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TEMPORAL AND SEASONAL VARIATION IN MALARIA CASES AT SPECIALIST HOSPITAL BAUCHI, NIGERIA: A RETROSPECTIVE ANALYSIS, 2016–2025

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ABSTRACT

Malaria remains an important public-health problem in Nigeria, and understanding its temporal and seasonal distribution is essential for targeted prevention and service planning. This study examined quarterly malaria incidence recorded at Specialist Hospital Bauchi over ten years (2016–2025). A retrospective longitudinal design was used with secondary hospital records comprising 40 quarterly observations. Descriptive statistics, graphical temporal-trend analysis, regression analysis, one-way analysis of variance (ANOVA), and Tukey's honestly significant difference (HSD) procedure were applied. The quarterly means were 179.5 cases for Q1, 224.5 for Q2, 216.1 for Q3, and 174.4 for Q4, indicating that Q2 had the highest average burden and Q4 the lowest. Marked inter-annual fluctuations were observed in Q1 and Q3, whereas Q2 remained comparatively high and stable. The ANOVA showed statistically significant differences in mean malaria incidence among quarters, $F(3,35)=12.45$, $p<0.001$. Tukey HSD indicated significantly higher incidence in Q2 than Q1 (mean difference=45.2, $p=0.002$) and in Q3 than Q1 (38.1, $p=0.008$), while Q4 was significantly lower than Q2 and Q3 ($p<0.001$ and $p=0.001$, respectively). The regression analysis reported in the source project explained 74.1% of variation in the temporal outcome ($R^2=0.741$), but the overall model was not statistically significant at the 5% level, $F(4,5)=3.58$, $p=0.097$. The findings demonstrate a pronounced seasonal pattern, with the greatest malaria burden occurring in Q2 and Q3. Malaria-control activities, surveillance, and resource allocation should therefore be intensified before and during these high-risk periods.

KEYWORDS: malaria incidence; seasonality; quarterly surveillance; temporal trend; ANOVA; Specialist Hospital Bauchi.

INTRODUCTION

Background

Malaria is a mosquito-borne infectious disease caused by parasites of the genus Plasmodium and transmitted predominantly through the bite of infected female Anopheles mosquitoes. It remains a major health challenge in sub-Saharan Africa, where transmission intensity and malaria-related morbidity and mortality are disproportionately high. The burden is shaped by ecological conditions, vector dynamics, health-system access, prevention practices, and the availability and uptake of effective diagnosis and treatment. The source study identifies malaria as an important public-health problem in Nigeria and emphasizes the need to understand temporal patterns at local facility level. Recent evidence summarized in the project indicates that the African Region accounts for the overwhelming majority of global malaria cases and deaths and that Nigeria remains among the highest-burden countries. Despite the expansion of insecticide-treated nets, rapid diagnostic testing, artemisinin-based combination therapies and newer interventions, substantial transmission persists.

Temporal surveillance is particularly valuable because malaria transmission is not necessarily constant throughout the year. Rainfall, temperature, humidity and mosquito breeding conditions can generate recurrent seasonal fluctuations. The project's review notes that local evidence from Bauchi and northeastern Nigeria indicates variation in malaria burden according to season and environmental and socioeconomic conditions. However, standardized facility-level time-series analyses are less common than national or aggregated estimates. This creates a practical need for analyses that use routinely collected hospital records to identify periods of elevated disease burden and inform timing of interventions.

One of the most important characteristics of malaria transmission is its temporal and seasonal variability. Rainfall provides breeding sites for Anopheles mosquitoes, while temperature and humidity influence mosquito survival, parasite development and transmission potential. Consequently, malaria incidence commonly increases during or following periods favourable for mosquito proliferation. Studies conducted in Nigeria have therefore increasingly incorporated temporal and climatic information into malaria analyses.

For example, Umar et al. (2020) examined the relationship between weather variables and malaria occurrence in Abuja using monthly observations and statistical modelling. Their findings demonstrated that malaria incidence varied considerably across months and that rainfall, temperature and humidity were important explanatory factors. The study demonstrated the value of incorporating temporal environmental information when investigating malaria occurrence in Nigeria. This provides an important methodological basis for the present study because quarterly hospital records can similarly be used to investigate whether malaria incidence follows a recurring seasonal pattern.

More recent research has increasingly moved from simple descriptive analyses toward formal time-series modelling and forecasting**.** Oniyelu et al. (2025) investigated malaria in pregnancy across Nigerian states using wavelet and SARIMAX time-series models. Their study identified different temporal patterns across Nigerian regions, including cyclical and intervention-related fluctuations, and emphasized the importance of climate-sensitive forecasting and seasonal interventions. The authors concluded that malaria-control strategies should be tailored to regional transmission dynamics rather than assuming a uniform national pattern.

The work of Oniyelu et al. (2025) is particularly relevant to the present study because it demonstrates that temporal malaria patterns can differ substantially between Nigerian regions. However, its focus was on malaria in pregnancy and the application of relatively advanced wavelet and SARIMAX models across multiple Nigerian states. The present study takes a different approach by examining all recorded malaria cases at Specialist Hospital Bauchi and explicitly comparing malaria incidence among four quarters over a ten-year period.

Evidence from northeastern Nigeria further supports the importance of temporal analysis. Bakare et al. (2026) investigated the relationship between rainfall, temperature and malaria incidence in Adamawa State using monthly data covering January 2015 to April 2024. The authors applied time-series methods to characterize temporal patterns and generate forecasts, demonstrating the importance of climatic conditions in understanding malaria dynamics in northeastern Nigeria.

Similarly, Bakare, Mogbojuri, Bakare, and Odewusi (2026) examined malaria patterns in Nasarawa, Kwara and Zamfara States using ten years of confirmed malaria data from January 2015 to December 2024. Their study employed wavelet analysis and Seasonal Autoregressive

Integrated Moving Average (SARIMA) models. They identified strong annual cycles, with malaria peaks occurring predominantly around August and September in some states, while the strength and timing of seasonality varied between states. Their findings emphasized the need for state-specific interventions and the importance of aligning malaria-control activities with observed seasonal patterns.

These recent studies demonstrate that sophisticated time-series approaches can reveal patterns that may not be apparent from annual malaria totals. However, advanced models such as SARIMA, SARIMAX and wavelet analysis are primarily designed for modelling temporal dependence, periodicity and forecasting. There remains value in complementary analyses based on quarterly comparisons, particularly where the practical research question is to determine whether malaria incidence differs significantly between seasons or quarters.

This is important for health-facility planning. If malaria incidence is consistently higher during particular quarters, hospitals and public-health authorities can use such information to anticipate increases in diagnostic demand, antimalarial drug requirements, staffing needs and preventive activities. Thus, temporal analysis should not be restricted to forecasting future cases; it should also provide simple and interpretable evidence about when malaria burden is highest.

Although previous Nigerian studies, particularly Oniyelu et al. (2025), have demonstrated the importance of temporal modelling in understanding malaria dynamics, limited attention has been given to statistically testing quarterly differences in overall hospital-recorded malaria incidence at the facility level in Bauchi State. Existing studies have largely focused on malaria in pregnancy, climatic associations, multi-state surveillance or advanced forecasting techniques such as wavelet analysis and SARIMAX. Consequently, there remains a gap in simple, interpretable longitudinal evidence identifying whether malaria incidence differs significantly across calendar quarters and determining the specific quarter associated with the greatest burden at a major health facility in Bauchi. The present study addresses this gap by analyzing ten years of quarterly malaria records from Specialist Hospital Bauchi (2016–2026) using descriptive statistics, temporal trend analysis, regression, one-way ANOVA and Tukey HSD post-hoc comparisons.

Statement of the Problem

Malaria remains a major public-health challenge in Nigeria despite continuing efforts in prevention, diagnosis, treatment and vector control. However, malaria incidence is not constant throughout the year and may vary considerably across seasons and years due to environmental conditions, vector dynamics and other factors. Although recent studies such as Oniyelu et al. (2025) have demonstrated the importance of temporal analysis in understanding malaria patterns across Nigeria, their focus was on malaria in pregnancy and multi-state time-series modelling. Consequently, there remains limited facility-level evidence on the seasonal distribution of overall malaria incidence at Specialist Hospital Bauchi and on whether observed differences between quarters are statistically significant.

This study therefore addresses the need for localized statistical evidence on the temporal and seasonal pattern of malaria incidence in Bauchi. Using ten years of quarterly hospital records from 2016–2025, the study applies descriptive statistics, temporal trend analysis, regression analysis, one-way ANOVA and Tukey's HSD post-hoc test to determine the pattern of malaria incidence, assess differences among Q1–Q4, and identify the quarter with the highest malaria burden. Such evidence can support more effective seasonal planning of malaria surveillance, diagnostic services, treatment resources and preventive interventions at the hospital and local public-health levels.

Aim and Objectives

The study aimed to statistically characterize quarterly malaria incidence at Specialist Hospital Bauchi over 2016–2025. Specifically, it sought to:

- Summarize quarterly malaria cases;
- Examine temporal patterns across Q1–Q4;
- Assess the relationship between quarterly incidence and temporal progression;
- Test whether mean incidence differs among quarters; and
- Identify the quarter with the highest malaria burden.

Research Questions

The study seeks to answer the following research questions:

- What is the temporal trend of malaria incidence at Specialist Hospital Bauchi from 2016 to 2025?
- What is the relationship between time (year) and malaria incidence at Specialist Hospital Bauchi during the study period?

- Is there a statistically significant difference in malaria incidence among the four quarters (Q1, Q2, Q3 and Q4) at Specialist Hospital Bauchi?
- Which quarter records the highest malaria incidence at Specialist Hospital Bauchi during the study period?

Hypothesis

H_0: Mean malaria incidence does not differ significantly among Q1, Q2, Q3 and Q4. H_1: At least one quarterly mean differs significantly.

MATERIALS AND METHODS

Study Design and Setting

A retrospective longitudinal design was adopted. The study was conducted using records from Specialist Hospital Bauchi, Bauchi State, Nigeria. The source document describes Bauchi State as being in northeastern Nigeria, with a tropical climate characterized by a relatively long dry season and a shorter wet season. These climatic features provide a relevant context for examining seasonal malaria variation.

Data Source

The study utilized secondary data obtained from the medical records and routine health information records of Specialist Hospital Bauchi, Bauchi State, Nigeria. The dataset comprised recorded malaria cases for a ten-year period, from January 2016 to December 2025, aggregated into four quarters for each year, resulting in 40 quarterly observations. The quarterly records consisted of malaria cases reported in Q1 (January–March), Q2 (April–June), Q3 (July–September), and Q4 (October–December). The use of routine hospital records enabled the study to examine the temporal and seasonal distribution of reported malaria incidence over an extended period.

The data were obtained from the hospital's records/statistical unit following the necessary administrative procedures for access to institutional records. Records were reviewed for completeness and consistency before extraction and analysis. The study relied on routinely recorded malaria cases rather than primary interviews or questionnaires. This approach is appropriate for a retrospective longitudinal analysis because repeated hospital records provide an opportunity to evaluate changes in malaria incidence across years and quarters. Previous research conducted at Specialist Hospital Bauchi has also utilized hospital-based data to investigate malaria-related outcomes, demonstrating the relevance of the facility as a source of malaria epidemiological information.

Limitations of the Study

This study has several limitations that should be considered when interpreting its findings. First, the analysis was based on secondary hospital records from a single health facility, Specialist Hospital Bauchi; therefore, the findings may not be directly generalizable to the wider population of Bauchi State or Nigeria. The recorded cases may also be influenced by healthcare-seeking behavior, referral patterns, diagnostic practices and completeness of hospital reporting. In addition, the study relied on quarterly malaria counts and did not incorporate potentially important explanatory factors such as rainfall, temperature, humidity, malaria-control interventions, population movement and changes in health policies. Consequently, the observed quarterly differences describe temporal and seasonal variation in reported hospital cases but cannot independently establish the factors responsible for such variation.

The study also has statistical limitations. The quarterly observations are repeated across the ten-year study period, and the conventional one-way ANOVA assumes independence of observations, which may not fully account for the longitudinal structure of the data. Furthermore, the regression model used in the original analysis specified year as the dependent variable and quarterly malaria counts as explanatory variables, limiting its epidemiological and causal interpretation. The regression findings should therefore be regarded as exploratory rather than causal evidence. Future studies should model malaria incidence directly as the outcome and employ longitudinal or time-series methods that account for temporal dependence, seasonality and the count nature of malaria data.

- **Table 1: Data Structure for quarterly malaria cases at Specialist Hospital Bauchi, 2015–2024.**

The outcome variable was the number of malaria cases recorded in each quarter. The explanatory categorical variable was quarter, represented by four levels (Q1, Q2, Q3 and Q4). Year was retained as the temporal index. The quarterly observations used in the analysis are reproduced in Table 1.

Year	Q1	Q2	Q3	Q4	Annual total
2015	136	205	211	182	734
2016	201	206	234	143	784
2017	167	224	207	201	799
2018	247	206	176	216	845
2019	151	247	238	190	826
2020	168	223	233	163	787
2021	175	245	218	161	799
2022	189	226	207	179	801
2023	177	232	212	160	781
2024	184	231	225	149	789

Source: *2016-2025 Quarterly malaria cases recorded at Specialist Hospital Bauchi.*

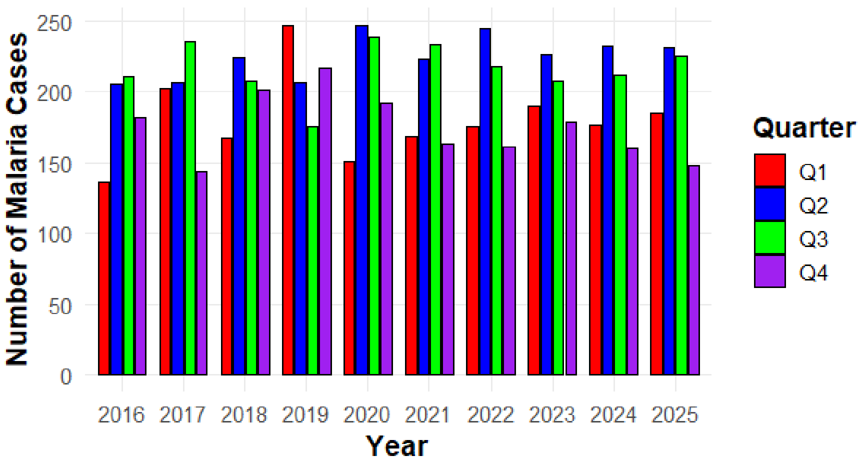

Figure 1: Quarterly Distribution of Malaria Cases, 2016–2025

Figure 1 presents the quarterly distribution of malaria cases recorded at Specialist Hospital Bauchi from 2016 to 2025**.** The figure demonstrates substantial variation in malaria incidence across both years and quarters, indicating the presence of temporal and seasonal fluctuations in the reported malaria burden. Overall, Q2 and Q3 generally recorded higher numbers of malaria cases than Q1 and Q4 across most years. The highest quarterly incidence was observed in Q1 in 2019 (approximately 247 cases**)**, while Q2 also recorded relatively high values in 2020 and 2022. Q3 showed consistently high incidence, particularly in 2017, 2020 and 2021, whereas Q4 generally remained comparatively lower throughout the study period.

The distribution further indicates that the seasonal pattern was not completely uniform across the ten-year period. For example, Q1 showed considerable fluctuations, increasing sharply from 2016 to 2019 before declining in 2020 and subsequently increasing again. Q2 and Q3 remained comparatively high in several years, suggesting a persistent concentration of malaria cases during the middle quarters of the year. In contrast, Q4 recorded relatively lower incidence in most years, with its values generally remaining below 200 cases. The pattern observed in the figure therefore suggests that malaria incidence at the hospital tends to be greater during the middle part of the year, although substantial year-to-year variation is evident.

Statistical Analysis

Descriptive statistics were used to summarize the distribution of cases by quarter, while line-trend visualization was used to examine inter-annual movements. The one-way ANOVA compared mean malaria incidence among the four quarters. Its model can be written as $Y_{ij} = \mu + \tau_i + \varepsilon_{ij}$, where Y_{ij} is the observed incidence, μ is the grand mean, τ_i is the effect of quarter i, and ε_{ij} is random error. The F statistic was calculated as F = MS_between/MS_within. When the omnibus test was significant, Tukey HSD was used for pairwise comparisons.

The source project also fitted a multiple linear regression using year as the dependent temporal outcome and quarterly malaria measures as predictors. The reported specification was $Y = \beta_0 + \beta_1 Q1 + \beta_2 Q2 + \beta_3 Q3 + \beta_4 Q4 + \varepsilon$, where Y denotes the temporal year index and Q1–Q4 are quarterly malaria measures. Because this specification model's year from malaria counts rather than malaria counts from time, its coefficients should be interpreted as exploratory statistical associations rather than causal effects of malaria on time. The reported model statistics are retained for transparency, but this limitation should be addressed in a future analysis by modelling malaria incidence as the outcome and time/season as explanatory variables.

All hypothesis tests were interpreted at the 5% significance level unless otherwise stated. The source project additionally described the regression as marginally significant at the 10% level. Given the repeated quarterly observations within years, the independence assumption required for a conventional one-way ANOVA is a methodological limitation; a repeated-measures or mixed-effects framework would provide a stronger confirmatory analysis in future work.

RESULTS

Table 2: Results for Quarterly Descriptive Statistics for malaria cases, 2016–2025.

Quarter	**Mean cases**		**SD (computed from source data)**	**Rank**
Q1	179.5		30.1	3
Q2	224.5	15.3	1	
Q3	216.1	18.2	2	
Q4	174.4	23.4	4	

Table two represent the results for the descriptive statistics for malaria cases between 2016 to 2025 where Q2 recorded the highest mean incidence (224.5 cases), followed by Q3 (216.1), Q1 (179.5) and Q4 (174.4). The ranking indicates that the second and third quarters were the dominant periods of malaria burden. The source data also show substantial year-to-year variation, particularly in Q1 and Q3.

Temporal Pattern

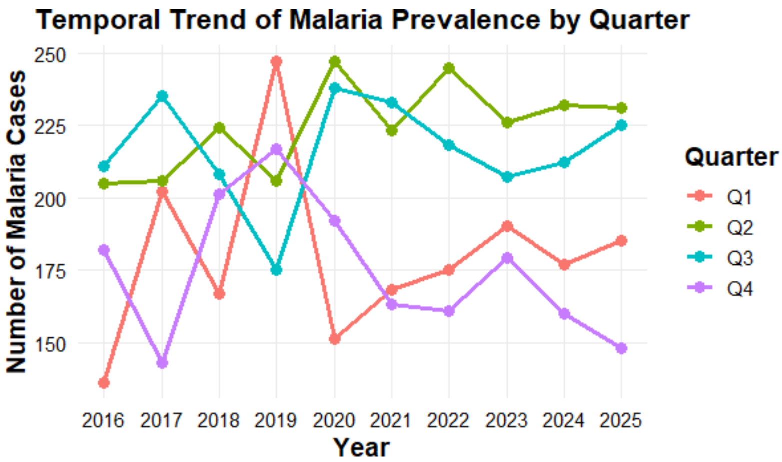

Figure 1: Temporal Trend graph for quarterly malaria cases 2016-2025.

Figure one present the temporal analysis plot for the ten-year series which showed a pronounced seasonal pattern. Q1 was comparatively unstable, rising to 247 cases in 2019 before declining and subsequently recovering. Q2 remained persistently high, reaching 247 cases in 2020 and 245 in 2022, while remaining above 200 cases in every year of the study. Q3 fluctuated considerably, with a low of 176 cases in 2019 and a high of 238 in 2020. Q4 generally recorded the lowest values and declined to 149 cases in 2025. Taken together, the pattern suggests a recurring mid-year concentration of malaria cases rather than a uniform distribution across the calendar year.

Table 3: Results for Regression Analysis for Malaria Cases for 2016-2025.

Term	Estimate	T	P-value
Intercept	2017.20041	81.839	<0.001
Q1	0.01786	0.595	0.578
Q2	0.16484	3.253	0.023
Q3	−0.10280	−1.497	0.195
Q4	−0.09001	−2.090	0.091

Table three represent the regression output for quarterly malaria cases from the period of 2016 to 2025. The reported regression had R^2=0.741 and adjusted R^2=0.534, with residual standard error 2.066 and an overall F statistic of 3.583 on 4 and 5 degrees of freedom (p=0.097). Thus, the model was not statistically significant at α=0.05. Q2 was the only quarterly predictor with a statistically significant coefficient (β=0.16484, p=0.023), whereas Q1 and Q3 were not significant and Q4 showed a negative marginal association (β=−0.09001, p=0.091). These findings should not be interpreted as evidence that malaria causes the passage of time; rather, they indicate how the quarterly case pattern covaried with the year index under the model used.

Table 4: ANOVA of Malaria Incidence by Incidence Across Quarters.

Source	df	SS	MS	F (p)
Quarter	3	19,275	6,425	12.45 (<0.001)
Residual	35	18,065	516	—

Table four represent the ANOVA output for the malaria cases from 2016-2025. The ANOVA indicated a statistically significant difference in malaria incidence among the four quarters, F(3,35)=12.45, p=0.0000108. The null hypothesis of equal quarterly means was therefore rejected at the 5% significance level.

Table 5: Pairwise Comparisons of Quarterly malaria Using Tukey HSD Post-hoc Comparisons.

Comparison	Mean difference	95% CI	Adjusted P
Q2 − Q1	45.2	18.5 to 71.8	0.002
Q3 − Q1	38.1	12.4 to 63.7	0.008
Q4 − Q1	−10.3	−35.9 to 15.2	0.680
Q3 − Q2	−7.1	−32.5 to 18.2	0.812
Q4 − Q2	−55.5	−80.1 to −30.8	<0.001
Q4 − Q3	−48.4	−73.0 to −23.8	0.001

Table five represent the results for the Tukey HSD test. The result showed that Q2 and Q3 were significantly higher than Q1, while Q4 was significantly lower than Q2 and Q3. Q2 and Q3 did not differ significantly, and Q1 and Q4 also did not differ significantly. On the basis of the observed means, Q2 was the highest-burden quarter.

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

This study examined the temporal and seasonal pattern of malaria incidence at Specialist Hospital Bauchi using quarterly records covering 2016–2025. Descriptive and inferential statistical methods were employed to characterize the distribution of malaria cases and determine whether incidence differed significantly across the four quarters. The results showed a clear seasonal pattern, with the highest mean malaria incidence occurring in Q2 (224.5 cases), followed by Q3 (216.1 cases), while Q4 recorded the lowest mean incidence (174.4 cases). The one-way ANOVA demonstrated statistically significant differences in malaria incidence across the quarters, $F(3,35) = 12.45$, $p < 0.001$. Tukey's HSD further indicated that Q2 and Q3 had significantly higher incidence than Q1, whereas Q4 had significantly lower incidence than Q2 and Q3. These findings indicate that malaria cases were concentrated particularly in the second and third quarters of the study period.

The temporal pattern has important implications for malaria surveillance and health-service planning. The relatively high incidence observed during Q2 and Q3 suggests that malaria-control activities and hospital preparedness should be strengthened before and during these periods. However, the findings should be interpreted within the limitations of the hospital-based dataset. The study was conducted at a single health facility, and recorded cases may be influenced by healthcare-seeking behaviour, referral patterns, diagnostic practices and completeness of reporting. In addition, climatic variables such as rainfall, temperature and humidity were not incorporated into the analysis, although they may contribute to the observed seasonal pattern. The regression analysis was also treated as exploratory because the original model used year as the dependent variable and quarterly malaria counts as predictors, limiting its epidemiological and causal interpretation.

CONCLUSION

The study concludes that malaria incidence at Specialist Hospital Bauchi exhibited significant seasonal variation during 2016–2025, with the greatest average burden occurring in Q2 and Q3. The significant ANOVA result and Tukey HSD comparisons provide statistical evidence that malaria incidence was not uniformly distributed across the four quarters. The findings therefore demonstrate the usefulness of quarterly hospital surveillance data for identifying periods of increased malaria burden and informing seasonal preparedness.

The observed concentration of malaria cases during Q2 and Q3 suggests that malaria prevention, surveillance and healthcare-resource planning should be intensified before the onset of these high-incidence periods while maintaining year-round control activities. Nevertheless, the findings should not be interpreted as representing the entire population of Bauchi State because the analysis was based on records from a single hospital. Future research should incorporate meteorological and intervention-related variables and employ longitudinal time-series or mixed-effects count models capable of accounting for trend, seasonality and temporal dependence.

RECOMMENDATIONS

Based on the findings, the following recommendations are proposed:

- Strengthen seasonal malaria control: Malaria prevention and control activities should be intensified before and during Q2 and Q3, particularly through insecticide-treated nets, appropriate vector-control measures, environmental sanitation and targeted community education.
- Improve hospital preparedness**:** Specialist Hospital Bauchi should use historical seasonal patterns to anticipate increases in malaria-related consultations and ensure adequate availability of diagnostic supplies, antimalarial medicines, personnel and other essential resources during high-incidence periods.
- Strengthen routine surveillance**:** Quarterly malaria surveillance and digital health-information systems should be improved to facilitate early identification of unusual increases in malaria cases and support timely public-health responses.
- Integrate environmental information**:** Future surveillance and forecasting should incorporate rainfall, temperature, humidity and other relevant environmental variables to improve understanding and prediction of seasonal malaria transmission in Bauchi.
- Improve future statistical modelling**:** Subsequent studies should model malaria incidence directly as the dependent variable, with time and season represented as explanatory variables, while applying longitudinal or time-series methods that account for repeated observations and temporal dependence.

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