

Seasonality of Malaria Disease Infection in Ghana: A review

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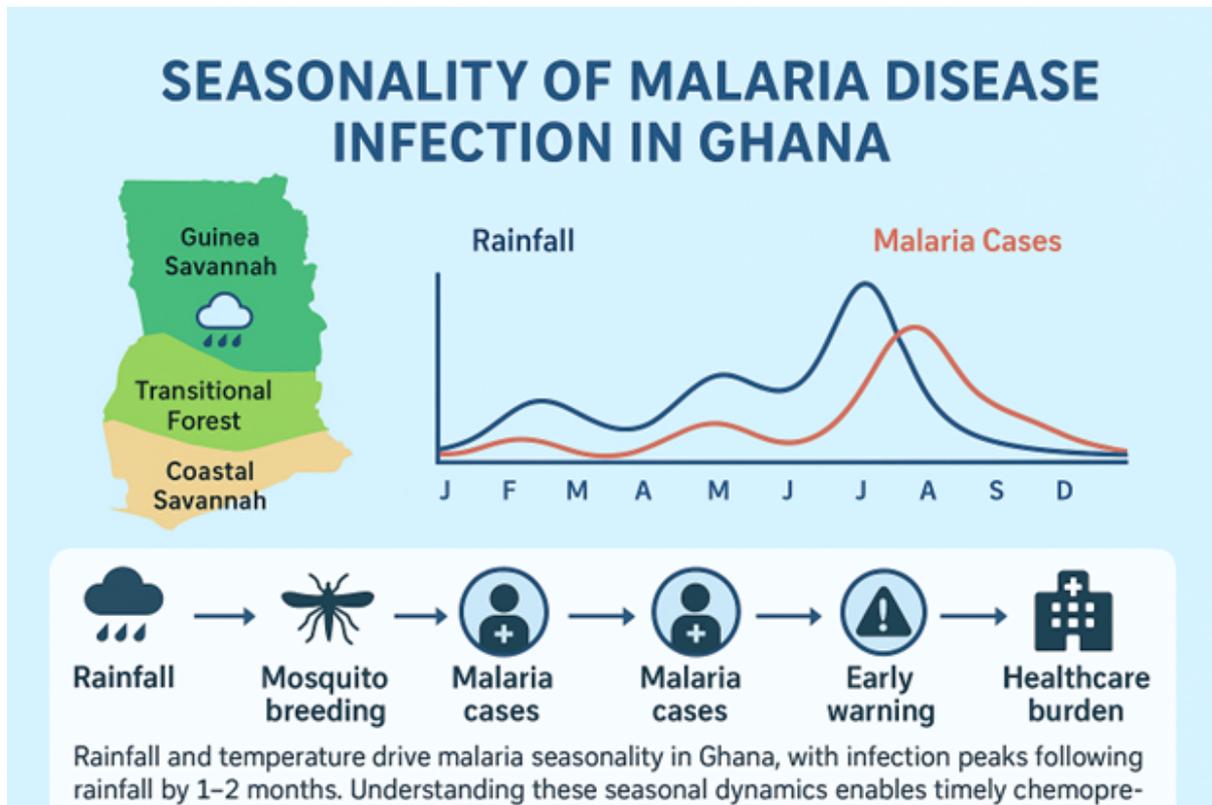
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Graphical Abstract



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Abstract

Malaria remains a significant public health challenge in Ghana, accounting for a substantial burden of morbidity and mortality, especially among children under five and pregnant women. SDG 3 Good health and wellbeing aims to prevent needless suffering from preventable diseases, and premature death, and end epidemics by 2030. The study aims to examine the Seasonality of malaria Disease Infection in Ghana and Its implications on Health care Delivery. A scoping review on Seasonality of malaria Disease Infection in Ghana and Its implications on Health care Delivery. Emphasis on Impact of Rainfall and Temperature on Malaria Transmission, Rainy Season (April to October), Dry Season (November to March), and the Implications of Malaria Seasonality on Healthcare Delivery. Rainfall and temperature play crucial roles in malaria transmission patterns across Ghana, influencing vector abundance, parasite development, and overall disease dynamics. Malaria morbidity patterns vary across the three ecological zones in Ghana, with the Guinea savannah zone having a single peak, while the Transitional Forest and Coastal savannah zones have two peaks in morbidity that follow the rainfall patterns in those regions. Malaria in Ghana exhibits strong seasonal patterns, with infection rates peaking during the rainy season due to favourable mosquito breeding conditions. Aligning malaria control measures with seasonal transmission patterns, Ghana can enhance its fight against malaria and strengthen its healthcare system to better respond to seasonal disease surges.

Keywords: Ghana; Impact; Malaria; Morbidity; Rainfall and Temperature; Seasonality

1 Introduction

Malaria remains a significant public health challenge in Ghana, accounting for a substantial burden of morbidity and mortality, especially among children under five and pregnant women (Charles Ehiem et al., 2021). The disease exhibits strong seasonal variations, with infection rates peaking during the rainy season when mosquito breeding conditions are most favourable (Dery et al., 2010). Understanding malaria seasonality is essential for optimizing healthcare delivery, ensuring efficient resource allocation, and strengthening control measures (Klutse et al., 2014).

Malaria infection in Ghana exhibits significant seasonal variation, with higher prevalence during the wet season compared to the dry season (Tiedje et al., 2017). This pattern is observed across different regions, including rural and urban areas (Donovan et al., 2012). The predominant parasite species is *Plasmodium falciparum*, with higher rates during the rainy season (Tiedje et al., 2017). Rainfall and temperature play crucial roles in malaria transmission, with varying lag times across different ecological zones (Awine et al., 2018). Asymptomatic infections are common and affect all age groups, including adults, particularly at the end of the wet season (Tiedje et al., 2017). Socioeconomic factors and spatial heterogeneity also influence malaria incidence (Donovan et al., 2012). Understanding these seasonal and geographic patterns is essential for optimizing malaria prevention and treatment strategies in Ghana (Awine et al., 2018).

Malaria remains a significant public health challenge in Ghana, with seasonal variations in transmission patterns (Dakorah et al., 2022). Studies have shown higher parasite rates and densities during the rainy season compared to the dry season (Tiedje et al., 2017). The forest-savannah transitional zone experiences high transmission rates, with entomological inoculation rates of 231-269 infective bites per person per year (Dery et al., 2010). Spatial and temporal variations in malaria incidence have been observed across the country, with higher risks in northern, central, and western regions (Appiah et al., 2011). Factors influencing malaria transmission include ecological settings, rainfall patterns, and temperature (Dery et al., 2010). Age and gender may also play a role in malaria risk, with variations observed between forested and coastal districts (Dakorah et al., 2022). These findings emphasize the need for targeted interventions and continuous monitoring of malaria transmission patterns to effectively control the disease in Ghana.

2 Methods

Scoping reviews have emerged as a popular approach for synthesizing research evidence, particularly in rapidly evolving fields (Pham et al., 2018). Scoping reviews serve as a valuable tool in the arsenal of evidence synthesis approaches, particularly when dealing with broad topics or emerging fields. We followed the five scoping review steps as proposed by (Arksey & O'Malley, 2005): (1) Identification of the research question; (2) Identification of relevant studies; (3) Study selection; (4) Data charting and (5) Collation and reporting of results. A narrative synthesis of the literature according to themed issues was developed, together with a summary of relevant numeric data.

This study employed secondary data from the PRISMA 2020 Checklist. This review aimed to assess behaviour-based safety and workplace culture approaches instituted in

construction firms in Ghana. It is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) with a PRISMA flowchart. To gather an extensive body of literature, a search was performed using Google Scholar, Scopus, and Web of Science. The search strategy utilised a blend of keywords and terms about BBS and workplace culture approaches instituted in construction firms in Ghana (behavioural-based safety, workplace culture, work culture, construction, firms, Ghana). Seven articles were included in the review, with a custom range between 2016 and 2023.

2.0.1 Flowchart Visualization

To provide a clear visual representation of the process, we developed a flowchart shown on Figure 1. This flowchart outlines each step, from the initial identification of studies to the final inclusion of the twenty (20) works, illustrating the systematic approach taken in the study.

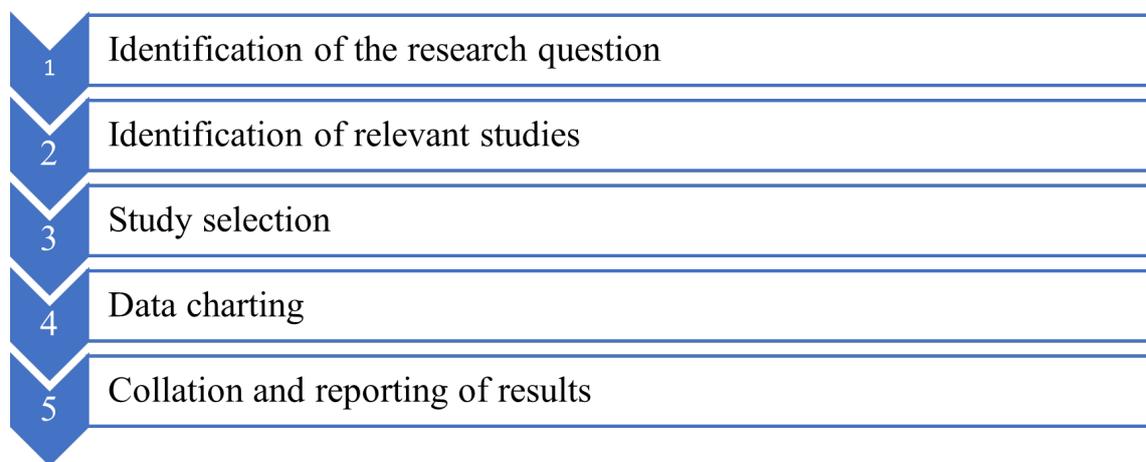


Figure 1: Structure of Scoping Review Methodology

2.1 Seasonal Variations in Malaria Infection in Ghana

Malaria transmission is closely linked to climatic conditions, particularly rainfall, temperature, and humidity, which influence the breeding and survival of Anopheles mosquitoes (Okech et al., 2007). The micro-geographical and seasonal variations in the biting and the level of malaria transmission observed in many areas showed that malaria transmission is heterogeneous in Ghana. The Entomological Inoculation Rate (the average infective bite an individual will receive from a mosquito per unit time) ranges from 418 in the Northern part of the country to about 20 in the South (MOH et al., 2023). Figure 5 shows the EIR Malaria in Ghana.

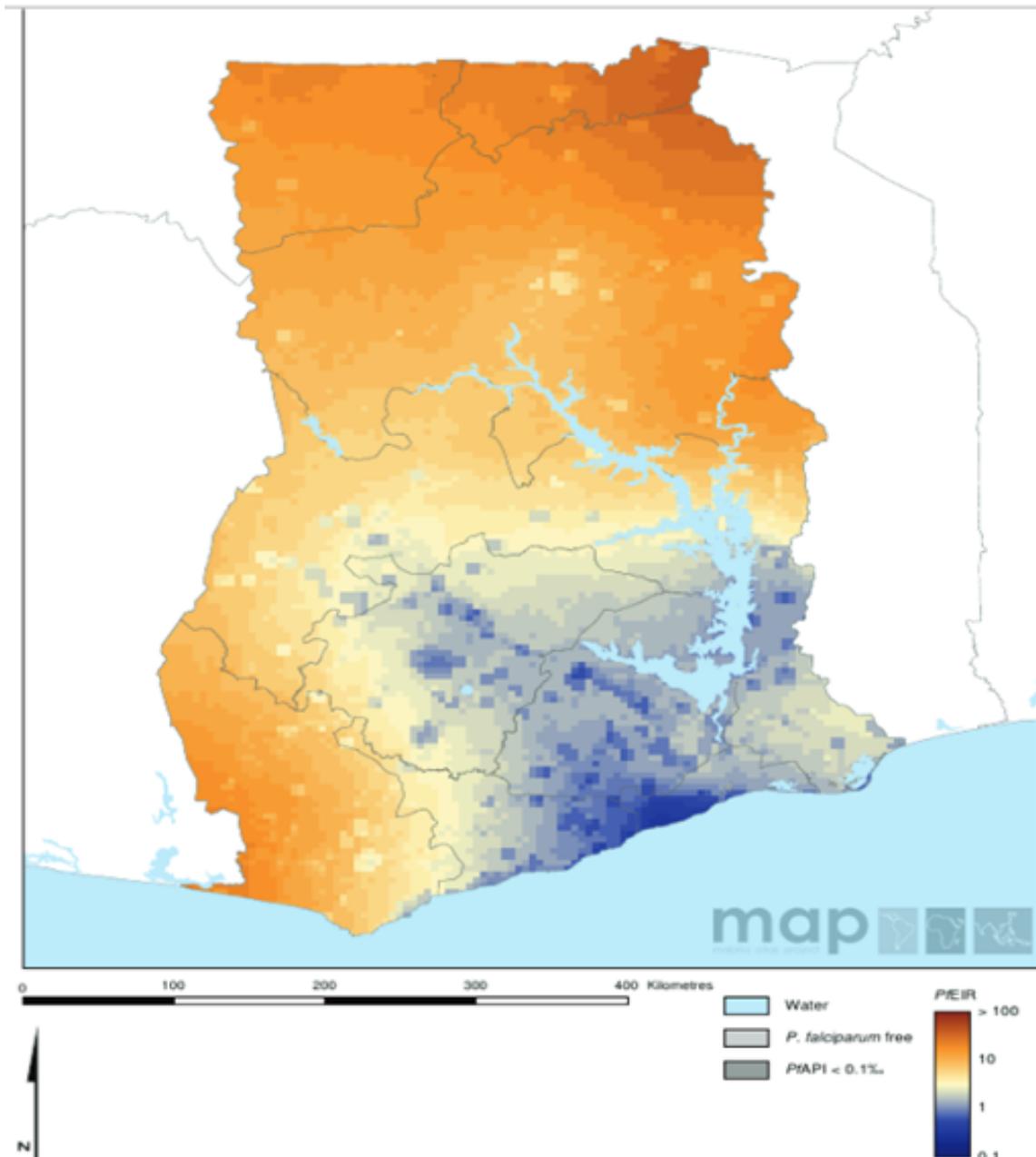


Figure 2: Entomological Inoculation Rate (EIR) Malaria Seasonality in Ghana. Source: MOH et al. (2023)

2.2 The Impact of Rainfall and Temperature on Malaria Transmission

Rainfall and temperature play crucial roles in malaria transmission patterns across Ghana, influencing vector abundance, parasite development, and overall disease dynamics. The impact of these climatic factors varies across different agroecological zones in the country, leading to heterogeneous malaria transmission patterns (Oheneba-Dornyo et al., 2022). Malaria transmission in the northern savannah zone was observed to be highly seasonal, with relatively high transmission occurring between June and October (MOH et al., 2023). Figures 3 a and b shown the seasonal transmission of malaria cases (MOH et al., 2023).

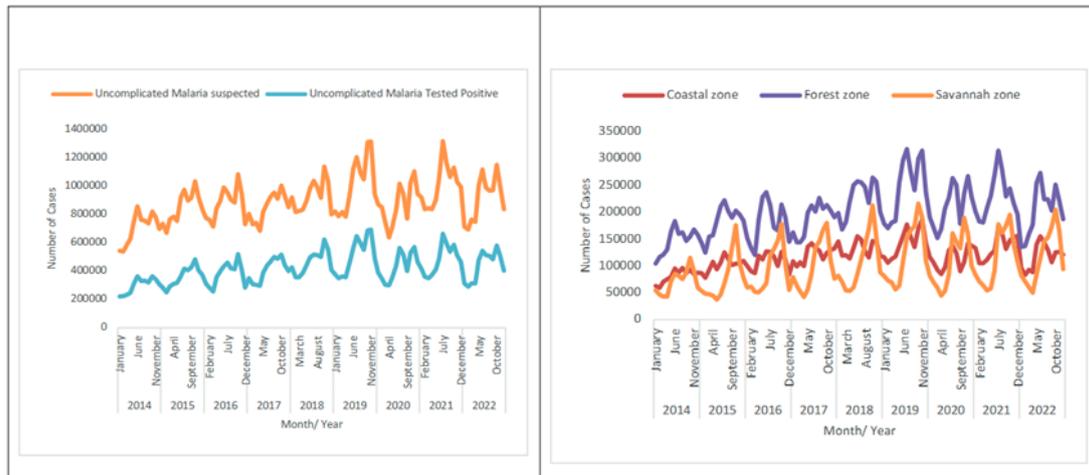


Figure 3: a) Monthly Trend of Malaria Cases in Ghana. b) Monthly Trend of Malaria Cases in Ghana by Zones.

The study (Donovan et al., 2012) found systematic and plausible patterns in malaria morbidity associated with seasonal variations in rainfall, even though the malaria diagnosis was not confirmed by parasitology (Donovan et al., 2012). The study found significant differences in malaria incidence across different socioeconomic groups, which may be linked to factors like location, occupation, or living conditions (Donovan et al., 2012). The study's findings on the seasonal and geographic patterns of malaria-like morbidity have important implications for the prevention and treatment of such illnesses in urban areas, for both children and adults (Donovan et al., 2012).

Malaria morbidity (Awine et al., 2018) patterns vary across the three ecological zones in Ghana, with the Guinea savannah zone having a single peak, while the Transitional Forest and Coastal savannah zones have two peaks in morbidity that follow the rainfall patterns in those regions. The effects of rainfall and temperature on malaria morbidity vary across the zones, with rainfall leading morbidity by 1 month in the Guinea savannah and Transitional Forest zones, while temperature leads morbidity by 2 months in the Transitional Forest zone. In the Coastal savannah, both rainfall and temperature lead morbidity by 2 months (Awine et al., 2018).

According to Dakorah et al., (2022), malaria cases were significantly higher in forested districts compared to coastal districts, regardless of season. The risk of malaria was significantly higher during the dry season and lower in coastal zones. (Dakorah et al., 2022) Participants over 39 years old had a significantly reduced risk of malaria, while those between 10-19 years old had an insignificantly lower risk compared to those under 10 years old. However, in coastal districts, those under 10 years old had a lower risk of malaria (Dakorah et al., 2022). Higher maximum temperatures (Oheneba-Dornyoy et al., 2022) have a statistically significant negative impact on malaria incidence in Ghana. Increased rainfall with a 2-month lag has a statistically significant positive impact on malaria incidence in Ghana (Oheneba-Dornyoy et al., 2022). Malaria cases (Klutse et al., 2014) lag rainfall peaks by 1-2 months. Malaria cases are negatively correlated with maximum temperature, especially in the transition zone. Malaria cases are positively correlated with maximum temperature, with a 2–4-month lag (Klutse et al., 2014).

In Ghana, malaria transmission follows rainfall patterns with a two-month time lag, as demonstrated by the VECTRI (vector-borne disease community model) simulations (Asare & Amekudzi, 2017). The model reveals that malaria transmission ranges from eight to twelve months, with minimum transmission occurring between February and April (Asare & Amekudzi, 2017). This temporal pattern is primarily controlled by rainfall, which creates suitable environmental conditions for mosquito breeding and parasite development.

The relationship between rainfall and malaria incidence varies across different ecological zones in Ghana. In the Guinea savannah, malaria morbidity peaks once a year, while in the Transitional Forest and Coastal savannah zones, it peaks twice annually, following similar rainfall patterns (Awine et al., 2018). The effects of rainfall on malaria morbidity are delayed by one month in the Guinea savannah and Transitional Forest zones, while in the Coastal savannah, malaria incidence is significantly associated with a two-month lead in rainfall (Awine et al., 2018). The estimates for 2019 to 2022 are shown in Figure 4 (MOH et al., 2023).

Temperature also plays a significant role in malaria transmission in Ghana (Tiedje et al., 2017). In the Transitional Forest zone, the effects of temperature on malaria morbidity are delayed by two months, while in the Coastal savannah, there is a two-month lead association between temperature and malaria incidence (Awine et al., 2018). These temporal relationships between climatic factors and malaria transmission highlight the importance of considering regional variations in malaria control strategies (Awine et al., 2018). Interestingly, the impact of rainfall on malaria transmission is not always linear. While moderate rainfall increases transmission, excessive rainfall may not necessarily lead to higher malaria incidence. This non-linear relationship is observed in some African regions, where high amounts of rainfall do not have a proportionally greater effect on malaria transmission (Sinigirira et al., 2024).

The Kintampo area in the forest-savannah transitional belt of Ghana provides a specific example of how rainfall and temperature influence malaria transmission (Dery et al., 2010). Entomological surveys conducted from 2003 to 2005 revealed that the dynamics and seasonal abundance of malaria vectors in this area were influenced by micro-ecology, rainfall, and temperature patterns (Dery et al., 2010). The study estimated Entomological Inoculation Rates (EIRs) between 231 and 269 infective bites per person per year, highlighting the intense malaria transmission in this region (Dery et al., 2010).

Climate change is expected to alter malaria transmission patterns in Ghana and across Africa (Klutse et al., 2014). Projections suggest that areas with temperatures suitable for year-round, highest-risk transmission may shift from coastal West Africa to the Albertine Rift between the Democratic Republic of Congo and Uganda (Ryan et al., 2015). This shift could have significant implications for Ghana's coastal regions and necessitate adaptive malaria control strategies (Dakorah et al., 2022).

The relationship between climatic factors and malaria transmission in Ghana is further complicated by land use changes (Klutse et al., 2014). A study in the Amazonian region, which shares some similarities with Ghana's forest zones, found that changes in land use,

such as increases in forested areas, urban infrastructure, and water edges, resulted in a constant increase in mosquito carrying capacity (Gonzalez Daza et al., 2023). Similar dynamics may be at play in Ghana's rapidly changing landscape, particularly in areas experiencing urbanization and deforestation.

In the mining areas of Ghana, such as the Brong Ahafo Region, the interaction between climatic factors and malaria transmission is of particular concern (Donovan et al., 2012). A cross-sectional survey conducted in 2006/2007 revealed high malaria transmission rates in these areas, with the highest Entomological Inoculation Rates (EIRs).

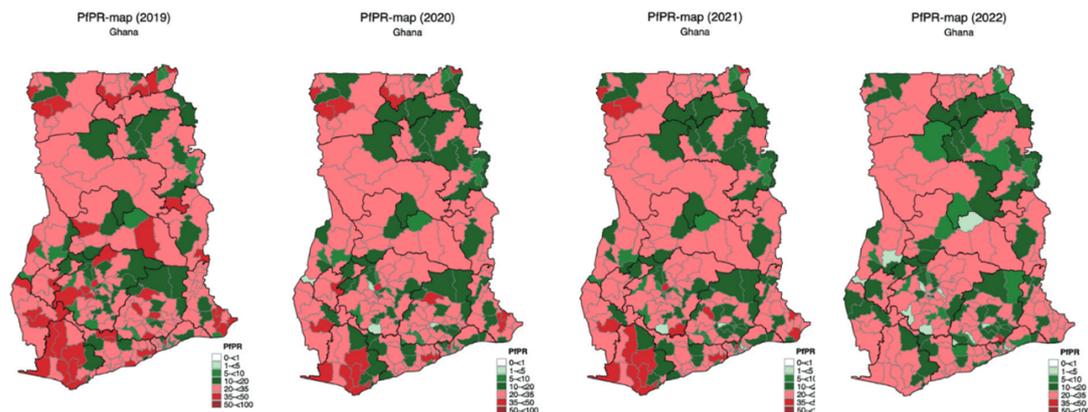


Figure 4: Shows Prevalence of Malaria in Ghana; 2019 to 2022

2.2.1 Rainy Season (April to October)

Increased rainfall leads to the formation of stagnant water pools, which serve as breeding grounds for mosquitoes. The humid conditions favour mosquito survival and increase malaria transmission. Example studies in Ghana have shown that malaria cases peak between June and October, coinciding with the highest rainfall levels (Amoah et al., 2021).

2.2.2 Dry Season (November to March)

Lower rainfall reduces mosquito breeding sites, leading to a decline in malaria transmission. High temperatures and low humidity also reduce mosquito survival rates (Amoah et al., 2021).

2.2.3 Regional Variations in Malaria Seasonality

Ghana's geographical and climatic diversity results in variations in malaria seasonality across different ecological zones (MOH et al., 2023). Figure 3 shows the seasonal transmission of malaria cases in Ghana by zones.

2.2.4 Northern Ghana (Savannah Zone)

Single peak of malaria cases during the rainy season (June to October). Dry conditions in the harmattan season (November to March) significantly reduce transmission. A study in the Upper East Region showed that over 60% of malaria cases occur between June and October (Tiedje et al., 2017).

2.2.5 Middle Belt (Forest Zone)

Prolonged transmission period due to moderate rainfall throughout the year. Malaria cases are more evenly distributed but still peak in the main rainy season (MOH et al., 2023).

2.2.6 Southern Ghana (Coastal Zone)

Bimodal rainfall pattern results in two peaks of malaria infection (May to July and September to November). Urban areas with better drainage systems experience lower malaria prevalence (Tiedje et al., 2017).

2.3 Implications of Malaria Seasonality on Healthcare Delivery

Malaria seasonality has significant implications for healthcare delivery in Ghana, particularly in terms of resource allocation, intervention timing, and treatment strategies. The seasonal nature of malaria transmission in certain regions of Ghana necessitates a tailored approach to malaria control and prevention efforts.

In Ghana, malaria transmission patterns vary across different agroecological zones, with the northern regions experiencing more intense seasonal transmission compared to the southern parts of the country. The VECTRI model simulations reveal that malaria transmission in Ghana ranges from eight to twelve months, with minimum transmission

occurring between February and April (Asare & Amekudzi, 2017). This seasonal variation is predominantly controlled by rainfall patterns, with malaria transmission peaks following rainfall peaks after a two-month time lag.

The seasonal nature of malaria transmission has led to the implementation of Seasonal Malaria Chemoprevention (SMC) in northern Ghana, where malaria transmission is intense and seasonal (Dieng et al., 2019). SMC involves administering antimalarial drugs to children during the peak transmission season to prevent malaria infections.

The effectiveness of SMC in reducing malaria incidence has been demonstrated in a randomized controlled trial conducted in the Ashanti Region of Ghana (Tagbor et al., 2016). The study found that children given SMC during the rainy season had a lower incidence of malaria compared to those given placebo SMC (adjusted hazard ratio: 0.62, 95% CI: 0.41, 0.93).

The implementation of SMC has implications for drug resistance monitoring and healthcare resource allocation. In the northern region of Ghana, where SMC has been implemented since 2015, a higher prevalence of mutations associated with sulfadoxine-pyrimethamine resistance was observed compared to other regions (Dieng et al., 2019). This highlights the need for ongoing surveillance of drug resistance patterns in areas where SMC is implemented to ensure the continued effectiveness of the intervention.

The seasonal nature of malaria transmission also affects healthcare utilization patterns. A study examining the impact of the COVID-19 pandemic on malaria cases in northern Ghana found that overall outpatient department visits and malaria cases decreased during the months of March and April 2020, coinciding with major movement and social restrictions (Heuschen et al., 2022). This suggests that seasonal factors, combined with external events like the pandemic, can significantly influence healthcare-seeking behaviour and malaria case detection.

The economic implications of malaria seasonality are substantial. A cost-effectiveness analysis of SMC in the Upper West Region of Ghana estimated that the economic cost per child dosed was US\$67.35 from a societal perspective and US\$22.53 from a provider perspective (Nonvignon et al., 2016). The study concluded that SMC is economically beneficial in reducing morbidity in children under 5 years old. However, the seasonal nature of the intervention means that resources must be mobilized and allocated efficiently during specific periods of the year.

Interestingly, the seasonal patterns of malaria transmission have different implications for various population groups. For instance, while overall malaria cases in outpatient departments decreased during the COVID-19 pandemic, malaria cases among pregnant women increased after the first COVID-19 wave (Heuschen et al., 2022). This suggests that pregnant women may have experienced reduced access to preventive measures such as insecticide-treated nets and intermittent preventive treatment during pregnancy, highlighting the need for targeted interventions for vulnerable groups during peak transmission seasons.

The seasonality of malaria also influences the choice of malaria control strategies. In

Ghana, there has been a shift from continuous delivery systems like insecticide-treated net (ITN) voucher schemes to mass distribution campaigns (Scates et al., 2020). While voucher schemes can provide continuous access to ITNs, they require complex arrangements among public, private, and non-governmental sectors. Figure 5 shown Malaria burden stratification based on operational zones in Ghana, 2023 (MOH et al., 2023).

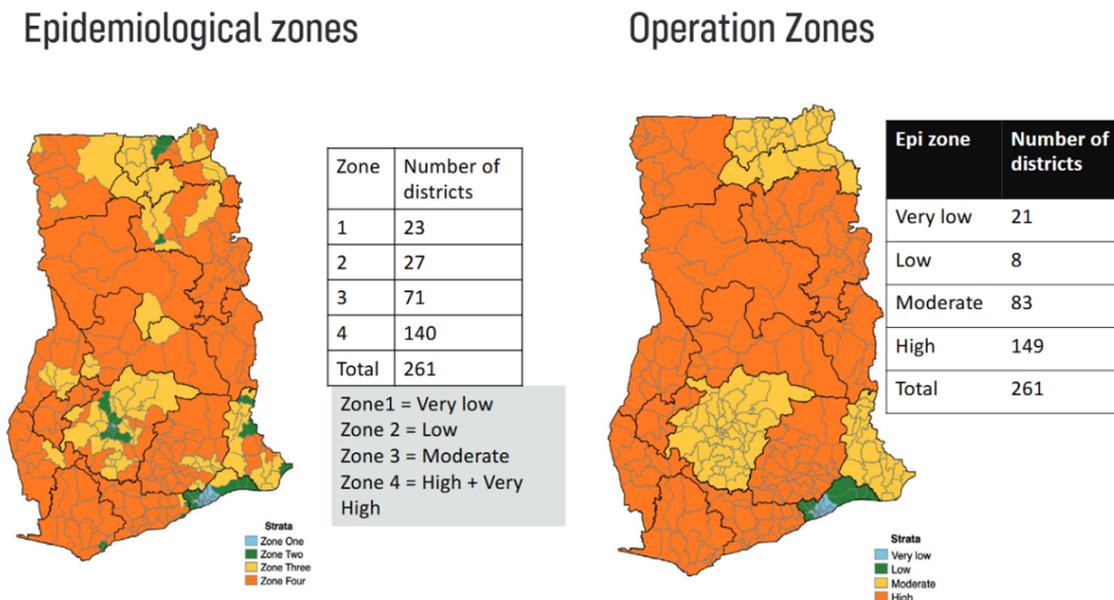


Figure 5: Malaria Burden Stratification based on Operational Zones in Ghana

2.4 Increased Healthcare Burden During Peak Malaria Seasons

The surge in malaria cases during the rainy season places immense pressure on health facilities, medical personnel, and resources, leading to overcrowding in hospitals and clinics, shortages of antimalarial drugs and rapid diagnostic kits, and Increased workload for healthcare professionals (Deku et al., 2019). Example during the 2019 peak season, the Ghana Health Service (GHS) reported that over 40% of outpatient cases in northern hospitals were malaria-related, leading to delays in care for other conditions (Oti Agyekum et al., 2023).

2.5 Challenges in Malaria Control and Prevention Programs

Seasonal insecticide spraying and mosquito net distribution are time-sensitive and must align with transmission peaks. Indoor Residual Spraying (IRS) programs are often implemented before the rainy season to maximize effectiveness. Example a study in Kumasi found that distributing long-lasting insecticide-treated nets (LLINs) in March and April reduced malaria cases by 30% during the peak season (Dakorah et al., 2022; Kevin Baird et al., 2002).

2.6 Financial and Economic Strain on the Healthcare System

The cost of treating malaria rises significantly during peak transmission periods. The government and international donors allocate substantial funds to seasonal malaria prevention strategies, such as mass drug administration (MDA). Example In 2021, Ghana

spent over \$200 million on malaria control, with the highest expenditure occurring during the rainy season (Oti Agyekum et al., 2023).

2.7 Disruptions to Routine Healthcare Services

The influx of malaria patients reduces attention to other critical health services such as maternal care and immunizations. A survey of primary healthcare facilities in Accra found that child vaccination rates dropped by 15% during malaria peak months, as nurses were redeployed to malaria treatment (Charles Ehiem et al., 2021).

3 Strategies to Address Malaria Seasonality and Improve Healthcare Delivery

Improved malaria forecasting using meteorological data to anticipate outbreaks and allocate resources efficiently. The Ghana Meteorological Agency collaborates with the Ghana Health Service to predict malaria risk using climate models. Administering antimalarial drugs to high-risk populations (e.g., children under five) before peak transmission periods. The introduction of Seasonal Malaria Chemoprevention (SMC) in northern Ghana reduced malaria cases by 50%. Increasing hospital capacity and staffing during peak malaria seasons to reduce patient overload. Deploying mobile clinics in high-burden areas to improve access to treatment. Encouraging local involvement in environmental management, such as clearing stagnant water. Promoting public awareness campaigns on malaria prevention before peak seasons.

4 Conclusion

Malaria in Ghana exhibits strong seasonal patterns, with infection rates peaking during the rainy season due to favourable mosquito breeding conditions. This seasonality has profound implications for healthcare delivery, causing hospital overcrowding, financial strain, and disruptions to routine services. Effective risk mitigation strategies, including early warning systems, seasonal chemoprevention, and enhanced resource allocation, are essential to reduce malaria burden and improve healthcare efficiency. Aligning malaria control measures with seasonal transmission patterns, Ghana can enhance its fight against malaria and strengthen its healthcare system to better respond to seasonal disease surges.

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