IMPACT OF CLIMATE ON THE VECTORIAL CAPACITY OF MALARIA

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Dedication

as to everyone else who contributed to the success of this project.

Abstract

The focus of this study was to figure out the impact of some climatic factors on the vectorial capacity (malaria distribution) aside the non-climatic factors. Climate change has been a challenge for about forty years now. The variation of Climatic factors such as temperature and rainfall with the vectorial capacity have been studied thirty-nine years in this research within some selected areas in Ghana. A temperature and rainfall data have been collected with a temporal domain from 1981 to 2020 for Accra in the coast agro-ecological zone , Kumasi in the forest zone, Navrongo and Tamale in the Savannah zone of Ghana. The temperature data was from Ghana Meteorological Agency(GMET) with a temporal resolution of daily and a spatial resolution of point data. The rainfall data-set was obtained form Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) with a daily temporal resolution and 0.25 spatial resolution.

The monthly mean maximum, minimum and mean temperatures were computed for each of the stations under study. It was deduced that the vectorial capacity reduces as the temperature get extremely high. It was deduced that vectorial capacity was higher in the regions where temperature was between the range of 22 and 28 degrees celcius. Accra and Kumasi which experience temperatures within this range have higher vectorial capacity which means that the probability of the vector(Mosquito) surviving was

very high. Tamale and Navrongo which experience temperatures within and out the range have a very low vectorial capacity which means that the vectorial survival probability was low. This brought the conclusion that temperature as one of the climatic factors has a greater effect on the vectorial capacity(Rate of malaria distribution) . The monthly mean rainfall was computed for all the areas under study and it was deduced that that the greater the value of rainfall the higher the vectorial capacity. This is because the vector breeds in a stagnant waters hence areas which receive higher amount of rainfall are unfurled for more mosquitoes leading to higher malaria distribution. The result from this study provides knowledge on how climate affect the life cycle of mosquitoes causing malaria distribution.

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Acknowledgment

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CHAPTER 1

INTRODUCTION

Nearly half of the world's population suffers from malaria which falls amongst the most pressing diseases caused by vector. Plasmodia parasites which are the cause for malaria, are transmitted to persons via the bites of infected female Anopheles mosquitoes.Malaria in humans mostly is caused by five distinct species of parasite, with the most threat being posed by the P. falciparum and P. vivax. Most of the world's tropical and subtropical regions are home to Anopheles. There are increasingly more cases of imported malaria being reported as a result of migrant flows from malaria endemic countries and international travels. This may result in the resurgence of malaria in previously Malaria free countries, together with favorable conditions of climate and capable vector and signs of changing environment. The receptivity and sensitivity in a specific location determine the danger of malaria spreading there. Climate factors, including temperature, rainfall patterns, and humidity, have a significant impact on the life cycles and survival of parasites and vectors, and as a result, strongly influence the susceptibility to transmission of diseases like malaria and other vector-borne illnesses. Climate change is defined as a long term change in the state of climate which is observable by climate property variations which can last for an extended time period, generally for dacades or more. Environmental factors such as temperature increase, precipitation, sea level rise, ocean acidification, and extreme weather occurrences are all impacted by climate change (heat weaves, floods, windstorms). According to the

WHO, receptivity is the extent to which an ecosystem in a certain location at a specific moment permits the spread of Plasmodium spp. The idea incorporates the mosquito's ability to transmit malaria, the vulnerability of the general population to the disease, and the effectiveness of the healthcare system, including malaria therapies. Receptivity is controlled by ecological and climatic conditions, as well as vector susceptibility to specific Plasmodium species. An area's vulnerability, also known as the "importation risk," is determined by the regular in movement of affected people and infected female Anopheles mosquitoes.

1.1 PROBLEM STATEMENT

The ability and proficiency of local mosquitoes as vectors have a serious impact on the intensity of malaria transmission in humans(Cohuet et al., 2010). Thus, climate change affects or has an impact on the ability of malaria vectors to transmit malaria; However, important details have been forfeited, and the effect of change in climate on the ability of malaria vectors to spread the disease is frequently disregarded. Out of about more than hundred million cases more than four hundred thousand deaths as a result of malaria Worldwide recorded by the World Health Organisation in 2019, 11 nations were part,10 coming from Africa with Ghana inclusive. In Ghana,malaria continues to be a major cause of sickness and death, especially in children and pregnant women, accounting for 41 percent of suspected, 21 percent confirmed, and 18 percent inpatient malaria cases in 2020.Climate change is one of the causes of malaria. Most cases are documented between May and July, when the heaviest rainfall is experienced. (Martens et al., 1995), for instance, researched on the potential effects of climate change on the risk of malaria. They came at the conclusion that the immensity of malaria increase risk will depend on how the transmission of the disease changes due to socioeconomic development, expansion of population, and the effectiveness of preventative efforts. Additionally, a study conducted by (Ceccato et al., 2012) that examined the malaria vector's ability to transmit the disease had scant data and was restricted to the region of Africa where the disease was endemic.

1.2 STUDY QUESTIONS

For solutions or answers to the listed problems, the study posed the following questions:

1. How does temperature change(seasonally) determine the surviving ability and capacity of vectors of malaria over the zones in Ghana?

2.Is there a change in the agro-ecological zones when it comes to survival and vectorial capacity of malaria?

1.3 AIMS

To evaluate the climatic footprint on the survival and the malaria vector's capacity over the agro-ecological zones of Ghana.

1. Identify the effect on changes in seasonal temoerature change on the surviving and transmital capacity of vectors of malaria.

2. Determine if there is a diffrernce between the surviving and vectorial capacity of Ghana's environment and climate.

1.4 RESEARCH IMPORTANCE AND JUSTIFICATION

Knowing how change in climate have an impact on the capacity of vectors and survival chance of malaria vectors over the main zones in Ghana will be of much significance to Ghana and will yield great advantages. Having this sort of informative knowledge will give research information on the impact climate heating on malaria vector capacity. Again, it will also give an idea on the distinctive weight of climatic impact of malaria and its surrounding. Ghana is faced with an unpreventable task owing to the increase in death rate for children in particular, which pose a threat on Ghana's future.

This study will give knowledge which will be essential in designing programs aimed at controlling malaria with the possibility of eliminating the disease. With such information, targeted mediation can be made to encounter Ghana's malaria mortality and morbidity in children specifically. This study outcome would be very crucial in accordance to gaining sustaining Goal in Development.

CHAPTER 2

THEORETICAL BACKGROUND

2.1 MALARIA

Although there are many different themes covered in the literature on malaria and related problems, this review will focus on a few important ones. These subjects may cover malaria and its parasites, the malaria life cycle, factors that make malaria vectors more effective, the competency of the malaria vector, and evaluated works (articles). Plasmodium is a single-celled parasite that causes malaria. When female anopheles mosquitoes feed on an infected person's blood, the parasite infects them (Odikamnoro et al., 2018). Malaria can be prevented and cured . Infected individuals typically show signs 10 to 20 days after being infected. Symptoms may involve general body weakness,fever,headaches etc., which are the most prevalent symptoms shown by an affected person. Adults and infants can have malaria, but the latter is more likely to die from it. Globally, malaria is transmitted, but South Asia and sub-Saharan Africa are the two regions most severely impacted. Malaria can be deadly, even though most illness and death malaria cases can be avoided. The infected Anopheles mosquito is the cause of malaria. If one receives contaminated blood after a blood transfusion, an organ transplant, or the sharing of sharp unsterilised objects like syringes and needles. It may also be passed from mother to foetus when pregnant(congenital malaria). Malaria is a disease caused by a vector called the female anopheles mosquito, which differs from other mosquito species by having distinctive physical traits. Anopheles mosquito species are many, but only a few can spread the infection. The five malaria parasites are P.falciparum,P.knowlesi,P.ovale, Plasmodium vivax and P.malariae. P.falciparum is the one that causes the most of the malaria disease globally, from these five known malaria parasite. In every part of the world, not all five parasites are necessarily to blame for malaria. For instance, the pathogens in Ghana are P. falciparum, P. malariae, and P. ovale. Examples of the vector that transmit malaria are, An. Gambaiae sl and An. Funestus. In various regions of the world, it is the Anopheles mosquito species that is responsible for transmitting malaria.

2.2 LIFE-CYCLE OF MALARIA

The lifecycle of malaria starts with an infected vector biting a human to feed on his blood. The parasites that cause malaria are released into the host's blood stream as it consumes this blood (human being). This bite is infectious. The parasites after the bite swiftly migrate to the cells of the liver after entering the bloodstream and that is where they mature and multiply i.e. schizogony. Numerous merozoites are released into the circulation by the infected liver cells, and then infiltrate the Red Blood Cells. This stage may take 8-15 days. Afterwards, within the Red Blood Cells the parasites form from ring form into blood schizonts. The Red Blood Cells are then raptured by the schizonts releasing several daughter parasites called the merozoites which invade the newly formed Red Blood Cells. The process that starts the chills and fever that are a defining feature of malaria occurs when the infected red blood cells rupture. The release of the merozoites from raptured Red Blood Cells into the bloodstream causes

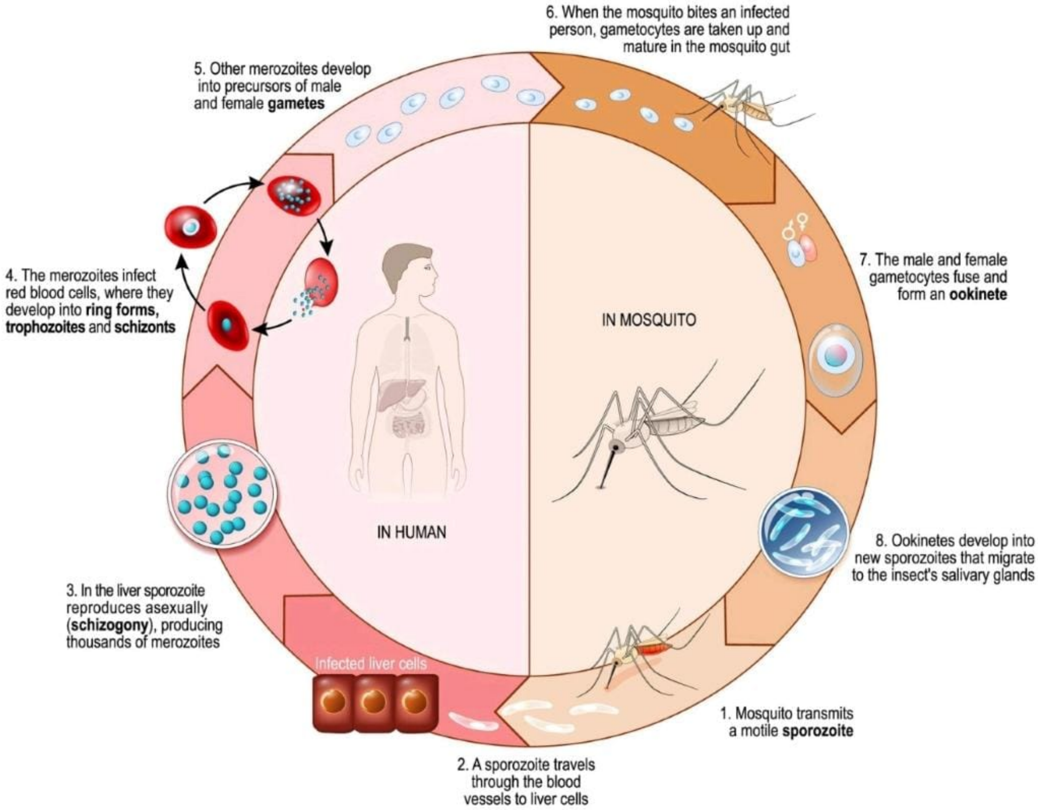

Figure 2.1: Life Cycle of Malaria

the fever peaks associated with malaria. Incubation period is the period following the infective bite of the vector and the time for the appearance of the symptoms.The perioid takes 7-14 days but maybe shorter or longer for some species; example short for P.falciparum and longer for P.vivax and P.malariae.

2.3 FACTORS OR ELEMENTS THAT AMPLIFIES MALARIA

There are climatic factors and non-climatic factors that affect malaria.

2.3.1 CLIMATIC FACTORS

Temperature, Rainfall and Humidity are the three main elements that affects Malaria.

Temperature

The parasite and its vector, which governs the transmission of malaria, are significantly impacted by the low and high temperature ranges. In the intestines of a mosquito, a parasite may take around 10 days to develop, but this time will depend on the temperature; a lower temperature will lengthen the time needed for development to be finished, while a higher temperature will shorten it. Higher temperatures also cause mosquitoes to consume more blood and lay more eggs, increasing the overall population of mosquitoes in a particular location. Because temperature drops as altitude rises, highlands are colder while lowlands are warmer.

Rainfall

The preferred breeding ground or place for some mosquitoes is water. The adequate rainfall amount is often crucial for breeding for these mosquitoes. Water clumps that facilitate vector breeding generally form after Following the rainy season, malaria transmission is at its greatest. Although, too much rain might temporarily remove nesting grounds, mosquitoes begin to spawn as soon as as soon as it stops raining. The mosquito life cycle is not suitable for all water sources. The majority is of stagnant water collections, which are often seen after rainfall.

Humidity

Relative humidity refers to the percentage of moisture in the air. 0% humidity would indicate that the air is completely dry, else 100% humidity indicates that the air is totally saturated with moisture. The survival of mosquitoes and their activities depends on the relative humidity and impact the transmission of malaria. For mosquitoes to spread malaria, they must survive for at least 8–10 days. High humidity levels are helpful for the survival of mosquitoes. Additionally, increase in humidity increases the activeness of the mosquitoes. Due of the higher environmental relative humidity at night, mosquitoes are more active and as such they choose to feed at night.

2.3.2 NON-CLIMATIC FACTORS

Some elements influences malaria transmission, yet have nothing to do with the climate and weather. Mosquitoes or vector type and parasites, environmental change, urban growth and migration, human host immunity, resistance to insecticides by vectors(mosquitoes) and parasite resistivity to drug are few of the non-climate relating factors that affect malaria transmission.

2.4 VECTORIAL CAPACITY AND PROFICIENCY

Vectorial capacity is an equation that accounts for the major factors of pathogen transmission by mosquitoes and its defined as the average number of new vertebrate infection per day resulting from an initial case index. Earlier case index is the first documented patient in a disease epidemic within a population. Counter to the definition by the World Health Organization for "vector efficiency", the vector capacity of the mosquito is a density dependent characteristic. It is a function of the absolute level of vectorial capacity, which is calculated as the result of the multiplication of the rate of man-biting, the anticipated infective life, and the habit of man-biting (Garrett-Jones et al., 1964). The amount of the mosquito's vectorial capacity at every location and time (or the total of connected vectors' capacities) corresponds to the daily proportion of the basic reproduction rate, which is the daily reproduction rate of malaria. As a part of vectorial capability, vector proficiency is controlled by intrinsic (genetic) characteristics that affect a vector's capacity to transmit a pathogen to another host. Vector competent or proficient is when a female mosquito is able to carry the pathogen from a host to another host at the time of blood feeding. Both the proficiency and the capacity are crucial for the arbovirus transmission analysis. The intrinsic traits of the mosquito and the pathogen, like the pathogen strain and genotype, are related to this proficiency.

2.5 WORK REVIEW

The majority of the research on the malaria vector had interest on malaria transmission and seasonality. This study looked at a number of papers or research works to determine what had been done and what had not been done. Example is the work of,(Ceccato et al., 2012) which examined a product with a vectorial capacity to keep track of changes in the potential for malaria transmission in an epidemic region of Africa. In their research, the vectorial capacity model (VCAP) was expanded to take into account the impact of temperature and rainfall variables on the likelihood of malaria transmission. They used the data from two remote sensing techniques to track temperature and rainfall. They descried that Eritrea has an effective malaria management programme that has led to a significant drop in the number of malaria cases between 2000 and 2009. The country is nevertheless thought to be more susceptible to malaria when the weather is bad. Finally, the extended VCAP accurately monitors the risk of malaria in both areas where rainfall is a limiting factor.

(Mutunga et al., 2012)conducted study on how climate change affects the geographic distribution of illnesses. The Millennium Ecosystem Assessment has shown how the functioning of ecosystem services contribute to the preservation or otherwise of human health, whereas the Intergovernmental Panel on Climate Change has demonstrated that the climate will change and provides various scenarios on what may happen and when. It is understood that communities in poor nations, notably in Africa, would bear the heaviest burden of anthropogenic climate change's repercussions. For instance, the IPCC predicts that some regions of Africa will get warmer and drier, and that there will be more storms and floods on a more frequent basis. Rainfall distributions and totals will change as a result, as water is a basic human need that also has an impact on wellbeing and health. The majority of research conclude that temperatures will rise as a result of global warming, carbon dioxide concentration, precipitation, drought, and humidity. These variables impact the intricate connections within the public health triad comprising the environment, host(human) and disease pathogens.

In Kerman, southeast Iran, (Mohammadkhani et al., 2016) conducted study on the relationship between meteorological variables and malaria occurrence. The medical schools in Kerman and Jiroft were contacted for information on the prevalence of malaria in the province, and the Kerman Meteorological Organization was contacted for information on climate variables. Monthly data from 2000 to 2012 were used. The STATA II programme was used to evaluate variations in malaria incidence with respect to climate conditions. They uncovered that temperature had the most meteorological impact on the prevalence of malaria. As monthly mean maximum and lowest temperatures rose, so did the incidence rate. To conclude, one climate parameter that might have an important effect on the likelihood of malaria is temperature, which should be considered when planning for prevention and control of the disease.

In a region of the western Kenyan highlands that is prone to malaria epidemics, (Afrane et al., 2008) looked at how deforestation affected microclimates and the growth of Plasmodium falciparum parasites in Anopheles gambiae mosquitoes. Through membrane feeders, P. falciparum-contaminated blood was given to An. gambiae mosquitoes. In a highland region (1,500 m above sea level), fed mosquitoes were placed in residences in forested and deforested areas, and parasite development was tracked. The temperature and relative humidity were higher in deforested areas, and the total mosquito infection rate was higher than it was in wooded areas. In areas with less vegetation, sporozoites developed on average 1.1 days earlier. environmental modifications Over the course of the entire experiment, the three locations' mean indoor temperatures in experimental homes varied significantly (lowland 23.9°C, deforested area 22.4°C, and forested area 21.5°C; $F_{2,8}$ 4.5, p0.05), Over the course of the entire trial, the mean outside temperatures in the experimental homes varied significantly amongst the 3 sites (forested 19.0°C, deforested 19.9°C, and lowland 22.4°C; $F_{2,8} = 58.1$, p0.0001). Change the ecological environment in which disease-carrying vectors and their parasites reproduce, grow, and spread, regardless of whether these changes are the consequence of natural processes or human activity.

Even as these earlier studies include details on the capacity and transmission of malaria vectors, they frequently offer scant details on the vectorial capacity or population density of malaria vectors. The majority of study projects focus on how climatic conditions affected malaria transmission. Particularly, there is little knowledge of the malaria vectors' ability to spread the disease. Therefore, it's crucial to look at the malaria vector population. The results of such a study will provide essential scientific data for the implementation of malaria control programmes. Additionally, the findings of this study would be crucial in assisting in the achievement of Sustainable Development Goal (SDG).

CHAPTER 3

STUDY AREA, DATA AND METHOD

The chapter focus mostly on the data obtained as well as the methods used for data gathering and analysis. It commence by a description of the study area or region, which is the agro-ecological zones located in Ghana. This is followed by the research data, or the information gathered. The chapter also featured data analysis.

3.1 AREA OF STUDY

The agro-ecological zones of Ghana are the focus of this research. Ghana is divided into four agroecological zones: Northern, Transition, Forest, and Coastal. Cities can be found in every single one these agroecological zones. We chose four cities with synoptic stations from various zones.

Kumasi is the Forest zone's focal point. Kumasi Metropolis is a Ghanaian metropolis and the capital city of Ashanti, located on the semi-island exclave Ashanti- land. Ashanti is centred on Kumasi, which is the Ashanti capital city, commonly called as 'Kumasi metropolis'. Kumasi is located 30 kilometres north of a crater lake known as Lake Bosumtwi, in the rain forest. Kumasi is situated west and the south of Lake Volta, an artifial lake in Ghana, and north of Lake Bosumtwi, which is located within Ashanti and roughly 500 kilometres or 300 miles north of the Equator and 200 kilometres or 100 miles north of the Gulf of Guinea. It is located in latitude 6 ° 41' 18.53" N and longitude 1 ° 37' 27.95" W.

Accra is the coastal zone's focal point. Ghana's capital and largest city. It is also the coterminous capital of the Greater Accra Region and the Accra Metropolitan District. It is located in latitude 5 ° 33' 21.67" N and longitude 0 ° 11' 48.84" E.

Tamale is the northern zone's focal point. It is the capital of Ghana's northern region. Tamale is Ghana's second largest city in terms of land area. According to the 2012 census, its population is expected to be 562,919 people. The village is 600 kilometres (370 miles) north of Accra. It is located in latitude 9 ° 24' 2.84" N and longitude 0 ° 50' 21.48" E.

Navrongo the capital of the Kassena-Nankana District in northern part of Ghana precisely Upper East Region, near the border with Burkina Faso. Navrongo had a settlement population of 27,306 persons in 2012. It is located at latitude 10 ° 53' 44" N and longitude 1 ° 05' 31" W.

3.2 DATA

Temperature data for Ghana (maximum, minimum, and mean) were collected from the Ghana Meteorological Agency (GMet) for the main Agro-ecological zones. Temperature values were collected between 1981 and 2020. These are the real temperature readings from the synoptic stations. The dataset's spatial and temporal resolutions are point data and yearly, respectively.

A precipitation data of a temporal domain from 1981 to 2020 from chirps for Ghana was downloaded. The temporal and spatial resolutions of the data are daily and 0.25 respectively. The monthly mean precipitation was calculated for each of the four stations under study

CHAPTER 4

RESULTS: ANALYSIS AND DISCUSSION

From the analyzed data, a time series chart was plotted to determine the variation of the vectorial capacity and the vectorial survival probability with temperature throughout the months for the monthly mean maximum, minimum and the mean temperatures. This is to identify how a vector transmit malaria within a specific period as temperature varies. Since mosquitoes breed in a stagnant water, we also considered the amount of rainfall within the months and plotted a time series chart. From our results, vectorial capacity decreases when temperatures are extremely high that is 30 degrees Celsius and above because the vector(mosquito) is unable to survive and hence the rate of transmission of malaria becomes low.

Accra which has its monthly mean maximum temperatures ranging from 24.31 to 28.67 degrees Celsius , the monthly mean minimum temperature between 23.06 and 26.38 degrees Celsius and the monthly mean temperature between 23.37 and 28.07 degrees Celsius has the higher peak of the vectorial capacity to be 0.086, 0.0863 and 0.0861. respectively. This means that the vector(mosquito) has a higher probability of surviving hence the faster the transmission of of malaria since the entrincic incubation period is shorter at temperatures 27, 28, 29 degrees Celsius and above. In the month of March, Accra has the highest monthly mean maximum temperature which recorded the lowest vectorial capacity and vectorial survival probability. This depicts that the vector cannot survive higher temperatures. This is why Accra experience low malaria

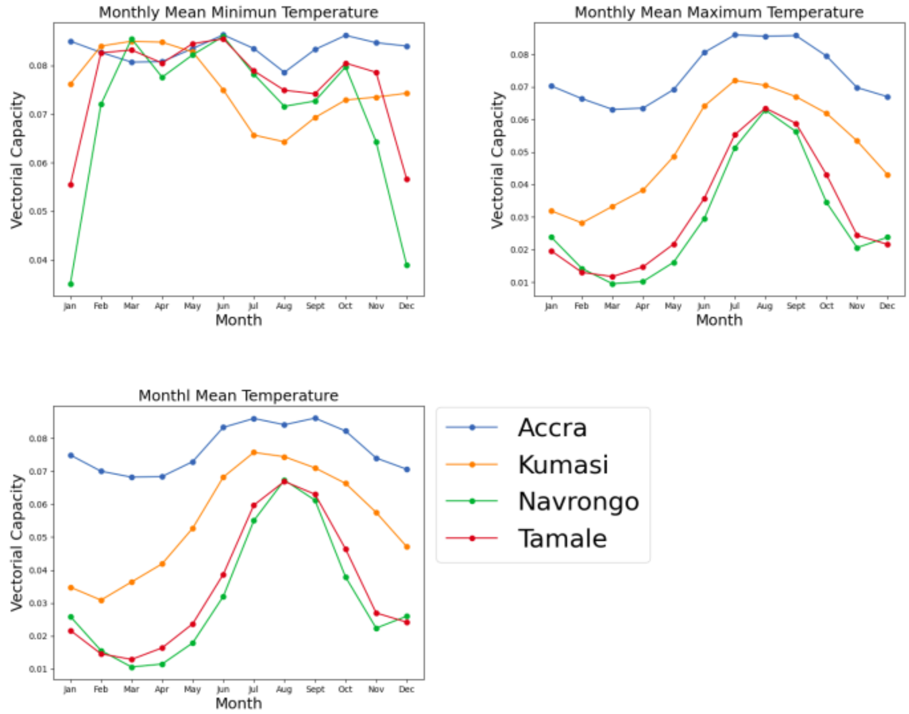

Figure 4.1: Monthly mean Maximum, Minimum and Average Temperatures with Month

infection in March but rather high in June, July and August. The maximum rainfall in June and July also contribute to the higher vectorial survival probability because the vector breeds in stagnant waters. At low and very low temperatures, example 16 degrees Celsius and below, the vector(mosquito) can survive but the parasite cannot survive.

Vectorial capacity is higher in Accra due to the temperatures they experience. It is lowest in Navrongo due to the extremely high temperatures that they experience. The rest of the stations, Kumasi and Tamale fall within the temperatures Accra and Navrongo experience. For the monthly mean rainfall, Navrongo recorded recorded the highest in in August lowest in December and January.

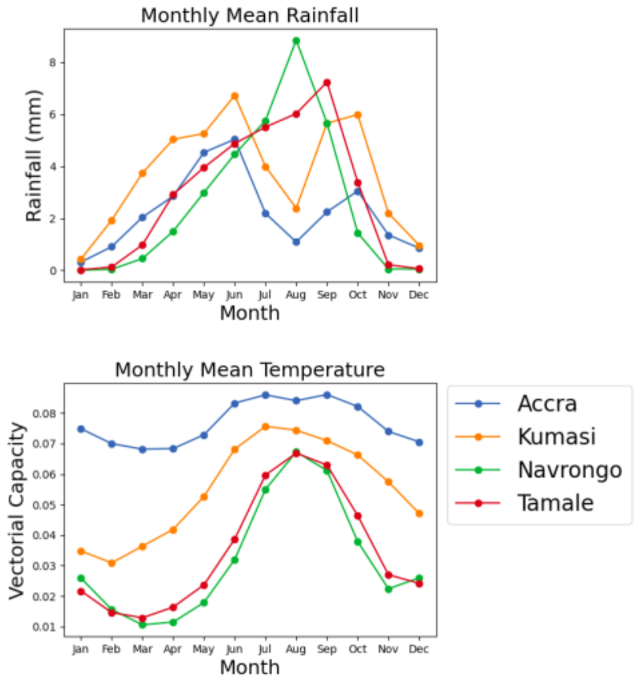

Figure 4.2: Rainfall and Vectorial Capacity with Month

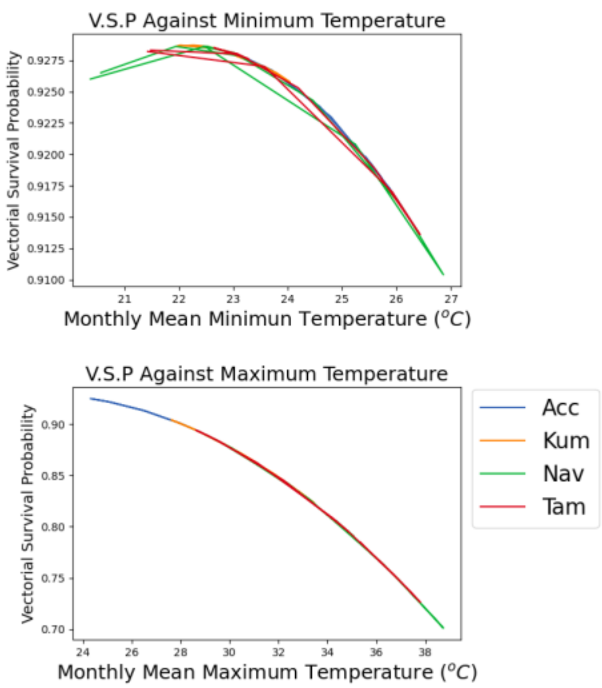

Figure 4.3: Vectorial Survival Probability against Maximum and Minimum Temperature

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Temperature and rainfall as climatic factors in Ghana have a huge impact on the life cycle of a lot of organisms such as mosquitoes. Extreme temperatures can depopulate mosquitoes while extreme rainfalls increase mosquitoes population within an environment.

From this study, it was observed that malaria is not only caused by only non-climatic factors but also climatic factors such as rainfall, temperature and humidity despite humidity was not part of the studied climatic factors. It was observed that Accra and Kumasi have recorded higher value of vectorial capacity which means that the climatic factors have a positive influence on the vectorial capacity as well as the vectorial surviving probability. Tamale and Navrongo have recorded a lower value of the vectorial capacity due to the temperature they experience despite the fact that they receive higher amount of rainfall, the vector(mosquito) live for only short period of time and then dies out. It was also observed that at very low temperatures, vectorial capacity was high but the rate of malaria distribution was low because the malaria parasite cannot withstand low temperatures. This means that we can have mosquitoes surviving at a very low temperatures but unable to transmit malaria. This knowledge will assist Ghanaians especially those within the study areas to take precautions as to how they increase human activities which brings climate variability.

5.2 RECOMMENDATION

Our method employed was very well scrutinised and as such we recommend it for future research relation similar case.

Our project examines the impact of Climate on the Vectorial Capacity of Malaria. However we believe our work raises several hypothesis that merit further and future research including:

1. Investigating how low temperatures affects Mosquito life-cycle
2. Developing test method for assessing the amount of plasmodium parasite in the bloodstream of humans under favourable conditions.

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