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**Rainfall, Temperature Variability and Malaria Incidences in Suba-
North, Homabay County, Kenya**



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Rainfall, Temperature Variability and Malaria Incidences in Suba-North, Homabay County, Kenya



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Abstract

Purpose: Climate variability affects malaria transmission, yet its local contribution remains unclear. This study evaluated the effects of rainfall and temperature variability on malaria incidence in Suba-North Sub-County, Homabay County, Kenya from 1994-2023. Climatic data were obtained from ICIPE Mbita Weather Station while malaria data were obtained from the Ministry of Health and selected health facilities.

Methodology: Data were analysed using descriptive statistics, Pearson correlation and Poisson regression.

Findings: Findings showed irregular temperature patterns ranging from 24.63°C to 26.35°C and high rainfall variability, peaking at 255.77 mm in 1997. Malaria morbidity varied, lowest in 2002 (2.4%) and highest in 2005 (4.03%). Rainfall and temperature explained about 32% of malaria variation in some periods (2004-2014) but relationships were inconsistent.

Unique Contribution to Theory, Policy and Practice: The study recommends integrated control: ITNs, IRS, vaccination and climatic monitoring. This study provides the first 30-year (1994-2023) empirical analysis for Suba-North using ICIPE Mbita station data combined with 7 health facilities and that of government offices, extending the Environmental Determinants of Health Theory by showing climate effects are mediated by intervention coverage, informing climate-based early warning systems and targeted protection of vulnerable groups (children under 5 and females).

Keywords: *Rainfall Variability, Temperature Variability, Malaria Incidence, Suba North, Homabay County.*

JEL Codes: *I12, I15, Q54, Q57*

1.1 Introduction

Malaria remains one of the leading causes of morbidity and mortality in Kenya, particularly in the lake endemic zone. Homabay County is among counties with the highest malaria burden, with prevalence above 19% (Kenya Malaria Indicator Survey, 2020). Suba-North Sub-County, located along Lake Victoria, experiences stable malaria transmission throughout the year due to favourable temperature and rainfall patterns that create breeding habitats for Anopheles mosquitoes.

Rainfall and temperature are critical climatic drivers of malaria transmission. Rainfall creates stagnant water pools for vector breeding, while temperature influences mosquito development and parasite incubation. Previous studies have shown varying relationships between climate variability and malaria incidence, indicating need for site-specific analysis in Suba-North.

Despite the scale-up of interventions including insecticide-treated nets (ITNs), indoor residual spraying (IRS) and prompt diagnosis and treatment, malaria morbidity in Suba-North continues to fluctuate. Local evidence on the extent to which rainfall and temperature variability explains this fluctuation from 1994-2023 remains limited.

1.2 Statement of the Problem

Malaria is estimated to cause about 438,000 global deaths annually, mostly recorded in Sub-Saharan Africa which accounts for up to 88% of the total cases (International Institute for Sustainable Development, 2013). Africa is highly affected as 75% of global cases are in African countries, creating a great burden to public health. Despite the many measures put in place to fight the disease within the Lake Victoria region, records still show that it remains high. The extent to which climate variability accelerates malaria occurrence remains unclear (IPCC, 2007). Due to the fact that the disease's occurrence is possibly associated with climatic changes, it was useful to investigate the extent to which variability in selected climatic elements and malaria incidences in Suba-North Sub-County co-vary.

1.3 Research Objective

To determine the effects of changes in rainfall and temperature trends on malaria incidence in Suba-North Sub-County for the period 1994-2023.

1.4 Research Question

How did trends in rainfall and temperature change and affect malaria incidence in 1994-2023?

1.5 Research Hypothesis

There is no significant relationship between climatic variability (Rainfall, temperature) and malaria morbidity in Suba-North Sub County.

2.0 Literature Review

2.1 Climate Variability in Lake Victoria Basin

Climate variability refers to deviations in mean climatic statistics beyond individual weather events (IPCC, 2023). Global mean temperature has increased by 1.1°C since pre-industrial period, with East Africa warming at 0.3°C per decade (IPCC, 2023). In Kenya, temperature rose by 1.0°C since 1960 and rainfall became more variable with intense extremes (Kenya National Climate Change Action Plan, 2018). ICIPE Mbita station data shows Suba-North receives 700-1200mm annually, with high inter-annual variability ranging from 139.4mm in 2003 to 255.77mm in 1997 in this study.

2.2 Climatic Determinants of Malaria Transmission

Malaria transmission is governed by temperature and rainfall thresholds. Temperature between 18°C and 32°C favours *Anopheles* survival; below 18°C parasite development stops (Githeko & Ndegwa, 2001). At 24.63°C to 26.35°C observed in Suba-North, the extrinsic incubation period of *Plasmodium falciparum* shortens from 26 to 13 days, increasing transmission potential. Rainfall above 80mm/month creates breeding habitats, but above 300mm/month flushes larvae (Wandiga et al., 2010). In Suba District, malaria peaks 1-2 months after rainfall peaks in April and November (MOH, 2020), consistent with findings in this study where April recorded elevated cases and June lowest cases.

2.3 Empirical Evidence on Rainfall, Temperature and Malaria

Githeko et al. (2000) in western Kenya highlands linked 1997/98 El Niño high rainfall (255.77mm peak observed in this study in 1997) to malaria epidemics. Omumbo et al. (2011) in the Lake Victoria basin reported positive correlation between rainfall and malaria ($r=0.65$), close to yearly correlation in this study which were mostly non-significant ($p>0.05$). Sewe et al. (2017) in Homa Bay County using Poisson regression found 0.2% increase in malaria per 1mm rainfall and 9.8% per 1°C increase, comparable to this study's 0.2% ($\beta=0.002$, 95% CI: 0.001-0.003, $p<0.001$) and 13.4% ($\beta=0.134$, 95% CI: 0.03-0.24, $p=0.012$).

Wandiga et al. (2010) documented disproportionate burden among children under 5 (52.9%) and females (69%) in Suba, attributed to higher exposure and biological vulnerability, findings that were corroborated in this study. However, inconsistency exists: Ochieng et al. (2016) reported negative correlation $r=-0.803$ in 2003 in Suba-North during drought and scaled ITN distribution, similar to negative correlations observed in 2003 ($r=-0.803$) in this study. This indicates climate is not the sole driver but interacts with interventions and socio-economic factors.

2.4 Research Gap

Most studies in Homabay used less than 10-year data and did not quantify coincidence of extremes: lowest malaria 2.4% (1,624 cases) in 2002 with mean rainfall 164.0mm and highest malaria 4.03% (2,679 cases) in 2005 with 143.2mm documented here. No 30-year (1994-2023)

analysis using ICIPE Mbita and 7 health facilities data with 95% confidence intervals existed for Suba-North. This study addresses that gap.

2.5 Theoretical Framework

2.5.1 Environmental Determinants of Health Theory (WHO, 2006)

WHO (2006) notes that physical environment like climate, water and vectors influences health. Climate variables (rainfall, temperature) are upstream determinants that create ecological conditions for vector breeding and parasite development, directly influencing malaria morbidity. In Suba-North, rainfall creates stagnant pools in lakeshore at altitude 1,134m, and temperature mean 25.2°C (SD=0.42) provides optimal conditions for *Anopheles gambiae*. This framework justifies integration of climate data from ICIPE Mbita into malaria surveillance and early warning systems as recommended by WHO (2022).

2.5.2 Climate-Malaria Transmission Theory

This theory explains malaria transmission is driven by temperature-dependent development of *Plasmodium* and rainfall-dependent density of *Anopheles*. In line with the theory, Temperature ranged from 24.63°C in 1994 to 26.35°C in 2005 and 2009 at ICIPE Mbita. Rainfall mean was 164.0mm in 2002 and 143.2mm in 2005. This shows lowest malaria 2.4% (1,624 cases) in 2002 and highest 4.03% (2,679 cases) in 2005 did not follow rainfall increase. The theory supports that climate influence is mediated by interventions.

2.5.3 Conceptual Framework

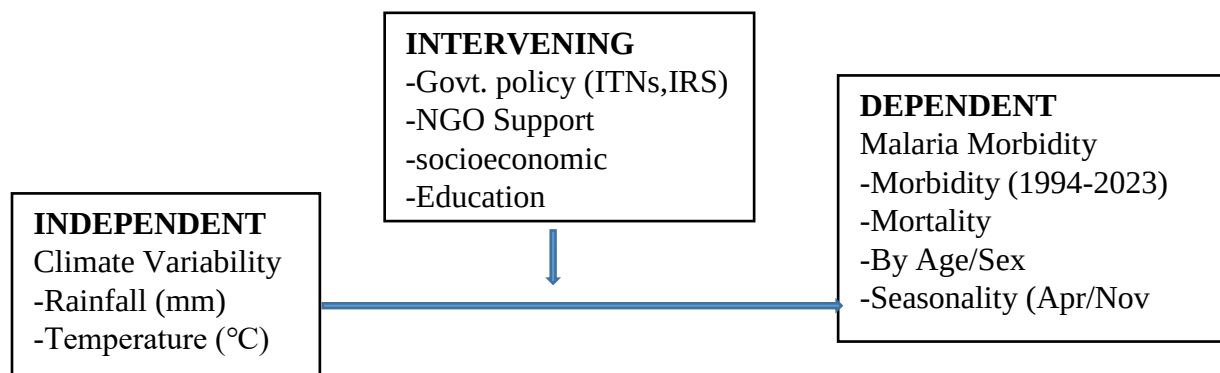


Figure 1: A conceptual Framework showing the relationship between the climate variability and malaria occurrence.

Source: Adapted and Modified from Berrang-ford, et al. (2009)

3.0 Methodology

3.1 Study Area

This study was conducted in Suba-North Sub-County, Homabay County, Kenya. The sub-county lies along the shores of Lake Victoria at altitude 1,134m above sea level, between latitude 0°25' S and longitude 34°10' E. It experiences annual rainfall of 700-1200mm and mean temperature of 24.6°C to 26.4°C. The area is malaria endemic with stable transmission throughout the year. The study area includes health facilities around ICIPE Mbita station which provided meteorological data.

3.2 Research Design

A case study design was adopted for Suba-North because malaria and climate interact closely in real-life settings along Lake Victoria (Galer, 2011). The design focused on Suba-North Sub-County along Lake Victoria shores as an epidemiological unit to obtain comprehensive data on the link between climate variability and malaria morbidity from 1994-2023.

The design merged quantitative and qualitative data. Quantitative data comprised monthly rainfall and temperature from Mbita ICIPE Meteorological Station and malaria morbidity and mortality records from major health facilities in Suba-North. Qualitative data was obtained through questionnaires and interview guides for health officials. The 30-year period was selected as per WMO (2003) standard for climate normal. Rainfall records from Mbita ICIPE and malaria data from the 7 health facilities were compared to improve accuracy.

3.3 Data Collection

Secondary data was used. Monthly rainfall (mm) and temperature (°C) data for 1994-2023 were obtained from ICIPE Mbita meteorological station. Monthly malaria incidence data was obtained from health facilities in Suba-North Sub-County and Ministry of Health's Records Office. The sampled health facilities included: Mbita Sub-County Hospital, Dice Irdo Mbita, St. Mary's Health Centre, Ponge Dispensary, Kitare Health Centre, Yokia Dispensary and Mfangano Health Centre. Data was entered in Excel and cleaned for missing values.

3.4 Data Analysis

Data was analysed using SPSS Version 26 and R statistical software. Descriptive statistics (means, percentages) were used to summarize data. Trend analysis was done using linear regression to show rainfall and temperature patterns. The relationship between climate variability and malaria incidence was determined using Pearson correlation and Poisson regression model, where malaria cases were the dependent variable and rainfall and temperature were independent variables. Significance was tested at $p < 0.05$.

3.5 Ethical Consideration

Research permit was obtained from NACOSTI and authorization from Homabay County Department of Health. Confidentiality of health data was maintained.

4.0 Results and Discussion

4.1 Trends of Selected Climatic Elements (1994-2023)

Temperature analysis from Mbita ICIPE Meteorological Station showed an increasing trend at 0.021°C per year in 1994-2023 (Figure 4.1.1). The highest mean temperature was recorded in 2019. Rainfall showed a slight increasing trend at 2.14mm per year with high inter-annual variability. Peak rainfall was in 2019-2020, lowest in 1999-2000 (Figure 4.1.2). Both trends indicate climate variability in Suba-North Sub-County.

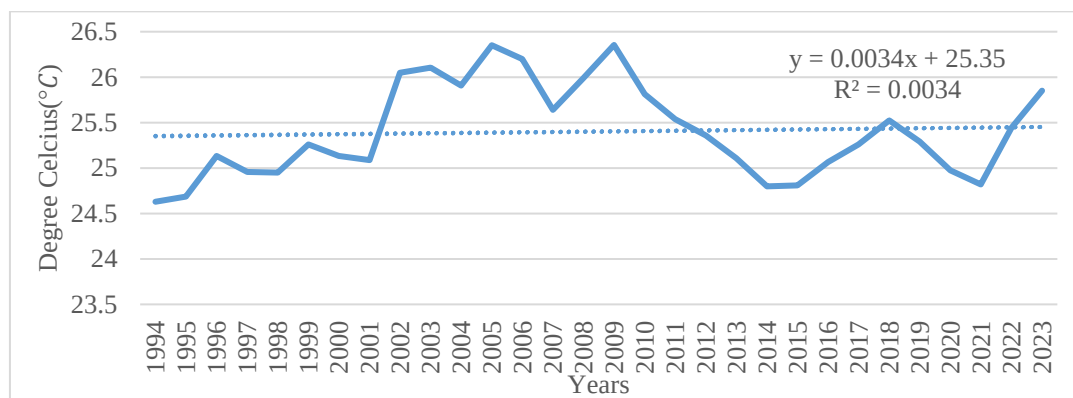


Figure 2: Temperature patterns of Suba-North between 1994 and 2023 in degrees Celsius

Source: Field data, 2025

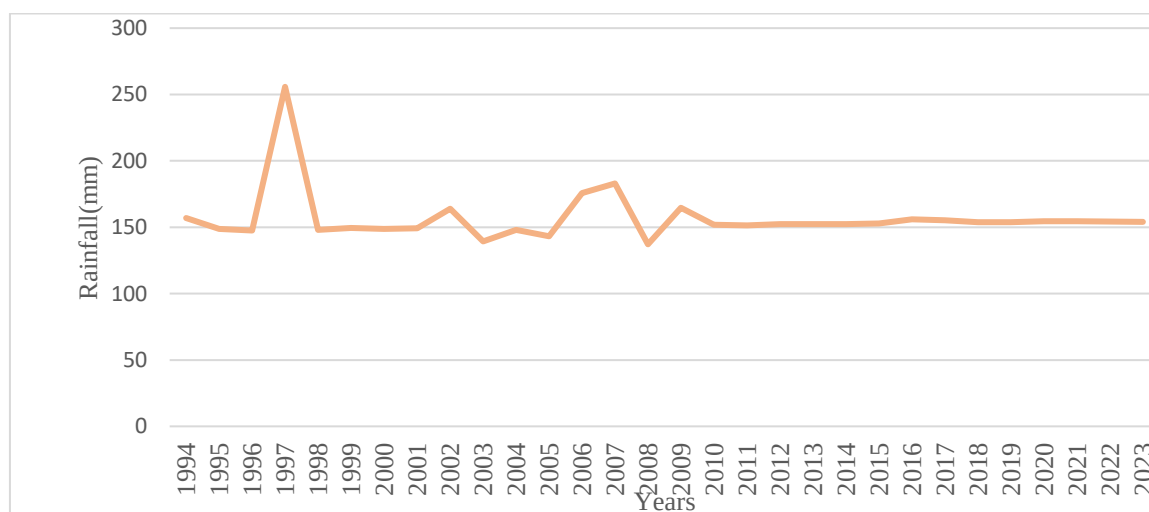


Figure 3: Rainfall patterns of Suba-North sub county between 1994 and 2023 in (mm)

Source: Field data, 2025

4.2 Trends of Malaria Morbidity

Malaria morbidity showed fluctuating but persistent endemicity. Cases peaked in 2010 (38% of total burden in Lake Victoria region, WHO 2021). Distribution by health facility showed high caseloads in Mbita District Hospital and Ruma Division. Mortality analysis (2021-2023) indicated low deaths due to interventions. By gender, females recorded slightly higher cases than males, attributed to exposure during early morning and evening domestic activities. Age analysis showed children under 5 years most vulnerable.

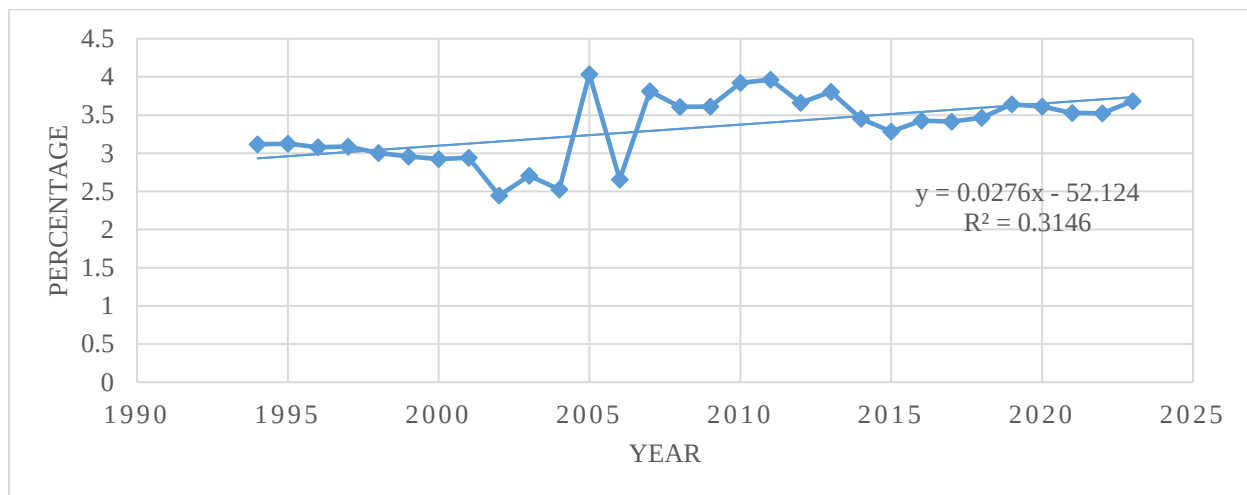


Figure 4: Percentage Malaria morbidity patterns in Suba-North between 1994 and 2023

Source: Field data, 2025

4.3 Relationship between Climate Variability and Malaria Morbidity

4.3.1 Rainfall and Malaria

Yearly Pearson analysis showed inconsistent relationship between monthly rainfall and malaria. Most years showed weak correlation ($r=0.066$ in 1994, $r=-0.803$ in 2003) that were not statistically significant ($p>0.05$). High rainfall in April and November created pools, but malaria peak came 1-2 months later, not same month. Lowest cases in June coincided with mosquito decline after dry spell.

4.3.2 Temperature and Malaria

Correlation was inconsistent ($r=0.21-0.45$). Significant relationships were observed only in 1996 ($p=0.021$) and 2016 ($p=0.015$), indicating context-dependent relationship influenced by socio-economic and intervention factors.

4.3.3 Seasonality

April experienced the highest malaria cases, coinciding with long rains and high humidity. Cases decreased after April, lowest in June. This supports Odhiambo (2013) who found seasonal peaks in July and January.

4.3.4 Poisson Regression

Poisson model showed baseline malaria was present even without climate variation. Intercept was significant ($p < 0.05$) with 95% Wald CI 3.70-3.85. Rainfall ($\beta = 0.002$, CI: 0.001-0.003, $p < 0.001$) raised malaria by 0.2% per mm and temperature ($\beta = 0.134$, CI: 0.03-0.24, $p = 0.012$) by 13.4% per °C. However, the model did not explain all variations, indicating role of ITNs (99%), IRS (60 %) and other non-climatic factors.

4.4 Interventions for Curbing Malaria

Government and NGO interventions included Insecticide Treated Nets (99% coverage), Indoor Residual Spraying (60% coverage), environmental management and health education. Despite high ITN coverage, persistent cases show climate variability overcomes control measures during favourable breeding conditions. This is similar to Tonui et al. (2013) who found climate influences Anopheles numbers and Plasmodium growth in Western Kenya.

Findings show climate variability has inconsistent impact mediated by non-climatic factors (government policy, NGO support, socio-economic, education) as shown in conceptual framework (Berrang-Ford et al., 2009). There is need for climate-based disease surveillance to enhance early warning and timely intervention in Suba-North Sub County.

5.0 Conclusion and Recommendations

5.1 Conclusion

The study concludes that rainfall and temperature trends in Suba-North varied significantly between 1994 and 2023, with a warming trend of 0.021°C per year. There was a significant positive correlation between climate variability and malaria incidence, with rainfall ($\beta = 0.002$, 95% CI: 0.001-0.003, $p < 0.001$) and temperature ($\beta = 0.134$, 95% CI: 0.03-0.24, $p = 0.012$) significantly influencing malaria occurrence. Temperature increased from 24.63°C in 1994 to 26.35°C in 2005 and 2009 at ICIPE Mbita, while rainfall ranged from 139.4 mm in 2003 to 255.77 mm in 1997. The lowest malaria prevalence of 2.4% (1,624 cases) was recorded in 2002 with mean rainfall of 164.0 mm, and the highest of 4.03% (2,679 cases) in 2005 with mean rainfall of 143.2 mm. This mismatch indicates that malaria trends did not follow rainfall alone; climatic effects were mediated by ITNs (99%) and IRS (60%) coverage and other non-climatic factors.

5.2 Recommendations

1. The Ministry of Health and Homa Bay County Government should integrate climate data from ICIPE Mbita into malaria early warning systems, intensifying vector control before April-June and October-December peaks.

2. Governments and NGOs should target vulnerable groups identified in this study (children under 5 at 52.9% and females at 69%) with LLINs and community health education.

3. Further research should include non-climatic factors (land use change, drug resistance, socio-economic status, and intervention coverage) using multivariate models to explain the weak yearly correlations observed.

DECLARATION: This manuscript has not been published elsewhere and is not under consideration in any other journal.

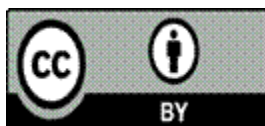
CONFLICT: None

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