonotrophic cycle, the more often the female mosquito will come in contact with the human host leading to increased production and higher population density. Therefore, at lower temperature (minimum temperature for the mosquito parasite) the development of mosquitoes' larvae and pupae is hindered resulting in the delay of the infectiousness of mosquitoes and leads to low malaria incidences. Arab *et al.* (2014) also reported negative correlation between temperature and malaria, and was described by a non-linear response of malaria spread to temperature, with a negative association for higher temperature. This elucidation can be related to districts of the ecological zone 1 in Zambia which recorded the highest annual temperature of 25ºC among all the selected districts of the three ecological zones and had the lowest confirmed malaria incidences. This temperature may hamper the completion of mosquito growth cycle and development. Okiring *et al*. (2021) reported that annual temperature of 35ºC was significantly associated with malaria incidence compared to the median observed temperature (30ºC). A study by Ogega and Alobo (2020) reported that the temperature of 26.7ºC as the threshold within which maximum suitability for survival for Anopheles mosquitoes is achieved and 13°C and 30°C as thresholds below/above which the suitability drops to zero. This means the annual temperature falls between the range temperature that is associated with decrease in malaria incidences (Mordecai, 2013). Temperature is an important environmental determinate in the biological behavior and activity of mosquito as it affects the breeding and incubation rate, adaptation, blooding and frequency of contact. The flight activity of malaria mosquito is important for lifecycle traits such as reproduction, nutrition and host seeking, for example *Ae. aegypti* is able to fly in a temperature range of 15- 32ºC with an optimum temperature of 21ºC. Additionally, Carrington *et al*. (2013)

indicated that temperature has a bearing on the adult stage of mosquitos and in female mosquito, the longevity significantly increased when the adult holding temperature is decreased.

In a study by Zhou *et al*. (2016) conducted in a temperate region in China reported that the annual temperature had the low negative correlation with monthly incidence and this relation was also seen with one-month lag and 1^{o}C increase in minimum temperature resulted in 12 to 16% increase in incidence and minimum temperature was more effective than maximum temperature. Mosquito vector lifecycle is directly affected by temperature and different mosquito species respond differently to this temperature variations. For example, at temperature below 14^{o}C *P. vivax* survival rate is reduced translating into low numbers of mosquitoes and less malaria incidences. *P. falciparum* mosquitos' life cycle is negatively affected at temperature below 18^{o}C and this shows that *P. vivax* mosquito survive lower temperatures than *P. falciparum* mosquito.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusions

The study was looking at the effects of annual atmospheric temperature and rainfall on confirmed malaria incidences in six selected districts of the three ecological zones of Zambia from 2014 to 2020. The study found that there was a direct relationship (low positive correlation) between annual rainfall and confirmed malaria in six selected districts of the three ecological zones. Atmospheric temperature and rainfall play a role in influencing malaria incidences. There was an inverse relationship (low negative correlation) between annual atmospheric temperature and confirmed malaria incidences but this relationship was statistically significant. The two selected districts of the ecological zone 1 recorded the lowest number of confirmed malaria incidences but had the highest atmospheric temperature than selected districts of the other ecological zones. The two selected districts of the ecological zone 3 registered the highest number of confirmed annual malaria incidences and annual rainfall.

6.2 Recommendation

From the findings in this study, it is clear that the six selected districts of the three ecological zones in Zambia have different levels of susceptibility as regards prevalence of malaria cases. With the findings showing that, the incidences of malaria cases are highest in selected districts of the ecological zone 3, seconded by districts of the ecological zone 2 and districts of the ecological zone 1 is the least. Therefore, it is hereby recommended that the research be expanded by considering more districts from each ecological zone to get the fully representations of the population.

6.3 Limitations of the Study

The study only considered six selected districts from the three ecological zones in Zambia. This was due to the following study limitations;

- Lack of financial resources
- Time constraints

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APPENDICES

Appendix 1: Application letter for Ethical approval for the research study

C/O School of Veterinary Medicine
University of Zambia
PO Box 32379
LUSAKA

11th August, 2021

The Secretary,
ERES Converge (Private REB)
33 Joseph Mwilwa Road,
Rhodes Park,
LUSAKA

RE: REQUEST FOR ETHICAL APPROVAL FOR EFFECTS OF ATMOSPHERIC TEMPERATURE AND RAIN ON MALARIA INCIDENCE RATES IN THREE ECOLOGICAL OF ZAMBIA, OVER A SEVEN-YEAR PERIOD: A RETROSPECTIVE STUDY

Dear Secretary,

Thank you for reviewing the attached application seeking ethical approval for the research study. Approval is being sought from your institution ERES Converge IBR.

Documents detailing the research are enclosed and include:

1. Research proposal.
2. Seeking permission from institutions to access records and collect data.
3. ERES review application form.
4. Curriculum Vitae for Investigator.
5. Curriculum Vitae for Supervisors.

If you have any questions, please call 0974887272.

Yours sincerely,

Mwenya Silombe

Page 1 of 1

Appendix 2: Approval of research proposal

THE UNIVERSITY OF ZAMBIA
SCHOOL OF VETERINARY MEDICINE
OFFICE OF THE ASSISTANT DEAN (POSTGRADUATE)

Telephone: 293727
Telegrams: UNZA LUSAKA
Telex: UNZALU ZA 44370
Fax: 293727/253952
School Fax: 293727
Vet. Clinic Telephone: 291515

P.O. Box 32379
Lusaka, Zambia

Your Ref:

Our Ref:

12th May, 2021

Mwenya Silombe
C/o Department of Disease Control
School of Veterinary Medicine
University of Zambia
P.O. Box 32379
LUSAKA

Dear Mwenya Silombe

RE: APPROVAL OF RESEARCH PROPOSAL

On behalf of the Board of Graduate Studies, I am pleased to inform you that your proposed research project entitled *"Effects of Climate change on malaria incidence rates in selected Districts of Zambia, over a twenty-year period: a retrospective study"* has been approved.

I wish you success as you apply for ethical approval and carry on with your research activities.

Yours sincerely

Dr Chisoni Mumba
ASSISTANT DEAN (PG), SCHOOL OF VETERINARY MEDICINE

Cc *Dean, School of Veterinary Medicine*
Head, Department of Disease Control
Dr R.Ndongo L5awa

Appendix 3: Proposal review application

ERES CONVERGE IRB
33 Joseph Mwilwa Road
Rhodes Park
LUSAKA
Tel: +260 955 155633
+260 955 155634
E-mail: eresconverge@yahoo.co.uk

IRB No. 00005948
FWA No. 00011697

PROPOSAL REVIEW APPLICATION FORM

Please note that this form should be submitted with a letter from the PI or CO-PI requesting ERES CONVERGE IRB to review your proposal. Address all correspondence to the Secretary.

TITLE OF STUDY: EFFECTS OF ATMOSPHERIC TEMPERATURE AND RAIN ON MALARIA INCIDENCE RATES IN SELECTED DISTRICTS OF ZAMBIA, OVER A SEVEN-YEAR PERIOD: A RETROSPECTIVE STUDY

---

2. **PRINCIPAL INVESTIGATOR:**

Name: Mwenya Silombe

Qualifications: Bachelor Degree

Present Appointment/Affiliations: Tutor- Information and Communication University

FOR STUDENTS: Qualification being pursued Master of Science in Ecological Public Health

---

3a. **OTHER INVESTIGATORS:**

Name:

1

Qualifications:

Present Appointment/Affiliations:

Name:

Qualifications:

Present Appointment/Affiliations:
(Other names to be included on a separate page.)

3b. **SUPERVISORS: FOR STUDENTS ONLY**

1. Name: Dr. Rosemary Ndonyo Likwa

   Qualifications: PhD

   Present Appointment/Affiliations: Senior Lecturer/One Health Coordinator (Human), Africa Centre of Infectious Diseases for Human and Animals (ACEIDHA)
   University of Zambia
   School of Public Health

2. Name: Prof. Musso Munyeme

   Qualifications: Professor

   Present Appointment/Affiliations: Senior Lecturer, Project Coordinator, Zambia: Sustainable Small Ruminants Production, One Health Coordinator, Africa Centre of Excellence for Infectious Diseases of Humans and Animals [ACEIDHA]
   The University of Zambia,
   School of Veterinary Medicine,

3. **FOR STUDENTS REGISTERED IN INSTITUTIONS OUTSIDE ZAMBIA (WHERE APPLICABLE)**

   Name of local supervisor

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4. SUMMARY

Study aim/s

The main aim of the study will be to determine the effects of atmospheric temperature on malaria incidence rates in three Ecological Zones of Zambia, over a seven-year period.

Specific objectives

1. To establish annual trends in confirmed malaria incidences in three ecological zones,
2. To establish the annual malaria trends in atmospheric temperature and rainfall in three ecological zone,
3. To determine the relationship between annual atmospheric temperature and confirmed malaria incidences, and
4. To determine the relationship between annual rainfall and confirmed malaria incidences.

5. SUMMARY OF STUDY METHODOLOGY

Retrospective study will be used in this research, which will involve looking backwards at the climate and malaria incidence rates data for the last twenty years in these six selected districts of Zambia. All malaria incidence data from 2014 to 2020 for the six selected districts will be collected from the Ministry of Health (MoH) at respective district offices. The data collected monthly and annually incidences using the data sheets. Climate data will be collected from Zambia Meteorological department (ZMD). The sample size for each group will be calculated using the formula from Krejcie and Morgan, 1970.

The data obtained will first be entered into Microsoft Office Excel version 2019 spreadsheets, cleaned, collated and analyse using SPSS version 21. All data will be assessed for normality following which the appropriate parametric or nonparametric tests were applied at an alpha (α) of 0.05. Pearson correlation regression model in SPSS 26 version will be used to determine the influence of air temperature and seasonal rainfall on malaria incidence rates.

difference among the three ecological zones climate for past twenty years. The average climate for each agro-ecological zone will calculate then use Mann-Whitney U test to test for significance.

6. NAME OF SPONSOR/S OF STUDY

Africa Centre of Infectious Diseases for Human and Animals (ACEIDHA)

6. PROPOSED LENGTH OF STUDY

Six (6) months

7. PLEASE ENSURE THAT THE FOLLOWING ARE IN/WITH YOUR PROPOSAL (where applicable). Please tick

- C.V of PI and CO-PI (if first submission)
- Information sheet for participants
- Informed consent form
- Address of ethical issues (rights, risks, benefits, compensation, confidentiality)
- Questionnaire/s
- Authorization letter from study site
- Clearance letter from Regulatory Authorities (e.g. Pharmaceutical Regulatory Authority)
- Data and Safety Monitoring Board – DSMB
- Approval letter/s from other Research Ethics Committees

8. SUBMITTED BY:

PRINCIPAL INVESTIGATOR/CO-PI (NAME) Mwenya Silombe

DATE 11/08/2021 SIGNED [signature]

OTHER (NAME) ____________________

DATE ____________________ SIGNED ____________________

Contact Address: ____________________

____

4

Appendix 4: Letter Seeking permission to access record from the institutions

Seeking permission from the institution to access the records and collect data

My name is Mwenya Silombe, a student at The University of Zambia (UNZA) under the School of Veterinary Medicine pursuing Master of Science in Ecological Public Health. I am conducting a study on "Effects of atmospheric temperature and rainfall on malaria incidence rates in three ecological zones of Zambia, over a seven-year period: A Retrospective study".

1. Procedure to be followed

Participation in this study will require that I collect data from Ministry of Health (MoH) and Zambia Meteorological department (ZMD) in Microsoft excel. I will collect data on:

(a) Malaria incidences in six selected districts of Zambia from January 2014 to December 2020. This data will be obtained from each district offices of the Ministry of Health.

(b) Temperature and seasonal rainfall in six selected districts of Zambia from January 2014 to December 2020 from Zambia Meteorological department headquarter offices- Lusaka.

2. Purpose

The purpose of the accessing and collecting data is for the research study to be conducted. The data collected will help in achieving the objective of the study to investigate the effects of climate factors (atmospheric temperature and rainfall) on confirmed malaria incidence rate in selected districts of Zambia. This study will help in the fight of malaria in this country and globally, and also will help in developing policies that will reduce on activities contributing to climate change.

3. Confidentiality

All the data collected from the institutions will be kept safe and only used for this research study. All the information given will not be disclosed/ given to a third party at any cost.

4. Contact information

If you have any further questions about the study, you may contact;

The Secretary,
ERES Converge (Private REB)
33 Joseph Mwilwa Road,

Rhodes Park,
LUSAKA

5. Investigator's statement

I, the undersigned, have explained to the institution of the study procedure, purpose, confidentiality and contact information in a language the institution understands.

Name of the investigator MWENYA SILOMBE

Signature of the investigator  **Date 11/08/2021**

Appendix 5: Ethical clearance approval

ERES CONVERGE

Plot No. 1, Cnr Joseph Mwilwa & Great East Road
Rhodes Park, Lusaka - Zambia
Tel: +260 955 155 633
+260 955 155 634
Cell: +260 977 493220
Email: eresconvergeltd@gmail.com

I.R.B. No. 00005948
F.W.A. No. 00011697

03rd November, 2021.

Ref. No. 2021-Aug-008

The Principal Investigator
Mr. Mwenya Silombe
C/O School of Veterinary Medicine
University of Zambia
P.O. Box 32379
Lusaka, Zambia

Dear Mr Silombe

REF: EFFECTS OF CLIMATE CHANGE ON MALARIA INCIDENCE RATES IN SELECTED DISTRICTS OF ZAMBIA, OVER A TWENTY-YEAR PERIOD: A RETROSPECTIVE STUDY

Reference is made to your protocol resubmission. The IRB resolved to approve this study and your participation as Principal Investigator for a period of one year.

Review Type	**Ordinary**	Approval No. **2021-Aug-008**
Approval and Expiry Date	Approval Date: 3rd November, 2021	Expiry Date:
Protocol Version and Date	Version - Nil.	2nd November, 2022
Information Sheet, Consent Forms and Dates	• English.	2nd November,2022
Consent form ID and Date	Version - Nil	2nd November,2022
Recruitment Materials	Nil	2nd November,2022
Other Study Documents	Questionnaire.	2nd November,2022
Number of participants approved for study	-	2nd November,2022

Appendix 6: Letter to the Zambia Mereological Department requesting to access weather data

THE UNIVERSITY OF ZAMBIA
SCHOOL OF VETERINARY MEDICINE

Telephone: 293727 Telegrams:
UNZA LUSAKA Telex: UNZALU
ZA 44370 Fax: 293727/253952
School Fax: 293727
Vet. Clinic Telephone: 291515

P. O. Box 32379
Lusaka, Zambia

Your Ref:

Our Ref:

6th February, 2022

To
The Director,
Zambia Meteorological Department,
P.O. Box 30200,
Lusaka

RE Request for past weather/climate data for retrospective ecological study purposes by a Master of Science student

The above subject matter refers.

Mr. Silombe Mwenya (Student Identity number: 2019098938) is a *bona fide* Master of Science student in Ecological Public Health of the School of Veterinary Medicine at the University of Zambia where did his first taught component and successfully completed the course work.

The second phase consists a one year full-research phase within the field of ecology. Accordingly, Mr. Mwenya's interest is to analyze past weather (temperature and rainfall) trends in relation to malaria incidence rates in selected districts of Zambia. He wants to relate old malaria cases with weather trends and patterns using Chipata, Chililabombwe, Livingstone, Sesheke, Solwezi and Lusaka District as a case study.

It's for this purpose that we are writing to the Zambia Meteorological Department, being the only key and legally mandated institution in Zambia that is and has been documenting as well as recording a full complement of climate variable data. We envisage that through a retrospective study design, the student will be able to bring out important climate data patterns/trends that shall not only be important to the student, but for your Department as well.

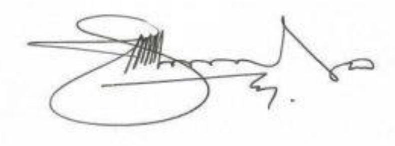
Should authority be given for him to utilize part of the data, we shall be requesting mainly the weather data for the named districts inclusive temperature and rainfall records for the past seven (7) years.

All the data and information generated thereof, shall be solely for education purposes and the student shall abide to all ethical considerations relating to the ethical conduct of research and data handling for important government installations and institutions such as your Department.

Your response to our request will be appreciated.

Should you need any further information or clarifications, I shall be more than glad to assist through mobile contact: +260955751013 as well as email: mussomunyeme@gmail.com. The contacts for the student are as follows:, cell number 0974887272, email silombe@gmail.com.

Yours sincerely



Prof. Musso Munyeme
Senior Lecturer & Researcher, Program Coordinator: ECOLOGICAL PUBLIC HEALTH

cc Assistant Dean Postgraduate, School of Veterinary Medicine

Appendix 7: Letter to Ministry of Health requesting for permission to access malaria incidences records

THE UNIVERSITY OF ZAMBIA

SCHOOL OF VETERINARY MEDICINE

Telephone: 293727 Telegrams:
UNZA LUSAKA Telex: UNZALU
ZA 44370 Fax: 293727/253952
School Fax: 293727
Vet. Clinic Telephone: 291515

P. O. Box 32379
Lusaka, Zambia

Your Ref:

Our Ref:

25th August, 2021.

To
The Director,
Ministry of Health,
Ndeke House,
PO Box, 30205,
Lusaka

RE Request for Malaria incidences data for retrospective ecological study purposes by a Master of Science student

The above subject matter refers.

Mr. Silombe Mwenya (Student Identity number: 2019098938) is a *bona fide* Master of Science student in Ecological Public Health of the School of Veterinary Medicine at the University of Zambia where did his first taught component and successfully completed the course work.

The second phase consists a one year full-research phase within the field of ecology. Accordingly, Mr. Mwenya's interest is to analyze past weather (temperature and rainfall) trends in relation to malaria incidence rates in selected districts of Zambia. He wants to relate old malaria cases with weather trends and patterns using Chipata, Chililabombwe, Livingstone, Sesheke, Solwezi and Lusaka District as a case study.

It's for this purpose that we are writing to the Ministry of Health, being the only key and legally mandated institution in Zambia that is and has been documenting as well as recording a full complement of malaria incidences data. We envisage that through a retrospective study design, the student will be able to bring out important malaria data patterns/trends that shall not only be important to the student, but for your Department as well.

Should authority be given for him to utilize part of the data, we shall be requesting mainly the malaria data for the named districts for the past seven (7) years.
All the data and information generated thereof, shall be solely for education purposes and the student shall abide to all ethical considerations relating to the ethical conduct of research and data handling for important government installations and institutions such as your Department.

Your response to our request will be appreciated.

Should you need any further information or clarifications, I shall be more than glad to assist through mobile contact: +260955751013 as well as email: mussomunyeme@gmail.com. The contacts for the student are as follows: cell number 0974887272, email silombe@gmail.com.

Yours sincerely

Prof. Musso Munyeme
Senior Lecturer & Researcher, Program Coordinator: ECOLOGICAL PUBLIC HEALTH

cc *Assistant Dean Postgraduate, School of Veterinary Medicine*