A CONTEXTUAL ANALYSIS: THE EFFECT OF CLIMATE CHANGE ON THE TRANSMISSION AND PREVALENCE OF MALARIA IN SENEGAL

by

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A THESIS

Presented to the Department of Environmental Studies
and the Robert D. Clark Honors College
in partial fulfillment of the requirements for the degree of
Bachelor of Science

May 2026

An Abstract of the Thesis of

Natalie Hartley for the degree of Bachelor of Science
in the Department of Environmental Studies to be taken June 2026

Title: The Effect of Climate Change on the Transmission and Prevalence of Malaria in Senegal

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Senegal, a developing country, has an extremely high prevalence of infectious diseases. Climate change exacerbates this issue, as developing nations often lack the resilience and access to resources necessary to mitigate outbreaks. Consequently, Senegal experiences an increase in infectious diseases despite efforts to establish resilient infrastructure and increase resource access. Flooding is intensified by limited infrastructure, causing water to lay stagnant in potholes, old tires, buckets, etc. Stagnant water or damp soil serves as breeding grounds for mosquitoes, as they lay eggs in these conditions, increasing the mosquito populations. Malaria is common in Senegal: it poses a severe threat to human health and can be fatal. It causes anemia by destroying red blood cells, making prevention the most effective protection.

I determined whether mosquito-borne diseases, like malaria, are more susceptible to transmission during periods of increased rainfall or flooding and how Senegal is disproportionately affected by climate change. To achieve this, I used Senegal's weather data over the past five years to observe rainfall patterns and compare them with malaria death and case data over the same period. This analysis helped establish a correlation between increased rainfall and malaria spread, which can be used to predict future trends. Examining annual average temperature over this period also helped identify climate change-driven temperature increases that may prolong and intensify the rainy season. A comparative analysis of rural and

urban areas provided insight into conditions that support mosquito proliferation and how resource access affects prevention. High-risk populations in Senegal include children under five and pregnant women, who disproportionately contribute to malaria incidence and mortality.

Acknowledgements

I would like to thank Dr. Jean Faye for his patience, knowledge, and resources. His contributions have been extremely helpful in my success in completing this project. I would also like to thank him for allowing me to have the opportunity to travel to Senegal in the summer of 2025. Learning about climate change issues, infectious diseases, and developmental challenges from him during my study abroad program increased my interest in this topic and inspired me to write this thesis. I would like to thank Dr. Dennis Galvan for his expertise and support.

I would like to thank my parents and grandfather for supporting my journey at the University of Oregon at Clark Honors College. The encouragement from my family has been the biggest help to get me to complete my thesis project. I would also like to thank the friends I made at the University of Oregon; you all were the most understanding and kind. I appreciate all you have done for me in the past four years.

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Chapter 1: Introduction

Climate drivers such as rainfall, humidity, and temperature lead to environmental conditions which increase suitable habitats for mosquito breeding and survival, this intensifies the environmental hazard of malaria transmission and prevalence resulting in increased malaria-related mortality in Senegal.

Senegal, a country situated in West Africa, extends to the westernmost point of the continent along the Atlantic coast. Senegalese climate is characterized by a tropical pattern, a distinct dry season, and a rainy season. The latter is predominantly influenced by the seasonal shifting of the intertropical convergence zone (ITCZ), a low-pressure region where warm, dry air originating from the land converges with moist air originating from the oceans. This convergence results in intense rainfall events (Camara, 2026). Senegal's already high rainfall and humid climate, contribute to the prevalence of malaria in the region (Talla et al., 2025). Moreover, the lack of resilient infrastructure in Senegal prolongs flooding following heavy rainfall events. (Global Climate Risks, 2025).

Less developed countries, like Senegal, are disproportionately impacted by climate change. Senegal experiences extreme flooding. The government allocated $4.5 million to assist those who have been affected by the floods in 2025. This aids in drainage works and food aid, shelter, and logistics (Ecofin Agency, 2025). More aid is needed to prevent flooding. The World Bank has approved $135 million to reduce and anticipate flooding in Senegal. This money goes to strengthening urban planning and management (The World Bank, 2023). The original completion date was 2026, but it has since been postponed to 2029. Senegal has been disproportionately affected by climate change compared to other countries. In this country, support for healthcare, infrastructure, finances, access to food and clean water is minimal

(USGLC, 2021). The lack of robust infrastructure, combined with increasingly extreme weather, causes significant flooding. Poverty impacts Senegal's roads as they are mostly dirt, with numerous potholes, and during severe storms, these potholes create stagnant water conditions, even in some homes and businesses, which also lack resilient infrastructure (United Nations, n.d.). The lack of drainage systems that mitigate flooding is another reason for malaria prevalence. Standing water, specifically created from flooded tires, buckets, plastic bags, and other garbage, indicates that malaria is tied to poverty. This standing water serves as an ideal breeding ground for mosquitoes, which are already prevalent in the region. However, climate change has extended their survival periods.

Figure 1, provided by the World Health Organization (WHO), presents data on malaria incidence in Senegal. The key variable in this graph is the cumulative number of malaria cases in Senegal from 2023. Limitations of this data is it only includes incidence not death data. This map indicates the countries with cases of malaria; Senegal had a high rate at the start of the 21st century. Senegal's decline in malaria incidence can be attributed to prevention measures, even though it is a less developed country, the incidence is very similar to the world's malaria incidence.

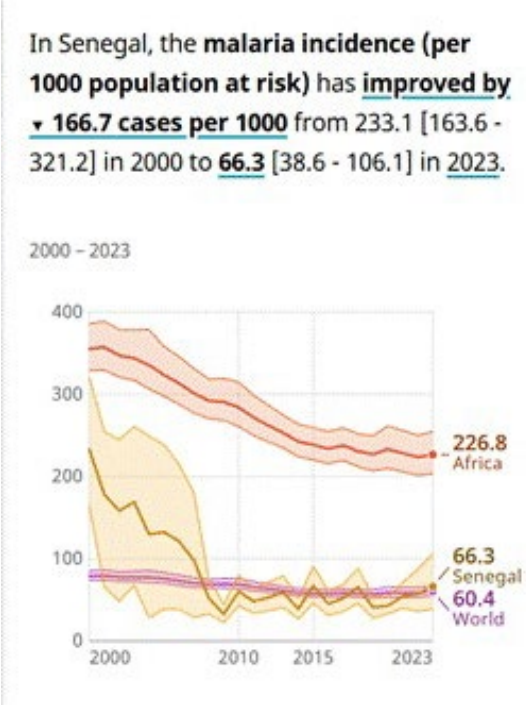

Figure 1. Senegal malaria incidence 2000-2023 compared to Africa and World

The importance of this study is how much of a burden malaria is in Senegal, especially on vulnerable populations and the healthcare system. Senegal can be described as a malaria-endemic country, this means 100% of the population is at risk of this infection and is the leading cause of morbidity and mortality (Thwing et al., 2017). Malaria transmission and mortality rates contribute to the strain on the country in terms of healthcare resources, healthcare related costs for families, and overall slowing the economy which contributes to cycles of poverty. This disease contributes to decreases in labor productivity and can negatively affect long-term economic growth (Mezieobi et al., 2025). These reasons make studying this topic very crucial for Senegal. More research done on this topic aids in effective prevention measures and control strategies.

Infectious diseases are associated with poverty, poor diets, and limited healthcare. (Bollyky, 2018). During my trip to Senegal, one of the lectures we attended by Dr. Boly Diop, the Minister of Health in Senegal and epidemiologist, took the time to speak to us and taught us

information on infectious diseases, specifically in Senegal. He explains that infectious diseases are an issue in Senegal and prevention and vaccination are important. In addition to limiting the breeding grounds for mosquitoes, strategies to limit vector-borne diseases, like malaria, include prevention and education, mosquito nets, housekeeping, washing hands, vaccines and medication (Diop, 2025).

Infectious diseases exhibit distinct patterns, including their initial emergence and long-term persistence. The initial appearance of an infectious disease has high mortality and morbidity rates, affecting individuals of all ages. It often occurs in epidemic stages characterized by instability and includes psychological factors such as fear. *Psychosocial consequences of infectious diseases* by Pappas et al describes how fear is a psychological consequence of infectious diseases. Fear is a physical response and can lead to individual protection. These protective measures can lead to an increase in morbidity; they can be a threat in and of itself (Pappas et al, 2009). Long-term presence (30-40 years) of infectious disease has low mortality, affects those more susceptible (children and elderly), has endemic stages (stable), and psychological factors are not very important. Diseases can either emerge or reemerge (Bollyky, 2018). Dr. Boly Diop indicates that climate change can cause diseases to emerge in new places due to more suitable environments. New diseases are always developing; there are two ways diseases can develop. An “emerging disease” is a disease that hasn't been previously observed in humans, such as COVID-19, while “re-emerging diseases” have existed in the past but are increasing today. Malaria can be described as a reemerging disease since it has been around for a long time but has increasingly been abundant (Diop, 2025).

Infectious disease in an Era of global change by Baker et al. (2012) explains that infectious disease outbreaks are only increasing in prevalence. These diseases are showing up

more aggressively and have global impacts. Not only have infectious disease outbreaks increased, but climate change has also become a significant concern. The increase in climate change has been attributed to increased air travel, which contributes to the release of carbon dioxide. Additionally, the growth of urban areas has led to higher populations' densities, further intensifying the greenhouse effect. Moreover, urbanization and deforestation have been linked to an increase in zoonotic diseases, as there are more direct connections between humans and animals (Baker et al., 2021).

Climate change influences malaria transmission in Senegal by altering temperature, rainfall, and humidity, which affect mosquito populations and disease prevalence.

Methodology

My project is structured around observations of malaria deaths and cases from 2020 to 2024 using a data set from Dr. Elhadji Doucoure, a medical specialist in public health. This data set is sourced from the National Malaria Control Program. By examining malaria transmission and prevalence, temperature, and rainfall data in Senegal, it is possible to establish correlations during the same time frame. Correlating this weather data can provide insights into how climate change is impacting Senegal and, in turn, escalating malaria cases. Creating and analyzing graphs from this data will demonstrate trends and explain the relationships between these three variables. Malaria-related death data serves as my dependent variable, as it is influenced by the two independent variables of average annual temperature and average annual rainfall. Malaria requires a specific habitat to spread. Gathering malaria death data from epidemiologists and other medical professionals in Senegal constitutes a highly valuable resource. This project links changes in climate to weather-level impacts by macro-trends in temperature, the longer and intense rainy season, and humidity levels that remain.

Dr. Diop Boly provided resources to obtain detailed malaria death and incidence data to observe from Dr. Elhadji Doucoure. Using numbers of deaths can demonstrate the intensity of the disease and how Senegal is being impacted. The World Health Organization provides malaria incidence data in Senegal which, combined with malaria death data, explains how malaria affects people differently and gives room for human adaptations of immunity and/or other medicinal prevention measures. The *World Bank Group* dataset is used to obtain average annual temperatures and precipitations over the last five years. I used this data to create graphs that demonstrate the average annual rainfall and temperature for each year from 2020-2024. I am also using this data to compare the relationship average annual rainfall and temperature with malaria related death. Dr. Elhadji Doucoure provided malaria deaths and cases not just for the entire country but also based on regions.

Additionally, I analyze malaria incidence across rural and urban regions to explain how geographical factors, infrastructure, and access to healthcare influence transmission. High-risk populations, such as children under five or pregnant women, significantly influence malaria transmission rates. I examine the burden on these communities and underline the substantial health burden of malaria in Senegal. To support my arguments, I draw upon existing literature to provide comprehensive background information and explain patterns that have been extensively studied. Additionally, my personal experience of visiting Senegal and its diverse regions during my residence provides a unique perspective on this project. I firsthand witness the large burden of malaria on the citizens of Senegal. I engaged in discussions with medical professionals and scientists in Senegal, gaining valuable insights into the topic. Plus, I observed the seasonal patterns affecting different regions of Senegal.

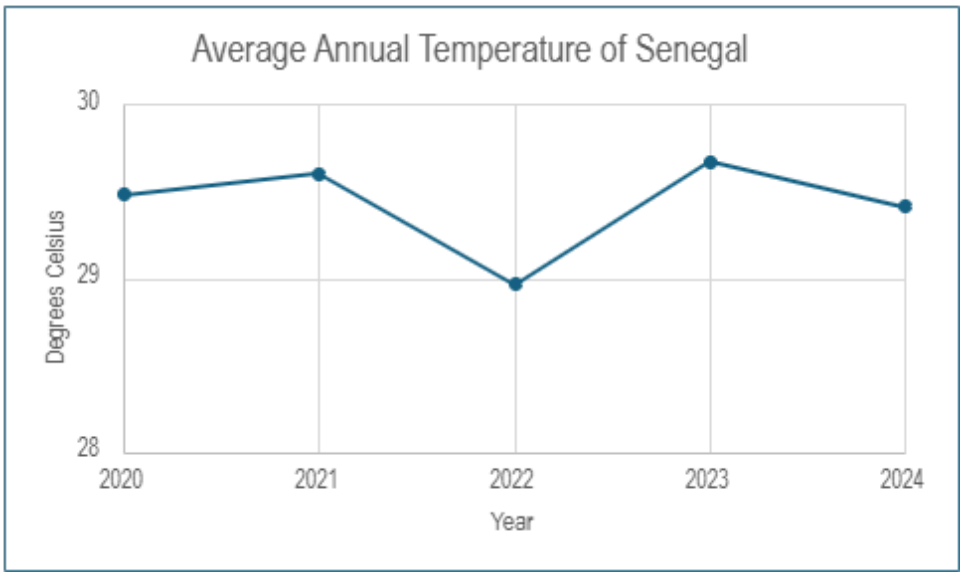

Figure 2. Graph of average annual temperatures of Senegal from 2020-2024.

In 2020, the average annual temperature was 29.48 degrees Celsius. In 2021, the average annual temperature increased to 29.6 degrees Celsius. In 2022, the average annual temperature decreased to 28.96 degrees Celsius. In 2023, the average annual temperature rebounded to 29.67 degrees Celsius. In 2024, the average annual temperature returned to 29.41 degrees Celsius. Not a lot of variances in temperature, about 0.6 degrees. These fluctuations demonstrate the significant impact of various factors on the variability of Senegal's annual temperatures.

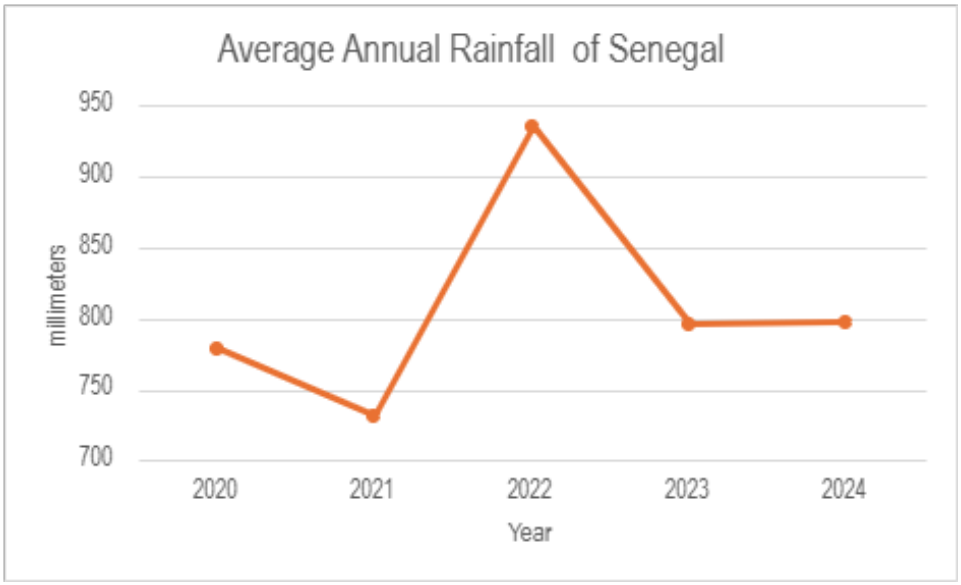

Figure 3. Graph of average annual precipitation in Senegal from 2020-2024.

In 2020 the average annual rainfall was 779.13 mm. In 2021 the average annual rainfall decreased to 731.7 mm. In 2022 the average annual rainfall increased to 935.91 mm. In 2023 the average annual rainfall decreased to 796.48 mm. In 2024 the average annual precipitation was 797.78 mm.

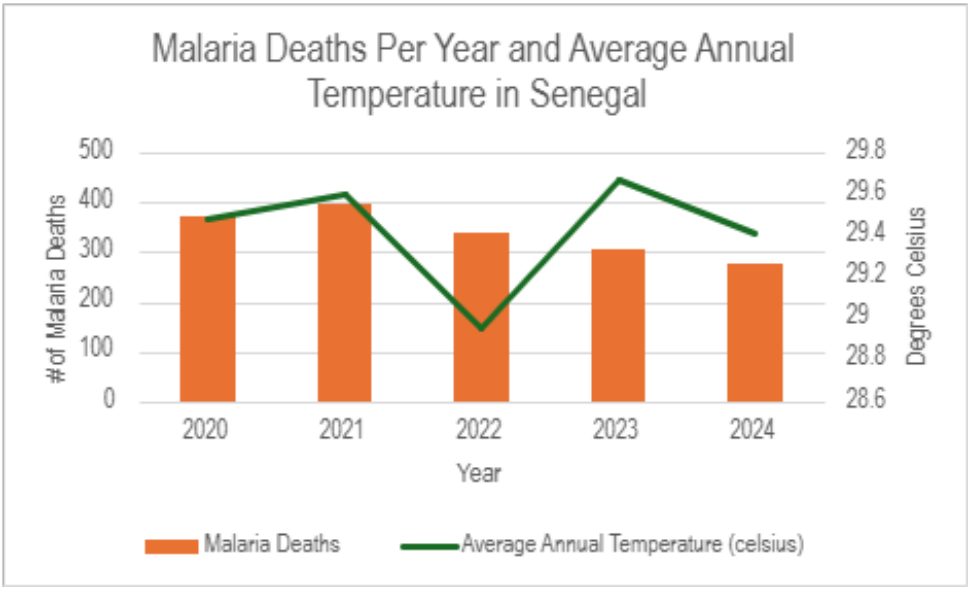

Figure 4. Graph of malaria deaths per year from 2020-2024 compared to the average annual temperature in Senegal.

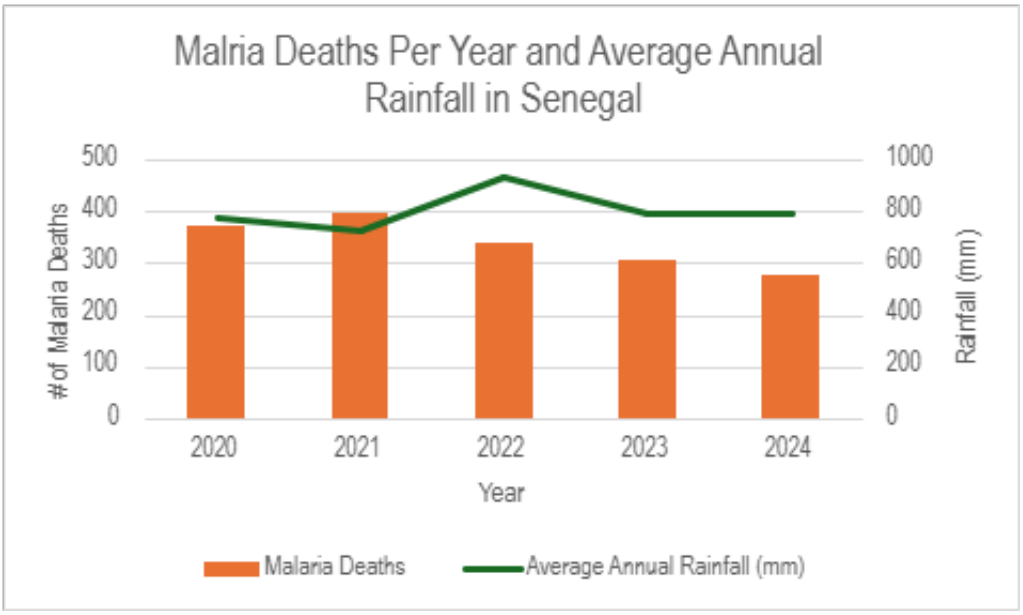

Figure 5. Graph of malaria deaths per year from 2020-2024 compared to the average annual rainfall in Senegal

These two figures indicate the correlation between climate factors and malaria mortality. There is a boost in malaria due to precipitation and temperature, but there is no direct cause because of many confounding variables.

Limitations

One significant limitation of this study is that it relies on previously recorded data from various datasets. Consequently, I have limited control over the data collection process. I can only assume this data is accurate and unbiased due to the reliability of the sources used. Another limitation includes the time frame of the study; only observing data over five years does not allow for large changes in climate affecting malaria transmission. Lastly, confounding variables could also be a limitation; healthcare access, prevention measures, socioeconomic conditions, land use changes, etc. These factors are not explicitly said in the databases I observed but must be considered when looking at the big picture of malaria incidence and prevalence.

Motivation

I studied abroad in Senegal and the Gambia summer 2025; during my time in West Africa, I noticed a significant difference between these countries and others I have traveled to. Developing countries have fewer resources, money, infrastructure, and aid than developed countries (Kulik, 2026). This makes them extremely vulnerable to storms and diseases; climate change only exacerbates those issues. The objective of this study is to explain the mechanisms through which climate change may exacerbate the transmission of infectious diseases, particularly malaria, in countries disproportionately affected by such diseases (Bollyky, 2018). Engaging in a collaborative dialogue with the Minister of Health, medical professionals, and scientists in Senegal gave me invaluable insights into the interplay between climate change,

infectious disease transmission, and the challenges faced by developing countries. This firsthand experience gave me beneficial knowledge that serves as a cornerstone of my thesis.

Chapter 2: Case Background

Malaria is a significant health issue in Senegal, averaging 339 deaths each year from 2020 to 2024. Although this is a significant health issue, Senegal has made extreme progress in prevention and innovation strategies for this disease (Diouf et al., 2024). There are still high-risk populations that experience malaria more frequently and intensely such as pregnant women, children under five, and those living in rural communities. Pregnant women are a focus for Senegal's health policy due to the risk for both the mother and the unborn child. There have been cases of malaria being asymptomatic, which is a threat to itself. Some women are unaware they have malaria while pregnant. This creates more health issues for both mother and child. Prevention strategies, again, are the main way to control and combat malaria, especially for those most at risk (Diouf et al., 2024).

Along with pregnant women and the unborn children feeling extreme effects of malaria, children under five are extremely susceptible. According to Figure 6, the total number of malaria deaths and the number of malaria deaths among children under five exhibit a consistent decline, due to the effectiveness of preventive measures. Analyzing the average number of malaria deaths in Senegal from 2020 to 2024, as reported by the National Malaria Control Program, it is evident that 339 individuals died from malaria during this period. In comparison, 70.6 children under five lost their lives to malaria. As a result, approximately 20% of all malaria deaths can be attributed to children under five, emphasizing the intense vulnerability of this age group to the disease.

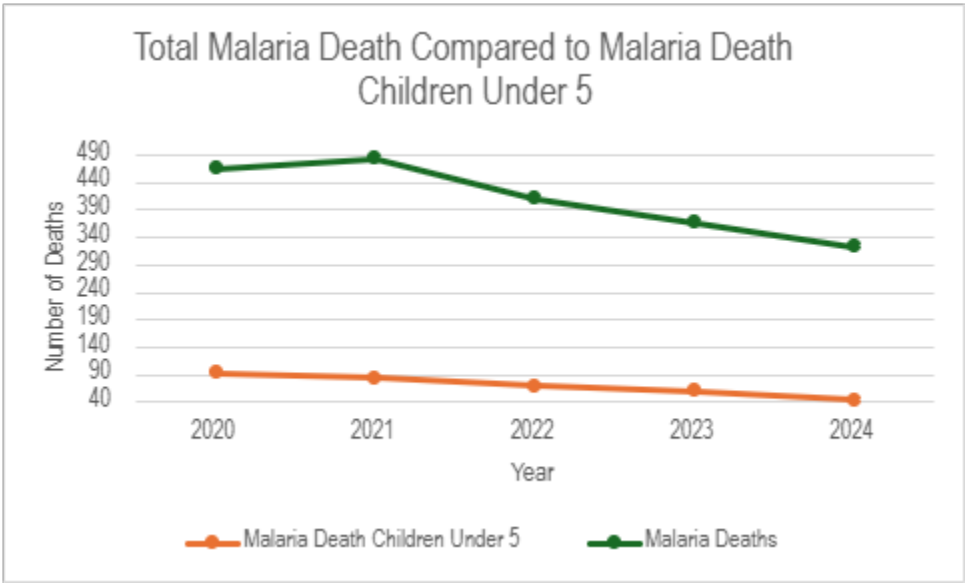

Figure 6. Total malaria death numbers compared to malaria death numbers in children under five years old in Senegal from the years 2020-2024.

Additionally, rural communities experience malaria at higher rates and risks than urban areas. This is due to many factors such as lack of access to healthcare, lack of health infrastructure, and housing conditions (Morlighem et al., 2025). During my visit to Tukar, I observed that the nearby health clinic faced significant challenges due to limited resources, understaffing, and a malfunctioning ambulance. The nearest hospital, situated approximately an hour's drive away, presents a considerable distance in case of emergencies. It is evident that rural regions lack the same healthcare infrastructure and accessibility as urban regions. This disparity leads to the prevalence and mortality rates of malaria. Using data from the National Malaria Control Program in Senegal, I conducted a comparative analysis between Kédougou and Dakar to find out the disparity in the number of malaria cases between rural and urban regions. According to Figure 7, comparing the rural area of Kédougou to the urban area of Dakar (the capital) indicates malaria following the same trends, but there is a significant increase in malaria cases in rural regions than in urban regions. Noting a spike in 2024 could be due to many factors; storms, sanitation habits, temperature, access to health services, etc.

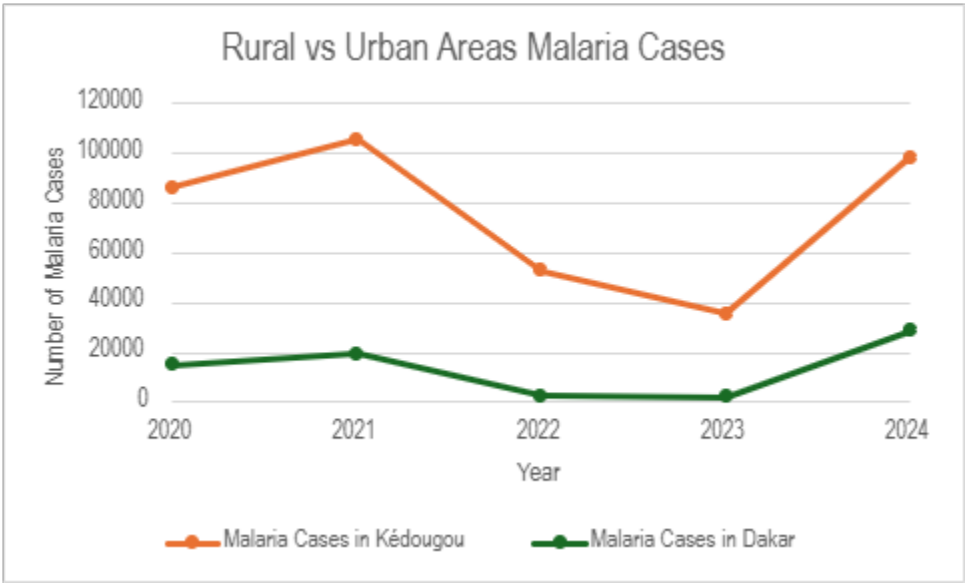

Figure 7. Number of malaria cases in a rural region (Kédougou) compared to the number of malaria cases in an urban region (Dakar) across a five-year span, 2020-2024

Malaria can be found in mosquitoes, in the protozoans, the parasite in the genus plasmodium falciparum. The different varieties of the protozoan include *P. Vivax*, *P. Ovale*, and *P. Malariae*. All these protozoans are found in the anopheles' mosquito, the primary vector of malaria (Raikar, 2025). The malaria virus lives in the red blood cells of humans, where it can be replicated. Plasmodium requires both mosquitoes and humans for development. Mosquitoes are the definitive host in which sexual maturity occurs, which is the extrinsic incubation period dependent on temperature. Humans are the intermediate host in which asexual development occurs, the intrinsic development period. Only female mosquitoes take blood, which helps them lay eggs. They lay the eggs on still water or moist soil and are mainly found in tropical and subtropical regions (Nureye, 2020). Figure 8 below explains this life cycle in a more straightforward way (Research Gate).

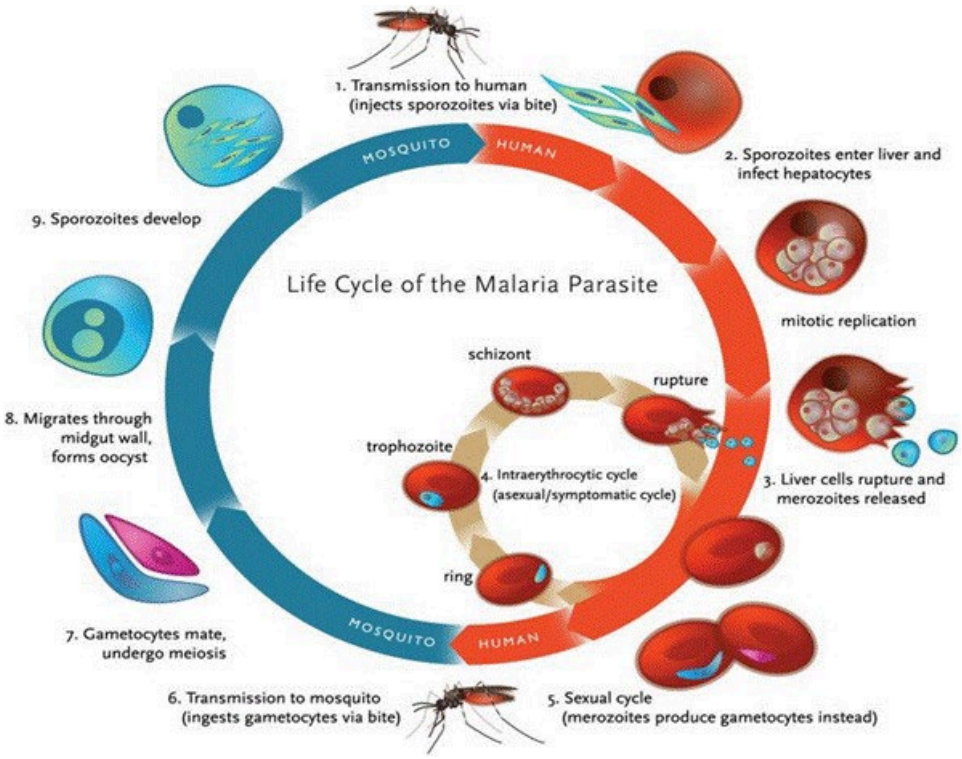

Figure 8. Life cycle of the malaria parasite

Symptoms of malaria include chills, fever, and sweat. There are human adaptations to malaria which include sickle cell anemia (*P. Falciparum*) and Duffy antigen (*P. Vitax*). Sickle cell anemia affects the shape of the red blood cells; this provides protection from malaria but has its own risks associated (Scott 2025). The Duffy antigen is located on red blood cells; the *P. Vitax* uses these antigens to enter the red blood cell. When people are Duffy negative, this disrupts the binding and allows for resistance to malaria (Akunwata 2022). The main issue is that malaria destroys red blood cells, which causes anemia. Hemoglobin in the bloodstream is removed in the kidneys, which causes black urine. The treatment that has been used for kids was blood transfusions; unfortunately, this led to more malaria spread and even cases of HIV. The incubation period for malaria is 8 to 30 days; it varies depending on the species of plasmodium. People can become immune to malaria; however, immunity can take up to 5 years to develop (Doolan et al, 2009). Treatment for malaria includes drugs called schizonticides. These drugs

don’t prevent the parasite from entering and developing in the liver, but it does eventually kill the parasites. Pesticides and vaccines are also used to control malaria; some issues include the development of resistance. Mosquito bed nets are a cheaper way to control malaria (World Health Organization, 2025). Cheaper alternatives are important to Senegal and other countries that are described as least developed countries (United Nations). These effective cheaper alternatives ensure that some malaria prevention is available to those who cannot afford many of the drugs and vaccines, or transportation to hospitals.

Malaria during the rainy season is a large contributor to malaria incidence, and rainfall creates standing water which is the perfect place for mosquito larvae to develop and grow. Malaria during the dry season still occurs due to the rate of metabolism and activity in mosquitoes and the parasites increasing with temperature. The dry season can lead to periods of drought which reduces the habitats for the mosquito larvae to thrive (Pesky Little Critters, 2025)

Seasonal patterns dictate when malaria risk is highest. Tropical regions, like Senegal, transmission peaks during or right after the rainy season. These patterns are also influenced by human behavior. Agricultural irrigation patterns change the amount of flooding/standing water which means even during dry months, there can be residual standing water for mosquitoes to lay eggs on. Prevention measures aligning with seasonal patterns can greatly decrease malaria incidence (Pesky Little Critters, 2025).

Senegal has a vast climate that ranges between regions. Dakar, for example, is a coastal city but there are many cities that are more inland. Coastal areas experience more year-to-year variability depending on sea surface temperatures. There is more of a definitive seasonal peak inland which is driven by rainfall and temperature (Pesky Little Critters, 2025).

Chapter 3: Literature Review

a) Impact of climatic factors on malaria in Senegal based on the surveillance system between 2015 and 2022

In Talla et al. (2025), the authors describe how prevalent malaria is in sub-Saharan Africa as a pressing public health concern. This study holds significant relevance to my thesis project, as it goes through the relationship between meteorological variables such as temperature, rainfall, and humidity and malaria incidence in Senegal spanning the period from 2015 to 2022. A distributed lag non-linear model (DLNM) is used in this study; it is a statistical tool that links these climate variables with malaria incidence. The Senegal syndromic sentinel surveillance network is how they collected the daily malaria case data. Other data was found using the Senegalese meteorology agency and NASA POWER DATA Access, which resulted in significant associations between climate factors and malaria cases. High temperatures and extreme rainfall resulted in an increased risk of malaria and increased malaria cases. Humidity resulted in non-linear, time-dependent effects on malaria incidence. This study displays similar results to what I found; my thesis project focuses on temperature and rainfall, and humidity. The temperature and rainfall results from Talla et al. (2025) indicate a direct relationship with those climate factors and malaria incidence. The findings indicate that climate variability should be a factor in malaria control strategies. Climate prevention and warning systems can contribute to vector control. This indicates the need for future research on socio-economic factors that influence prevention efforts, a topic I researched. Overall, this study presents detailed examples of how climate factors increase malaria transmission in Senegal, further supporting my argument that temperature, rainfall, and humidity are significant factors in increasing malaria incidence in Senegal.

b) Climate Change and the Rise of Emerging and Re-Emerging Infectious Diseases in Africa

Agyarko et al. (2025) demonstrates how climate change is the main driver of re-emerging and emerging infectious diseases in Africa. This review provides essential information on how climate change increased temperature, heat stress, floods, and drought which negatively impact Africa. All these factors tie together and impact the health of those living on the African continent, especially due to the weakness in the economies, infrastructure, and healthcare (Agyarko et al., 2025). Linking climate change to infectious diseases can be tricky because many factors are tied to the increase of infectious diseases. Some climate drivers include increased temperature and rainfall, increased flooding, deforestation, and land-use change. The increase in temperature and rainfall contribute to making the ideal conditions for mosquito habitats. Increased flooding leads to standing water and lack of clean water. These both contribute to water-borne infectious diseases, like malaria. Deforestation and land-use change create closer contact with mosquitoes and other animals, creating an increased spread of zoonotic diseases. African countries are extremely vulnerable due to their poor healthcare systems, limited clean water, and cycles of poverty (Agyarko et al., 2025). This review summarized related information from various scientific publications. West and central African countries experience more significant climate change instigated infectious diseases than other countries in Africa. Their goal of this review is to implement resilient interventions for these climate change induced infectious diseases. Recommendations from this review include a One Health approach, which integrates human, animal, and environmental health. This approach is implemented by strengthening public health systems, improving sanitation and hygiene, and creating early warning systems for climate-induced diseases.

Overall, this literature review focuses on climate change as a main driver of infectious diseases, which supports my argument, but land-use and deforestation problems contribute heavily to the incidence and mortality of malaria.

Chapter 4: Climate Change Trends in Senegal

Climate change is the rapid change in the climate driven by increasing greenhouse gas levels in the atmosphere. Anthropogenic climate change has been studied in Earth's climate since the mid-20th century; it can be described as human activities such as burning fossil fuels. The burning of fossil fuels releases greenhouse gases like carbon dioxide, causing an increase in the amount of infrared heat trapped by the Earth's atmosphere and raising global average temperatures (NASA, 2025). Human activity has caused an increase in atmospheric carbon dioxide beyond natural cycles, increasing global temperatures. An increase in temperature correlates to extremes of storms and natural disasters. This correlation can be seen in Chapter 11 of the IPCC AR6. Human influence is most likely the main driver of the intensification of heavy precipitation (IPCC AR6, 2023). This human influence can be seen through documentations from satellites, aircraft, ground measurements, and climate model projections that make connections (NASA 2020). Causation of human influence is difficult to define due to no way to be certain humans are the direct cause of malaria, but connections have been noted, for example the rising temperatures. Energy in the form of heat increases the atmospheric temperature; this energy could be responsible for the intensity and longevity of storms, which can lead to increased flooding (NASA, 2020).

Specific circumstances contribute to the proliferation of mosquitoes. Environmental factors such as temperature and irrigation play a significant role. As previously discussed, climate change increases atmospheric temperatures and intensifies storms, leading to flooding. These conditions create the ideal breeding ground for mosquitoes. Additionally, environmental degradation, including deforestation, further facilitates their spread (Lafferty, 2009).

The US Global Leadership Coalition describes 2020 as the hottest year ever recorded. It also explains how extreme weather and climate-driven disasters (floods, fires, and hurricanes) have been breaking records alongside the temperature increase. The poor and most vulnerable in developing countries are experiencing these climate-driven disasters more frequently and extremely than other countries. The different aspects that contribute to disproportionate discrepancies include lack of infrastructure, access to clean water and food, and lack of healthcare (USGLC, 2021). Senegal is described as a developing country and experiences these disproportionate discrepancies. The USGLC as a reference allows for a better understanding of how the developing world experiences climate-driven disasters. Sherman et al. (2025) reports that malaria results in over 600,000 deaths per year, mostly occurring in sub-Saharan Africa. The most effective prevention measure of malaria is insecticide treated mosquito nets (Sherman et al., 2025). However, temperature increases have changed sleeping habits and how these nets are used. This led to observations being completed on the increase in outdoor sleeping and mosquito net fragility (Sherman et al., 2025).

Climate change is a significant driver to infectious diseases, especially in Senegal. Background information from Baker et al. (2012) can help describe a correlation between climate change resulting in poor infrastructure systems and infectious diseases. In Dakar, Senegal, health authorities have described this region as having a low endemicity rate, indicating a relatively low incidence of malaria cases. Nevertheless, the large consumption of antimalarial drugs in Dakar suggests that the actual prevalence of malaria may be more significant than the reported figures suggest. Anopheles mosquitoes are the main vector of malaria and are thought to breed in polluted areas. Air pollution is an issue Senegal is suffering from, WHO’s guidelines suggest that Senegal’s air quality is unsafe (Interactive Country Finches). But air quality isn't the

only issue with pollution Senegal has. Solid waste management is poor and has led to the degradation of cities, which decreases economic opportunities and land value. This poor management also blocks storm water drains, increasing flooding, decreasing the surface and ground water quality, and increasing the spread of disease pathogens, water borne diseases like malaria (Interactive Country Finches). Due to this, malaria occurring in Dakar, an urbanized area, makes sense (Diallo et al., 2012).

Chapter 5: Mitigating Malaria in Senegal

The population of Senegal is 100% at risk of malaria, this is due to the endemic nature of the disease (Severe Malaria Observatory). The National Strategic Plan of Senegal is in place to reduce malaria incidence, mortality, and interrupt local transmission. This plan focuses on decreasing incidence and transmission from 2026-2028. This is done by eliminating malaria in areas where malaria is getting lower, eliminating it in areas where malaria is manageable, and achieving zero malaria deaths (Severe Malaria Observatory). By doing this, malaria incidence can be kept low, improve areas that are more prone, and stop all deaths.

Malaria case management strategies include “Pris en charge à domicile” (PECADOM), artemisinin-based combination therapies (ACTs), injectable and rectal artesunate, and free healthcare for children under five (Severe Malaria Observatory). These strategies allow to treatment and prevention of malaria; it is necessary for Senegal to have many options due to how severe and prevalent this disease is. “Pris en charge à domicile” (PECADOM) is a service where caregivers go to people's homes to test and treat malaria. This not only catches the disease early, but it allows more people to get healthcare access, like those in rural communities. This program started in 2008 and has since expanded (Severe Malaria Observatory).

Artemisinin-based combination therapies (ACTs) are the recommended drugs for malaria treatment; the three main treatments are artesunate-amodiaquine, artemether-lumefantrine, and dihydroartemisinic-piperaquine. Senegal’s malaria program introduced these drugs and quick testing kits in the early 2000s. Artesunate-amodiaquine is only used in areas where seasonal malaria prevention programs are lacking. In areas where malaria is less common, those that test positive get the routine treatment plus a small dose of primaquine to ensure the disease does not spread further (Severe Malaria Observatory). The first-line treatment for malaria is injectable

artesunate, this is used at health clinics all over Senegal, even in rural regions. Children under five in rural areas are given rectal artesunate as an emergency first step before they can get to the hospital (Severe Malaria Observatory). Senegal offers universal healthcare for children under five, they receive free healthcare at formal health facilities (Severe Malaria Observatory). This is extremely valuable because of how at-risk children under five are.

Malaria remains prevalent in many areas in Senegal even with these prevention tools and treatments. Availability of prevention measures is not the issue in Senegal; it is usage which creates ongoing transmission. This gap of people having access to prevention measures and using these prevention measures is a main reason for malaria persistence. To close this gap, education on consistency of using prevention measures is key (Tairou et al., 2024).

The National Malaria Control Program in Senegal provided data on specific regions in Senegal. Certain weather patterns and climate make specific regions more or less prone to malaria. Kédougou, is situated in southeastern Senegal, while Dakar, the capital situated on the west coast, a comparison of these two regions reveals a disparity in the prevalence of malaria cases. The climate of Kédougou, characterized by a tropical climate, experiences a prolonged rainy season from June to October, resulting in a lush green landscape (World Climate Guide). This climate provides mosquitoes with an ideal environment for survival and breeding, contributing to the higher incidence of malaria in Kédougou. Dakar, on the other hand, has a tropical arid climate with a long dry season from November to May. Being situated on the coast, Dakar experiences a temperate climate (World Climate Guide). This climate offers less suitable habitats for mosquitoes, potentially explaining the lower incidence of malaria cases in Dakar compared to Kédougou. Refer to Figure 7 for further information on the incidence differences

between Dakar and Kédougou, they both follow the same trends in incidence, but Kédougou has more cases.

Everyone in Senegal is at risk of malaria but pregnant women are more at risk, due to their immune system being compromised and all their energy going to grow the baby. In 2003, Senegal began a preventative malaria medication for pregnant women. A lot has changed since this program began; the current recommendations include getting at least three doses of this medicine during pregnancy (Severe Malaria Observatory). This medicine significantly reduces the number of pregnant women contracting malaria. Although malaria prevention during pregnancy is common, it is unevenly distributed in Senegal, women living in rural areas receive fewer preventative treatments than those in urban areas (Jiang et al., 2025).

Another example that could indicate rural regions having more malaria incidence is access to healthcare (Figure 7). Rural regions are more widespread, and health infrastructure is not as close by as it is in urbanized areas. From my observations in Senegal, Dakar has an extensive network of healthcare facilities, including doctors' offices, hospitals, pharmacies, all conveniently located within walking distance or a short drive away from various locations. You can obtain malaria medication from every pharmacy in Dakar. Dakar and other urban areas have air conditioning in houses and buildings; this also serves as a prevention measure. Mosquitoes cannot fly in the air conditioning, so urban areas have that benefit. In contrast, this accessibility is not as prevalent in more rural areas. Rural areas experience drug shortages, lower income levels, limited access to transportation, and fewer healthcare workers (Jiang et al.,2025). All these factors contribute to the higher incidence of malaria in rural areas.

Chapter 6: Conclusion and Recommendations

Senegal, a less developed nation, experiences climate change impacts more severely and has generally limited support for healthcare, infrastructure, food access, and clean water. The Senegalese government's financial resources are constrained, necessitating increased aid from international organizations to address these challenges. The World Bank has approved a huge project aimed at reducing and mitigating flooding risks, with its main goal of this project is to strengthen urban planning and management practices. Flooding poses a significant challenge in Senegal, leading to standing water that serves as breeding ground for mosquitoes. The cumulative effect of climate drivers, such as increased rainfall, can create environmental conditions conducive to flooding, thereby increasing the risk of malaria. This project emphasizes the importance of addressing this multifaceted issue, as many factors contribute to the incidence and prevalence of malaria.

Along with flooding, temperature also increases the spread of malaria. As mentioned previously, climate change increases the temperature of the atmosphere, which then increases the severity of storms, resulting in flooding. Climate change can be described as the main cause of malaria, but there are many other factors. Economic factors and land management also affect malaria transmission rates. Malaria creates a huge strain and burden on Senegal due to resources needed and costs for healthcare. This economic slowdown leads to cycles of poverty for many individuals. Also, deforestation and urbanization facilitate increased connections between humans and animals, resulting in a rise in zoonotic diseases like malaria.

Prevention is the best option because of how hard it is for people to get access to vaccines or drugs. The most effective prevention measure is insecticide treated bed nets. Not only does this work very well, but it is also easily attainable for the Senegalese population. It is the

cheapest way to protect oneself from malaria. When bed nets are directed to be used, they can be helpful; they are only as helpful as if people use them.

Recommendations include a need for continued research, adaptation measures, and development efforts on prevention and treatment. A study completed in the Euro-Mediterranean area indicated that climate change is the leading cause of malaria from the Anopheles mosquitoes thriving in that region. Malaria was not prevalent in Euro-Mediterranean regions before the climate started changing; it has been eradicated in that region for a century. These regions can be used as a prediction to indicate how with the right habitat conditions, malaria can be found in more places. There is a link to increased cases of malaria with the increase of temperature (Merkenschlager et al., 2025). More research can be done to determine how the mosquitoes are migrating to more places because the conditions are just right for them to thrive and breed. WHO provides information on expanding research and innovation of developing new tools for prevention, diagnosis, and treatment of malaria. They have a Global Technical Strategy for Malaria program which is participating in innovation strategies that will aim at their 2030 goals (World Health Organization).

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