THE IMPACT OF CLIMATE CHANGE ON VECTORIAL CAPACITY OF MALARIA VECTORS OVER THE AGRO-ECOLOGICAL ZONES OF GHANA

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DECLARATION

We hereby declare that this submission is our own work towards BSc Meteorology and Climate Science and that, to the best of our knowledge, it contains no materials previously published by another person or material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

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0.1 Acknowledgement

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Abstract

Malaria is a deadly parasitic disease that is spread to humans via female Anopheles mosquito bites. Malaria is most prevalent in Sub-Saharan Africa, and the disease's transmission capability is determined by malaria vectors. The amount of evidence available on how climate change affects the transmission capacity and survival of malaria vectors in Ghana is limited. Using temperature related functions and temperature data from the Ghana Meteorological Agency, we investigated how seasonal temperature fluctuations influenced the capability and survival of malaria vectors across Ghana's agro-ecological zones. The findings demonstrated that as temperature increased, the vectorial capacity and vector survival probability both reduced, and vice versa. The vectorial capacity and survival rates were higher from July to September and low from February to April. The results also revealed that in the coastal and forest zones, such as Accra and Kumasi respectively, the vectorial capacity and survival probability were higher than in the other zones. This study's findings give crucial research data for malaria control program implementation.

Contents

Chapter 1

Introduction

1.1 Background to the study

Malaria is a deadly parasitic disease that is spread to humans via female Anopheles mosquito bites (W.H.O, 2014).It's both avoidable and treatable. Plasmodium parasites are the cause of malaria. The five malaria parasites are Plasmodium vivax, Plasmodium falciparum, Plasmodium malariae, Plasmodium ovale, and Plasmodium knowlesi burden. Of these five known malaria parasites, it is the P. falciparum that causes most of the malaria burden globally. Malaria is not always caused by all five parasites in all parts of the world. Plasmodium falciparum, Plasmodium malariae, and Plasmodium ovale are the pathogens in Ghana, for example. The main vectors of these parasites are Anopheles gambiae s.s. and Anopheles funestus s.s.

According to W.H.O (2020), there were an expected 229 million cases of malaria globally, with an estimated 409,000 malaria deaths in 2019. The most vulnerable to malaria were children under the age of five, who accounted for 67 percent (274 000) of all malaria deaths worldwide in 2019. The disease is predominantly a tropical disease with a high morbidity and mortality rate, as well as a significant economic and social burden. It is a worldwide public health problem. About 90% of the malaria episodes occurred in the WHO Africa. This has been the trend over the years. Only 15 out of all the countries in the world accounts for 80% of these malaria cases. Of these, 14 are in the sub-Saharan Africa (SSA) Thus, there is the need for most of the efforts and support for malaria control to be directed to the heavily affected places in the SSA. This is necessary to enable the global malaria response to get back on track. Ghana is one of the SSA countries responsible for 80% of the global cases.

Climate change has an impact on the malaria population and vector density. Climate change will increase the likelihood of malaria transmission in both traditionally malarious and suppressed areas, as well as previously non-malarious places. Increases in temperature and rainfall may encourage the spread of malaria-carrying mosquitoes, resulting in an increase in malaria transmission. Rising temperatures will disrupt the parasite's growth cycle in the mosquito, allowing it to develop faster and so influencing disease load at lower elevations where malaria is already a problem. The World Health Organization and the World Meteorological Organization have classed malaria as one of the most climate-sensitive diseases, with a plethora of evidence suggesting significant correlations between temperature, rainfall, and humidity and malaria occurrence.

Over an eight-year period (2001-2008), Klutse et al. (2014) examined climatic data and malaria cases from two ecological zones in Ghana (the transition and coastal savannah zones, respectively) to see if there was a link between malaria cases, temperature and rainfall patterns, and the potential effects of climate change on malaria epidemiological trends. The data suggest that, especially in the transition zone, maximum temperature, rather than minimum temperature or precipitation, is a better predictor of malaria trends.

The purpose of this research is to see how climate change affects malaria vectorial competence in Ghana's various agro-ecological zones. Effect of the climatic factors such as temperature will be the main focus in this study. Using temperature related functions and temperature data from the Ghana Meteorological Agency, we will investigate how seasonal temperature fluctuations influenced the capability and survival of malaria vectors across Ghana's agro-ecological zones.

1.2 Statement of the problem

Malaria transmission intensity is greatly reliant on local mosquito vectorial capability and competency (Cohuet et al., 2010). As a result, the vectorial capability of malaria vectors is affected by climatic change. In recent years, several studies on the effects of climate change on malaria vectors have made tremendous progress; however, some aspects have been missed, and the impact of climate change on malaria vector vectorial ability is commonly overlooked.

Martens et al. (1995), for example, worked on a study called Global Climate Change and Malaria Risk. They arrived to the conclusion that changes in malaria transmission linked to socioeconomic development, population expansion, and the efficacy of control efforts will all influence the degree of a rise in malaria risk.

In Ghana's two ecological zones, Klutse et al. (2014) looked at the links between climate variables and malaria cases.The maximum temperature, rather than the lowest temperature or precipitation, was found to be a stronger predictor of malaria trends, especially in the transition zone.

Mohammadkhani et al. (2016) conducted study in Kerman, Iran, on the relationship between meteorological conditions and malaria incidence. Temperature was discovered to be the most effective meteorological element in the occurrence of malaria. The incidence rate grew dramatically as the mean maximum and minimum monthly temperatures increased. Finally, temperature is one of the most important climate variables influencing the occurrence of malaria, and it should be taken into account while planning for disease control and prevention.

Christian and Akpalu (2021) looked on the impact of malaria adaptive ability on subjective well-being in Ghana. To summarize, households receiving social assistance demand a lower amount of income. Those who provide support and those who do not provide any support are compared to achieve the same degree of verbal quantification of welfare.

Also one of the research work which focused on the vectorial capacity of the malaria vector had little information and it was concentrated at the epidemic region of Africa that article was conducted by (Ceccato et al., 2012). They used a tool termed vectorial capacity to track changes in malaria transmission potential in epidemic locations across Africa. The vectorial capacity model (VCAP) was expanded in this study to account for the impact of rainfall and temperature factors on malaria transmission potential. They merged data from two remote sensing devices to monitor rainfall and temperature, and the VCAP was developed. They discovered that Eritrea has a robust malaria control program, with malaria incidence dropping significantly between 2000 and 2009. Malaria outbreaks are still a possibility in the country due to changing weather patterns. In conclusion, the extended VCAP accurately tracks the risk of malaria in both rainy and non-rainy locations.

Although the above research articles provide information on how climate change affect malaria vectors in many aspects. They mostly have limited information on how climate factors impact on the vectorial capacity or the population density of these malaria vectors. Also, most of these works conducted about or in Ghana was centered on one of the agro-ecological zones. Therefore there is the need to research in these areas since different agro-ecological zones have different climatic conditions. This research will help researchers better understand how climate change affects the capacity of malaria vectors, as well as provide information for the development of malaria control programs and the eventual eradication of the disease.

1.3 Study Question

The study asked the following questions to discover solutions or answers to the outline difficulties.

1. How does seasonal changes in temperature influence the seasonality of the survival and vectorial capacity of malaria vectors over the agro-ecological zones of Ghana?
2. Does survival probability and vectorial capacity of malaria vectors differ from one agro-ecological zone to the other?

1.4 Objectives

To assess the impact of climate change on the vectorial capacity and survival probability of malaria vectors over the agro-ecological zones of Ghana.
Specific objectives include:

1. Determine the influence of seasonal temperature change on the survival and malaria transmission capacity of malaria vectors.
2. Determine whether the survival and vectorial capacity of malaria vectors differ as a function of climate and environment in Ghana.

1.5 Research significance and justification

Having knowledge of how climate change influence the vectorial capacity and survival probability of the malaria vectors over their agro-ecological zones of Ghana will be of great importance to the country and will result in many benefits. Having such kind of information will provide research information on how the warming climate influence the capacity of malaria vectors. Also, it will provide knowledge on the differential burden of malaria as a function of climate and environment. As a country, we face an inevitable challenge pertaining to the high mortality rate especially in infants, which threatens the future of Ghana. As a matter of fact, this study will provide information useful for the design of malaria control programs and possible elimination of the disease. With this knowledge, targetted interventions can be made to counter the mortality and morbidity of malaria in Ghana especially in infants. The outcome of this study would be of much importance in contributing to achieving the Sustainable Development Goal (SDG) number 3.

1.6 Organization of the thesis

The thesis is divided into five sections. The first chapter introduces the project ideas, which include the research backdrop, problem statement, objectives, and research justification. A review of prior efforts is discussed in chapter two. It starts with a basic overview of malaria and the parasite that causes the disease. The review also looked at the malaria life cycle and how climatic and non-climatic factors affect malaria transmission. The study area, data, and method used in this project are all covered in the third chapter of this paper. Chapter 4 covers the results and discussion, while Chapter 5 covers the conclusion, recommendations, and references.

Chapter 2

Literature Review

2.1 Malaria

Although the literature on malaria and related issues covers a wide variety of topics, this review will concentrate on some key topics. These topics may include malaria and its parasites, the life cycle of malaria, factors that enhance the malaria vectors, vectorial capacity and its competency, and reviewed works(articles).

Malaria is life-threatening parasitic infection spread by bites of an infected female Anopheles mosquito. (Odikamnoro et al., 2018). Malaria is both preventable and curable. Malaria is caused by Plasmodium parasites. Infected people usually develop symptoms 10 to 15 days after being bitten by an infected insect. Such symptoms include headache, fever, body weakness, chills, these are the most common systems that an infected person exhibits. Adults and children are also affected by malaria, but children are at a greater risk of death than adults. Malaria is a disease spread by mosquitoes. As previously noted, the vector is a female anopheles mosquito with specific traits that set it apart from other mosquito species. Anopheles mosquitos come in a variety of varieties, but only a few can transmit the parasite. Plasmodium falciparum, Plasmodium ovale, Plasmodium malariae, Plasmodium vivax and Plasmodium knowlesi are the five malaria parasites. Plasmodium falciparum parasite, out of the five known malaria parasites, is the one that causes the majority of the global malaria load. Malaria is not always caused by all five parasites in all parts of the world. The pathogens in Ghana are Plasmodium ovale, Plasmodium malariae, and Plasmodium falciparum. Anopheles gambiae sl and Anopheles funestus are two types of Anopheles that cause malaria. In different places of the world, different kinds of Anopheles mosquitos transmit malaria.

2.2 The malaria life cycle

The Malaria parasite lifecycle begins when an infected adult female Anopheles mosquito bites to feed on human blood. It feeds on the blood of the host and releases malaria sporozoites (parasites) into the bloodstream (human being). This is the bite that causes the sickness. Parasites quickly find their way to the liver cells when they enter the human bloodstream, where they develop and multiply (schizogony). When infected liver cells break, a significant number of merozoites are released into the bloodstream, infecting red blood cells (RBCs). This stage might take anywhere between 9 and 14 days to complete. Within the RBCs, the parasites transform from "rings" to blood schizonts.After that, the schizonts burst the RBCs, releasing a swarm of merozoites that infest new RBCs. Malaria symptoms include chills and fever, which are produced by infected red blood cells rupturing. Indeed, the release of malaria parasites (merozoites) into the bloodstream from raptured RBCs corresponds to the peak of fever during malaria. The time between the infective bite and the onset of symptoms is known as the incubation period for malaria (fever, chills, etc.). Plasmodium malariae and Plasmodium vivax have a 7-14 day incubation time, however it can be shorter in Plasmodium falciparum or longer in Plasmodium malariae and Plasmodium vivax. The life cycle of malaria is depicted in the diagram below.

2.3 Factors that enhance malaria transmission

Malaria transmission is influenced by both climatic and non-climatic factors.

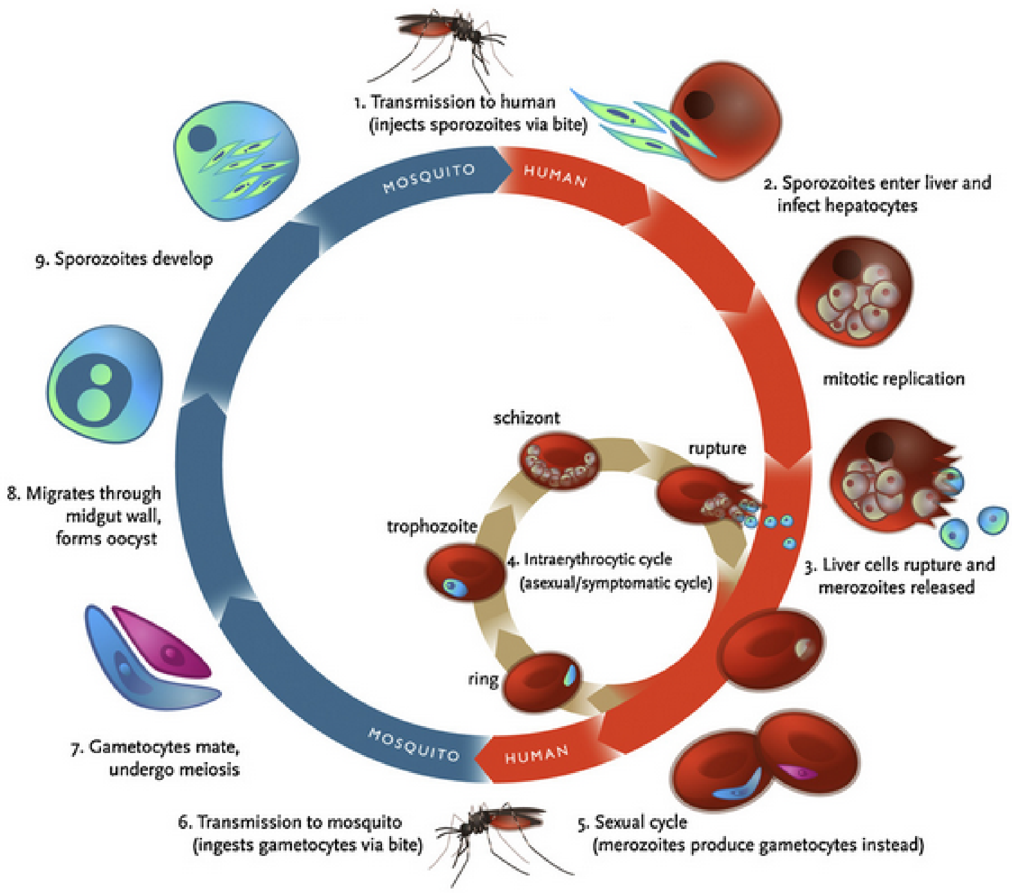

Figure 2.1: Life cycle of malaria (Source: `https://cddep.org`)

2.3.1 Climatic Factors

Malaria is affected by three key climate conditions. They are *temperature*, *rainfall*, *humidity*.

Temperature

The parasite and its vector are highly affected by temperature extremes. A parasite may take roughly 10 days to develop in the gut of a mosquito, but a lower temperature may take longer for the parasite to develop, while a higher temperature will take less time. Also, higher temperatures enhance the amount of blood meals taken and eggs laid by the vector, which result in an increase in the vector population in a given location.

Rainfall

In some circumstances, mosquitos breed in water. As a result, they frequently require the appropriate amount of rainfall to reproduce. Malaria transmission is at its peak during the rainy season, when water reservoirs that aid vector reproduction form. When it rains too much, mosquito breeding places are momentarily wiped out, but mosquitoes will begin spawning as soon as the rain stops. The life cycle of the mosquito is incompatible with several water sources. Malaria vectors thrive in stagnant water pools left over from heavy rains.

Humidity

Relative humidity is a measurement of the quantity of moisture in the air expressed as a percentage (0 percent humidity would mean the air is completely free of moisture and 100 percent humidity would mean the air is completely saturated with moisture). The impact of relative humidity on mosquito activity and survival on malaria transmission is significant. Mosquitoes need to live for at least 8–10 days in order to transmit malaria. High-humidity conditions are excellent for mosquitoes. They become more active when the humidity level increases. As a result, they are more active and prefer to feed at night, when the environment's relative humidity is higher.

2.3.2 Non-Climatic Factors

These are factors that influence malaria but are unrelated to the weather. The type of vectors and parasites, population movement and migration, the level of immunity in human hosts, environmental developments and urbanisation,, insecticide resistance in mosquitoes, and drug resistance in parasites are all non-climatic factors that influence the severity and incidence of malaria transmission.

2.4 Vectorial Capacity and Competence

The ability of the malaria vectors to transmit the disease from one person to another is defined as **"vectorial capacity"**. In contrast to the World Health Organization's definition of "vector effi-ciency," mosquito vectorial capacity is a density-dependent feature. **"Vectorial Competence"**, which is transmissibility and susceptibility is defined as the tendency of a vector to transmit a disease or a vector's intrinsic capacity to sustain and transfer a pathogen to another host. When an infected mosquito bites a person, who is vulnerable to infection, usually refers to a vector's ability to become infected with, sustain, and transfer an infectious agent.Female mosquitoes are called vector competent when they convey the infection from one vertebrate to another during blood feeding. In arbovirus transmission, vector competence and vector capacity are both essential aspects. The intrinsic properties of the vector and pathogen, such as pathogen strain, vector strain, and pathogen genotype, are linked to this competence. The occurrence of diverse virus-vector interactions is shown by the fact that different arboviruses have variable vector competence.

2.5 Reviewed Works

There have been numerous studies on the malaria vector, most of which have focused on its transmission and seasonality. This work examined a number of publications or research papers in order to determine what had been done previously and what had not. For instance

Ceccato et al. (2012) investigated the vectorial capacity product to track changes in potential of malaria transmission in Africa's epidemic regions. The vectorial capacity model was expanded in their research to account for the impact of rainfall and temperature variables on malaria transmission potential. They merged data from two remote sensing systems to monitor rainfall and temperature. They discovered that Eritrea has a successful malaria control program, which resulted in a significant reduction in malaria incidence between 2000 and 2009. Malaria outbreaks are still a possibility in the country due to changing weather patterns. In conclusion, the extended VCAP accurately tracks the risk of malaria in both rainy and non-rainy locations.

Mohammadkhani et al. (2016) conducted study in Kerman, Iran, on the relationship between meteorological conditions and malaria incidence. Temperature was discovered to be the most effective meteorological element in the occurrence of malaria. The incidence rate grew dramatically as the mean maximum and minimum monthly temperatures increased. Finally, temperature is one of the most important climate variables influencing the occurrence of malaria, and it should be taken into account while planning for disease control and prevention.

Caminade et al. (2014) concentrated on the impact of climate change on the global spread of malaria. They used bias-corrected temperature and rainfall simulations from the Coupled Model Intercomparison Project Phase 5 climate models to compare the metrics of five statistical and dynamical malaria impact models for three future time periods (2030s, 2050s, and 2080s). The findings show that the tropical highlands' climate may become more favourable to malaria transmission in the future. Other important socioeconomic factors, such as land use change, population growth and urbanization, migratory patterns, and economic development, will need to be considered more thoroughly in future risk assessments.In conclusion, climate-induced alterations are more consistent with observed changes in a few African and South American regions. Climate change may have serious consequences in the future in the east African highlands, where a big population is at danger.

Christian and Akpalu (2021) looked on the impact of malaria adaptive ability on subjective well-being in Ghana. They used Van Progg's (1960) theoretical framework to analyze the link between the urban and rural parts of Accra, Ghana. They discovered that in order to equalize subjective wellbeing between households with varying adopting capacity to malaria, they needed to find a way to equalize subjective welfare across households with varying adoption capacities. When compared to their counterparts with high adaptation capacity, those with low adaptive capacity demand more income. To summarize, households receiving social assistance demand a lower amount of income. Those who provide support and those who do not provide any support are compared to achieve the same degree of verbal quantification of welfare.

Over an eight-year period (2001-2008), Klutse et al. (2014) examined climatic data and malaria cases from two ecological zones in Ghana (the transition and coastal savannah zones, respectively) to see if there was a link between malaria cases, temperature and rainfall patterns, and the potential effects of climate change on malaria epidemiological trends. The data suggest that, especially in the transition zone, maximum temperature, rather than minimum temperature or precipitation, is a better predictor of malaria trends. Martens et al. (1995) studied on the topic of Global potential change of climate impact on Malaria Risk. They calculated the epidemic potential of a change in average temperature and rainfall patterns on malaria transmission using the UKMO-GCM model. An assessment of the possible impact of global climate change on malaria prevalence predicts a widespread increase in risk due to the extension of malaria transmission zones. Finally, the magnitude of an increase in malaria risk will be influenced by changes in malaria transmission linked to socio-economic development and the efficacy of control measures. Afrane et al. (2008) studied the impact of deforestation on microclimates and Plasmodium falciparum sporogony development in Anopheles gambiae mosquitoes in a malaria-prone location of the western Kenyan highlands. P. falciparum–infected blood was given to An. gambiae mosquitos via membrane feeders. In a highland environment fed vectors were placed in dwellings in deforested areas and forested areas and parasite development was observed. When compared to wooded sites, deforested sites showed greater temperatures and relative humidity, as well as a higher overall mosquito infection rate. Sporozoites arrived 1.1 days earlier on average in deforested areas. Changes in the environment During the entire experiment period, mean indoor temperatures in experimental dwellings differed significantly between the three sites and during the entire experimental period, mean outside temperatures within the experimental dwellings differed significantly between the three sites. Changing the ecological milieu in which vectors and their parasites breed, develop, and transmit illness, whether as a result of natural events or human intervention.

Even though these previous research articles provide information on the transmission and capacity of malaria vectors, they mostly have limited information on the vectorial capacity or the population density of malaria vectors. Most research works are centered on how climatic factors influenced the transmission of malaria. Specifically, there is limited information on the capacity of the malaria vectors. Examining the vector population of the malaria is therefore important. Information from such study will findings give crucial research data for malaria control program implementation. Also the outcome of this study would be of much importance in contributing to achieving the Sustainable Development Goal (SDG) number 3.

Chapter 3

Data and Research Methodology

3.1 Introduction

The data obtained and the procedures used for data gathering and analysis are the key topics of this chapter. It begins with description of the study area, which is comprised of Ghana's four agro-ecological zones. The study data, or information gathered, is then presented. Data analysis was also covered in this chapter.

3.2 Study Area

The Ghana's agro-ecological zones are the subject of this research. Fores, Northern, Transition, and Coastal zones are the four agro-ecological zone. Various cities make up each of these agro-ecological zones. We chose four cities across the various zones.

Tamale is the focus city for the Northern zone.It is the capital town of the northern region of Ghana. Tamale is the second-largest city in Ghana in terms of area. According to the 2012 census, the city has a population of 562,919 people. Located 600 kilometers (370 miles) north of Accra, the town is a popular tourist destination. It's location co-ordinate are latitude: $\mathbf{9^o}$ 24' 2.84" N and longitude: $\mathbf{0^o}$ 50' 21.48" E.

Navrongo is a town in Upper East Region of Ghana, near the Burkina Faso border,

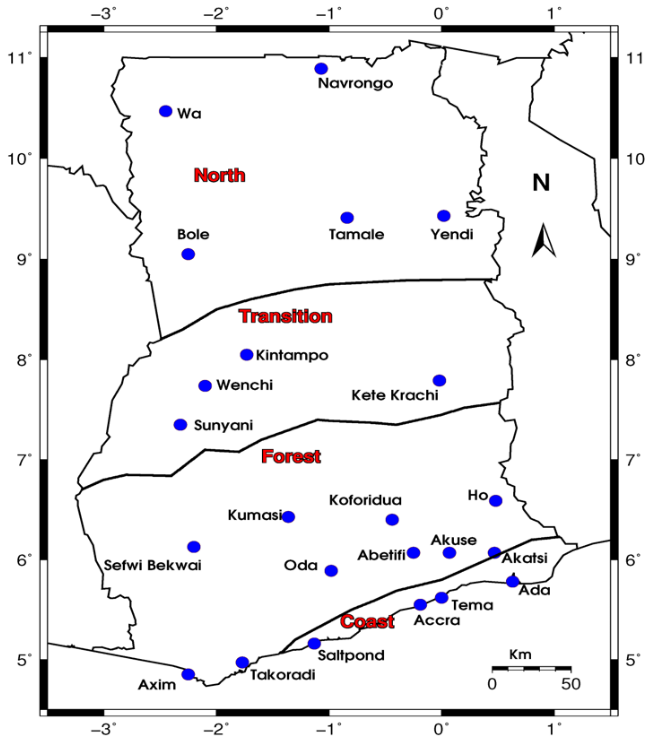

Figure 3.1: Map of Ghana showing the selected study areas. Adapted from Amekudzi et al. (2015)

and the capital of the Kassena-Nankana District. The capital of the Kassena-Nankana District, which is located in northern Ghana's Upper East Region, is Navrongo. In 2012, there were 27,306 people living in Navrongo. It's location co-ordinate are latitude: $\mathbf{10^o}$ 53' 44" N and longitude: $\mathbf{1^o}$ 05' 31" W.

Kumasi is the focus city for the Forest zone. Kumasi Metropolis is the capital of Ashanti and is located on the semi-island exclave Ashantiland in Ghana. Kumasi, the Ashanti capital city, is also known as Kumasi metropolis. Kumasi is located in a rain forest environment 30 kilometers north-east of Lake Bosumtwi, a crater lake. Kumasi is located west and south of Lake Volta, a massive artificial reservoir finished in 1965, and north of Crater Lake Lake Bosumtwi in Ashanti, some 500 kilometers north of the Equator and 200 kilometers (100 miles) north of the Gulf of Guinea. It's location co-ordinate are latitude: $\mathbf{6^o}$ 41' 18.53" N and longitude: $\mathbf{-1^o}$ 37' 27.95" W.

Accra is the focus city for the Coastal zone. It is Ghana's capital and largest city. It is also the coterminous capital of the Greater Accra Region and the Accra Metropolitan District. It's location co-ordinate are latitude: $\mathbf{5^o}$ 33' 21.67" N and longitude: $\mathbf{0^o}$ 11' 48.84" E.

3.3 Data

The Ghana Meteorological Agency (GMet) provided temperature data for the various agro-ecological zones. The data for temperature values spanned from the period of 1981–2020. These are the actual temperature values recorded at the various synoptic stations. The spatial and temporal resolution of the dataset are yearly and point data respectively.

Table 3.1: A table showing data used

DATA	SPATIAL RESOLUTION	TEMPORAL RESOLUTION	DURATION	SOURCE
Minimum Temperature	Point Data	Yearly	1981-2020	GMET
Maximum Temperature	Point Data	Yearly	1981-2020	GMET
Mean Temperature	Point Data	Yearly	1981-2020	GMET

3.4 Analysis

According to Paaijmans et al. (2012) the standard formulation for vectorial capacity (vc) is

$$\boldsymbol{vc = \frac{ma^2bcp^{Eip}}{-In(p)}} \tag{3.1}$$

where vc is the vectorial capacity of the malaria vector,Eip is the extrinsic incubation period, p is the monthly vectorial survival and a, b, c and m are parameters explained below in tabular form with their respective values.

Both the monthly vectorial survival, p and extrinsic incubation period, Eip depends on the temperature and these were calculated using 3.2 and 3.3 respectively.

The daily vectorial survival,

Table 3.2: A table showing parameter values used

PARAMETER	***VALUE***
Vector biting frequency, **a**	$\mathbf{0.01 - 0.5} \boldsymbol{day^{-1}}$
Probability of a person becoming infected, **b**	$\mathbf{0.02 - 0.5}$
Probability of a vector becoming infected, **c**	$\mathbf{0.5}$
Vector: Human ratio, **m**	$\mathbf{0.5 - 4.0}$

$$\boldsymbol{p = -0.00082T^2 + 0.0367T + 0.522} \tag{3.2}$$

(source: (Lunde et al., 2013))

where T represents the temperature.

Extrinsic incubation period,

$$\boldsymbol{Eip = \frac{111}{T - 16}} \tag{3.3}$$

(source: (Detinova et al., 1962))

where T represents the temperature.

The capacity of malaria vectors was then calculated using 3.1 after both the survival probability and the extrinsic incubation period were calculated using their respective functions specified above. This aid in achieving our objectives by determining the influence of seasonal temperature change on the survival and malaria transmission capacity of malaria vectors. Also to determine whether the survival and vectorial capacity of malaria vectors differ as a function of climate and environment in Ghana.

Chapter 4

Results and Discussion

4.1 Introduction

This chapter consist of two main parts namely results and discussion. It presents the findings and interpretations of the results. It also discusses the findings in context with literature. The findings are visualized using graphs.

4.2 Results

Figure 4.1 shows the trend of the monthly survival probability as a function of temperature across the various agro-ecological zones. The graph shows that the survival probability was higher at both coastal and forest zones than the northern zone. Also, the survival probability was higher between the month of June and October and lower between March and May across all zones.

Figure 4.2 shows the trend of the vectorial capacity as a function of temperature across the various agro-ecological zones. The graph shows that the vectorial capacity was higher at both coastal and forest zones than northern zone. Also the vectorial capacity was higher between the month of June and October and lower between March and May across all zones.

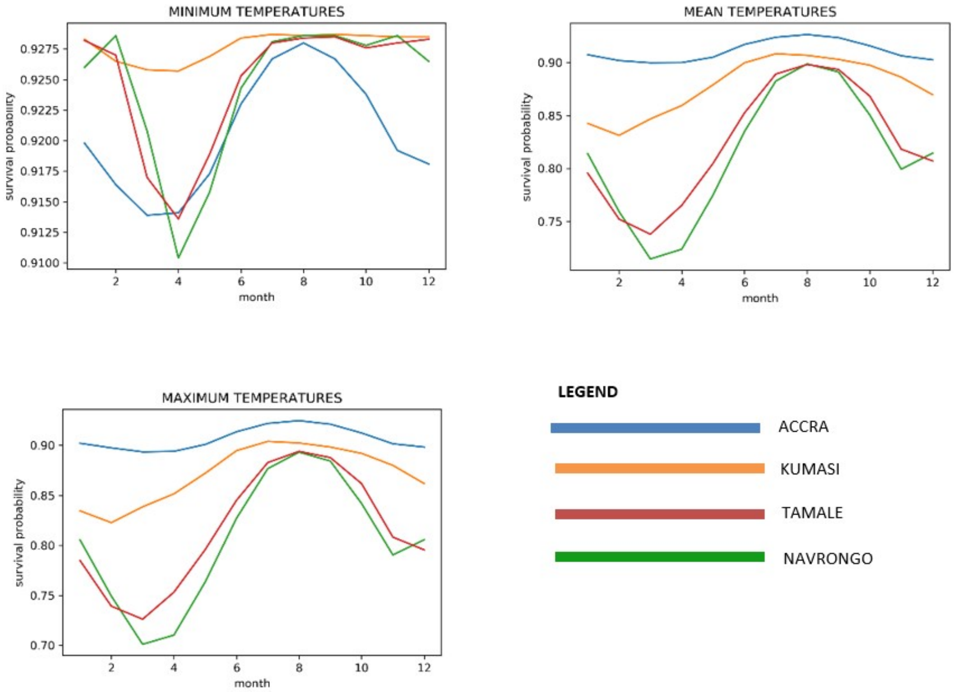

Figure 4.1: Monthly Survival Propability of the malaria vector

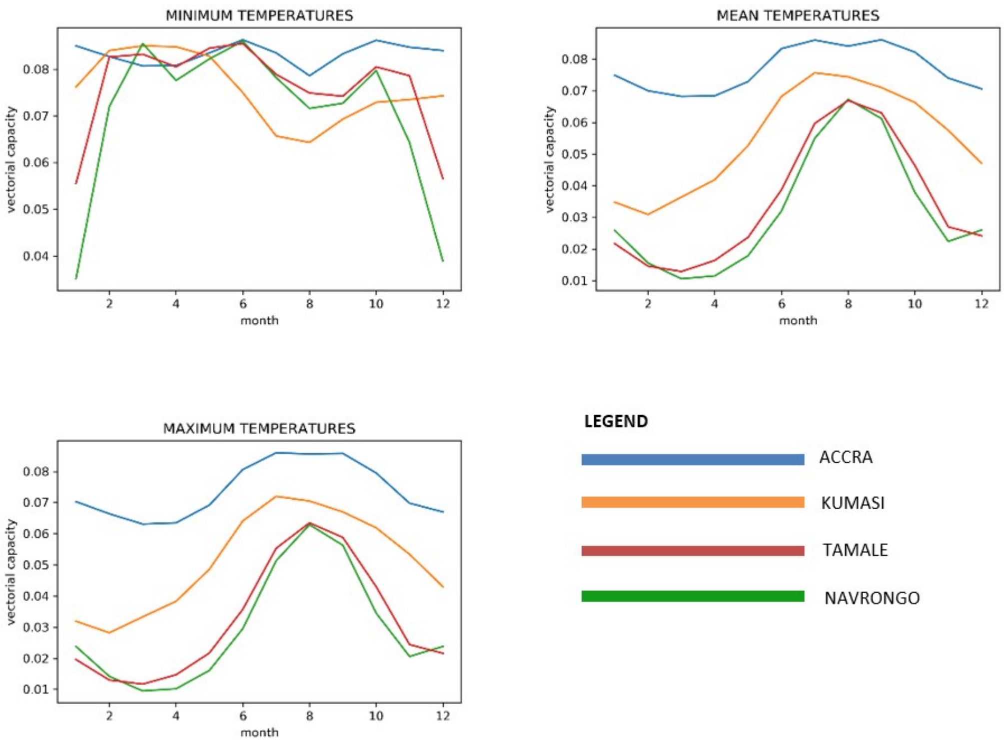

Figure 4.2: Monthly Vectorial Capacity of the malaria vector

4.3 Discussion

The goal of the study was to assess the influence of climate change on malaria vectorial capacity across Ghana's agro-ecological zones. The study discovered that in places with optimum temperatures, both vectorial capacity and survival probability were generally high. The vectorial capacity as well as the ability of malaria vectors to survive were also found to be low in places where temperatures were higher. The vectorial capacity and survival probability in the Northern zone were higher during the wet season but very low during the dry season. For areas found in both coastal and forest zone, the vectorial capacity as well as the survival probability of malaria vectors were higher throughout the year. Malaria vectors' survival and vectorial capacity are both reduced as temperature rises. The vectorial capacity and survival probability were both higher between July and September, with August having the biggest peak across all agro-ecological zones. From February to April, however, both vectorial capacity and survival probability were low in all agro-ecological zones. The results for the vectorial capacity were expected because the northern zone of the country has a very high temperatures which provides unfavorable conditions for the transmission of malaria. However, at the coastal and the forest zones, there is an increase in malaria transmission due to the fact that these areas provide optimum temperatures for malaria vectors. As a matter of fact, the population of malaria vectors are more in the coastal and the forest zones as compared to the other zones.

The study therefore showed that temperature seasonality have influence on seasonal changes in survival probability and the vectorial capacity of malaria vectors as well as determined how the survival probability and the vectorial capacity of malaria vectors differ as a function of climate and environment in Ghana.

Chapter 5

Conclusion and Recommendations

5.1 Introduction

This chapter discusses the conclusions reached as a result of the research. Also included in this chapter are recommendations related to the research project.

5.2 Conclusions

The purpose of this study was to determine the influence of climate change on malaria vectorial capability across Ghana's diverse agro-ecological zones. The extrinsic incubation duration as well as the survival probability across the various agro-ecological zones were estimated using the average monthly temperature from 1981 to 2020. The vectorial capacity increases as the temperatures increases for maximum and minimum temperature range and decreases with decreasing temperatures for minimum temperatures due to the fact that at extreme low temperatures the digestion rate of the vectors is low. However, for the survival probability, increasing in temperature decreases the probability of the malaria vector to survive and vice-versa. The trend of the graph revealed that, at rainy/wet seasons the vectorial capacity together with the survival probability were higher than during dry seasons.

The quest to find out whether vectorial capacity of the malaria vector differ as a function of climate and its environment in Ghana was answered by the study reviewing that at the northern zone the vectorial capacity and survival probability were higher during rainy season but lower during dry season whiles for coastal and the forest zones the vectorial capacity and survival probability of the vectors were higher throughout the year.

Having knowledge of how climate change influence the vectorial capacity of the malaria vector over their agro-ecological zones of Ghana will be of great importance to the country and will result in many benefits. Having such kind of information will provide research information on how the warming climate influence the capacity of malaria vectors. Also, it will provide knowledge on the differential burden of malaria as a function of climate and environment. As a country, we face an inevitable challenge pertaining to the high mortality rate especially in infants, which threatens the future of Ghana. As a matter of fact, this study will provide information useful for the design of malaria control programs and possible elimination of the disease. With this knowledge, targetted interventions can be made to counter the mortality and morbidity of malaria in Ghana especially in infants. The outcome of this study would be of much importance in contributing to achieving the Sustainable Development Goal (SDG) number 3.

5.3 Recommendations from this study

This study recommends that:

1. Government and stakeholders in controlling of malaria should target the northern zone during the rainy season and target both the coastal and the forest zone throughout the year.

2. Other future works should focus on more cities across the various agro-ecological zones since each city have it own micro-climate which influence the malaria vectors.

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