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Exploring the nexus between climatic factors and malaria risks in the Nigerian Sahel

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Abstract

Malaria is still a major public health concern, particularly in the Sahelian regions of the world, despite global efforts to eradicate it. As such, this study investigated the connection between climatic factors and malaria cases. To empirically support these relationships, the study primarily examined the effects of temperature and rainfall on the incidence of malaria. The study used time-series data of temperature, precipitation and malaria incidence from 2014 to 2023. The study employed trend analysis to examine temporal change, correlation analysis to quantify the relationship between variables, and regression modeling to determine the predictive impact of climatic variables on malaria incidence. The findings show distinct seasonal and inter-annual cycles in the incidence of malaria, with peaks in 2017, 2020, and 2023. A significant positive correlation was found between malaria incidence and temperature ($r = 0.97$) and an inverse correlation between malaria incidence and rainfall ($r = -0.89$). Results from regression analysis further indicated that rising temperatures increase malaria incidence, while high rainfall reduces transmission. The paper concluded that the incidence of malaria is greatly influenced by climatic variables. Thus, it recommends integration of climate into malaria surveillance, to strengthen climate-resilient malaria control efforts.

Keywords: Malaria Transmission; Temperature; Rainfall; Sahel, Yobe State

1. Introduction

In sub-Saharan Africa, malaria remains one of the most serious public health issues, particularly in the Sahelian regions where the climate plays a major role in influencing the patterns of transmission. With its semi-arid climate and wet and dry seasons, the Nigerian Sahel probably offers ideal conditions for a high

Prevalence of malaria. Because mosquito breeding habitats, vector lifespans and parasite development are

Influenced by temperature and rainfall (Abiodun et al., 2018; Hussien, 2020). These studies examined the relationship between malaria prevalence and climatic factors, demonstrating how disease risks are impacted by climate variability and change.

However, one of the most urgent scientific problems in the ecology of human diseases in the Sahelian belt is still how the variables interact at various spatiotemporal scales (Millogo et al., 2023). The development of mosquitoes, their increased propensity to feed on human blood, and the Plasmodium parasite's quicker maturation all contribute to the increased spread of malaria (Megersa & Luo, 2025). Rainfall, on the other hand, provided mosquito breeding grounds, extending the life of the vectors and raising the prevalence of the disease, whereas temperatures may disturb the life cycle of the mosquitoes and thereby impair the transmission rates (Fatima et al., 2025). Temperatures above specific thresholds may implicitly signal an increase in malaria cases. For example, the study by Fatima et al. (2025) claimed that heat had to be a fundamental factor because malaria increased by 9–10% at certain locations in Pakistan for every 1°C that the temperature rose above the 22.4°C mark. This was due to temperature changes; hence heat had to be a fundamental weather variable in the assessment of malaria risk. However, a number of studies have found a connection between malaria risks and climatic factors, with a particular emphasis on the role of temperature and rainfall (Gomes et al., 2016; Abiodun et al., 2018).

The primary goal of Gomes et al. (2016)'s mathematical modeling approach was to evaluate the risk of malaria in various infection scenarios. The results demonstrated that the primary factors influencing the spread of malaria were temperature and humidity. Ferrao et al. (2018) found that rainfall patterns, which offered fertile breeding grounds, were the factors that influenced the spread of malaria cases. Accordingly, rainfall was identified by Millogo et al. (2023) as one of the primary environmental factors associated with areas where malaria is endemic. Despite Hussien's (2020) excellent work evaluating the climate-malaria relationships through correlation analysis, the study's methodology relied on linear regression techniques, which were too simplistic for the complex interactions involved in malaria dynamics. Additionally, another challenge is the spatiotemporal disparities in the current studies. Many studies, like those by Millogo et al. (2023) and Megersa and Luo (2025), focused on short-term data sets or particular localities; as a result, their conclusions are rarely extrapolated to larger regional contexts. Thus, it is crucial to conduct a long-term, region-specific study that takes into account the changes in climate parameters and how they affect the spread of malaria. On the other hand, the literature on the links between malaria transmission and climate change is severely lacking, particularly in the Nigerian Sahel, where climatic fluctuations are particularly noticeable. For instance, Hussien (2020) stated that he would use ordinary least squares regression to address the climate-malaria relationship in Sudan; however, he did not address the climate projections to evaluate the risks of malaria in the future. Simultaneously, Megersa and Luo (2025) concentrated on how climate change affects malaria without illustrating how malaria prevalence varies across climatic zones. Geographical factors influencing malaria prevalence were identified by Millogo et al. (2023), but they neglected to account for time-related variations in malaria incidences, which prompted the use of the research for long-term control. Although Gomes et al. (2016) and Ferrao et al. (2018) assessed the risk of malaria, they did not incorporate any qualitative information from the local population.

To develop the most effective adaptation and intervention strategies, it is essential to investigate how communities are experiencing and responding to the risks of malaria brought on by climate change. Furthermore, when it comes to integrating independent data sets to validate the predictive models, the existing research has frequently been lacking. For instance, there are questions regarding the reliability of Ferrao et al. (2018)'s GIS-based spatial modeling and Hussien's (2020) regression analysis since they did not rigorously verify the validation. The accuracy of malaria risk forecasts is still highly questionable in the absence of reliable validation techniques, which significantly reduces their usefulness for public health planning. Therefore, the analysis of the relationship between climate and malaria risks in the Nigerian Sahel's Yobe State was the main focus of this paper. It contributes to the fields of science and policymaking by offering a deeper comprehension of how changes in the climate impact malaria endemicity.

2. Material and Methods

2.1 Study Area

One of Nigeria's well-known Sahelian states is Yobe State, which is primarily distinguished by its dwarf acacia trees, shrubs and grasslands. With a brief wet season that typically lasts from May to September and a dry season that lasts from October to April, the region experiences extremely variable temperatures and irregular rainfall patterns. The environmental and socioeconomic landscape of the region may be shaped by these climatic conditions, which could have a significant impact on a number of livelihood issues such as disease prevalence. It is also vulnerable to climate change, which makes it a perfect focus area for research on health effects, livelihood adaptation and resilience, particularly with regard to infectious diseases such as malaria.

2.2 Methods

This study made extensive use of climate (temperature and rainfall) and malaria incidence data gathered from the Nigeria Meteorological Agency (NiMet) and the Yobe State Epidemic Repository, respectively. An unsupervised machine-learning model in Python was used to analyze the gathered data in order to guarantee accuracy and clarity. This method made it possible to identify patterns and analyze trends, which improved the study's dependability in evaluating climate variability and its effects in the various microclimatic zones of Yobe State.

3 Results and Discussions

3.1 Trends of Malaria, Temperature and Rainfall

The dynamic relationship between climate variables and malaria transmission is highlighted in Fig. 1, which shows the trend and seasonality of malaria cases, temperature and rainfall in the study area. The trend showed that the number of malaria cases fluctuated widely, peaking in 2017, 2020 and 2023 before sporadically declining after that. These differences validated findings by Abiodun et al. (2018), which demonstrated that malaria prevalence has periodic peaks modulated by climatic and environmental parameters. While the malaria trend has these fluctuations, trends in rainfall and temperature are comparatively stable, which suggested that malaria variability may react more to short-term changes rather than long-term climatic parameter changes, as often hinted by Millogo et al. (2023). In terms of seasonality,

Fig. 1 showed a clear periodicity in malaria cases, with distinct peaks that corresponded with the seasons of highest transmission. This was in agreement with Ferrao et al. (2018), who concluded that seasonal patterns of rainfall, which provide ideal breeding conditions for Anopheles mosquitoes, are directly linked to the incidence of malaria. However, Fatima et al. (2025) showed that malaria transmission is highly dependent on threshold temperature variability rather than absolute ones, suggesting that although temperature is important for vector and parasite development (Megersa & Luo, 2025), its seasonality appears less extreme in the study area. The significance of seasonally responsive malaria control strategies adapted to the Nigerian Sahel's climate variability was highlighted by these findings.

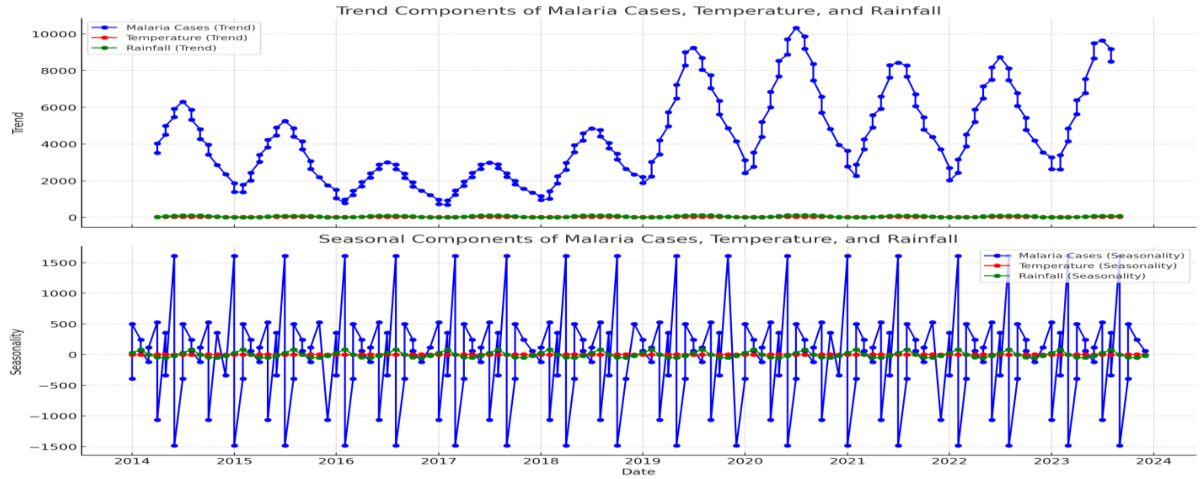

Figure 1 Relationship of Climate and Malaria incidences
Source: Fieldwork, 2024

3.2 Correlation between Climate and Malaria Cases

The correlational analysis (Fig. 2) quantitatively evaluated the interrelationships existing between malaria cases, temperature and rainfall, justifying the importance of climatic determinants in the epidemiology of malaria. A correlation coefficient of 0.97 between malaria cases and temperature was observed, which implied nearly a perfect positive relationship and rising temperatures are strongly linked with increased malaria occurrence. This is consistent with some earlier studies (Paaijmans et al., 2019) that have identified temperature as a key driver of malaria transmission, affecting both the rate of mosquito development and parasite maturation in the vector. Rainfall and malaria incidence, on the other hand, have a negative correlation (-0.89), indicating that the variables have the opposite relationship. Rainfall is crucial for mosquito breeding sites, but too much of it could destroy these sites by removing larvae, which would reduce vector populations (Mordecai et al., 2020). This agreed with the findings of Alonso et al. (2022), who argued that malaria transmission is sometimes optimized by rainfall patterns. Similarly, rainfall and temperature also have a high negative correlation (-0.84), which implied that high temperatures are more likely to coincide with low rainfall in the study area, a common characteristic prevalent for Sahelian and semi-arid conditions (Nicholson, 2018). In general, a negative malaria-rainfall relationship and a high, positive malaria-temperature correlation suggested that temperature fluctuations, rather than absolute rainfall patterns, largely control the dynamics of malaria transmission in the study area. These results emphasized the necessity of malaria interventions that are climate resilient, especially in areas where rising temperatures are frequently seen.

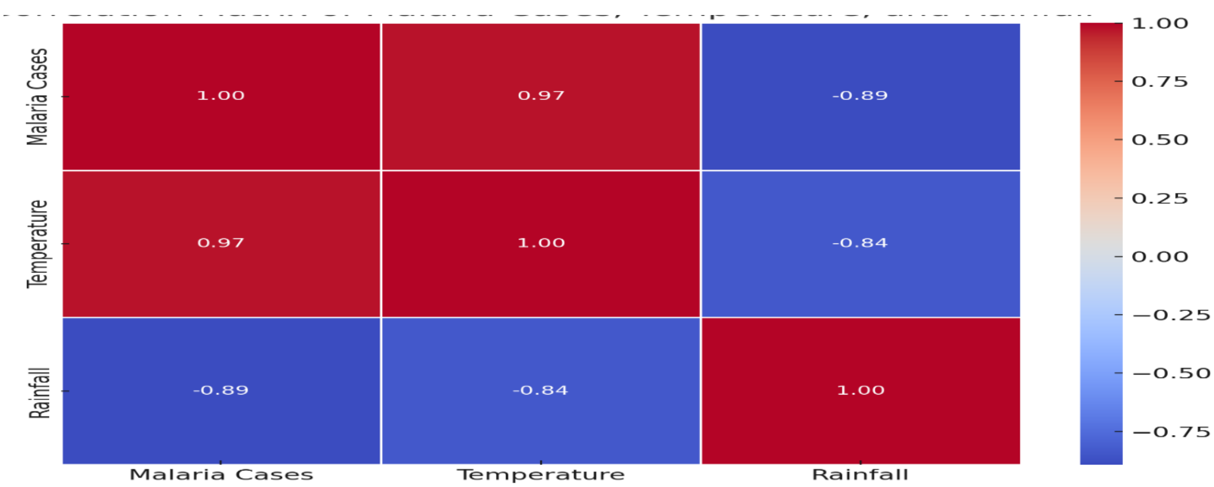

Figure 2 Correlation Matrix of Malaria Cases, Temperature and Rainfall

Source: Fieldwork, 2024

3.3 Regression Modeling of Malaria Cases, Temperatures and Rainfall

The results of the correlation analysis are further supported by the regression analysis (Fig. 3), which confirmed that rainfall and temperature can both predict the prevalence of malaria. Fig. 3's malaria-temperature regression line showed a positive slope, suggesting that even slight temperature increases significantly raise the incidence of malaria. While these findings aligned with those reported by Mustapha et al. (2021) and Adamu and Yau (2023), they hinted at the likelihood of higher temperatures accelerating not only the development of the *Anopheles* mosquito but also increasing transmission rates. It also reflected the responsiveness of malaria cases to changes in temperature and hence it is a major determinant of malaria dynamics in the study area. In contrast, the hypothesis of an inverse correlation between the variables was supported by the rainfall-malaria regression slope, which was negative. This backed up the argument that while mosquitoes can breed in areas with moderate rainfall, breeding grounds may be destroyed by heavy rainfall, which lowers vector densities and, in turn, transmission rates (Mordecai et al., 2020). This finding implied that, in contrast to times when there is an abundance of rainfall, the prevalence of malaria transmission may be highest during the transitional periods between the dry and wet seasons. Regression analysis thus highlights the need for climate-sensitive malaria control.

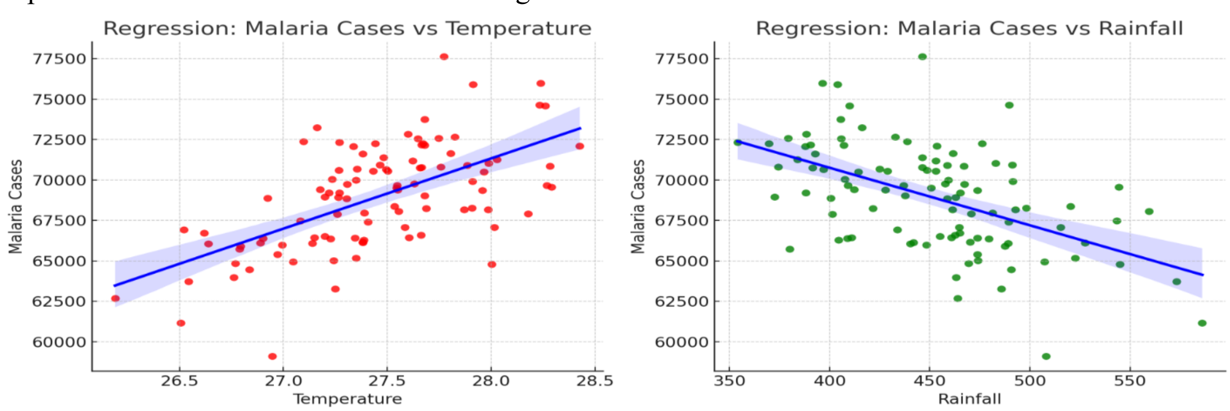

Figure 3 Regression Modeling of Malaria Cases, Temperature and Rainfall

Source: Fieldwork, 2024

4. Conclusion

The analyses demonstrated that, when all other factors are held constant, the risk of malaria in the study area is a function of temperature. This is due to the fact that the correlation analysis showed an inverse relationship between rainfall and malaria (r = -0.89), while temperature and malaria showed a strong positive association (r = 0.97). These results reaffirmed the necessity of climate-sensitive disease surveillance and intervention strategies and emphasized the significance of climate factors in malaria epidemiology.

5. References

[1] Abiodun, G.J., Witbooi, P.J., Okosun, K.O. and Maharaj, R. (2018). Exploring the Impact of Climate Variability on Malaria Transmission Using a Dynamic Mosquito-Human Malaria Model. *The Open Infectious Diseases Journal, 10*(1): 88 – 100. DOI: 10.2174/1874279301810010088

[2] Abubakar, S. and Yamusa, I.M. (2020). Community-Based Adaptation Strategies for Malaria Control in Yobe State, Nigeria. *Malaria Journal, 19*(1): 278 – 289.

[3] Adamu, A. A. and Bello, M. T. (2021). The socio-ecological drivers of malaria prevalence in the drylands: Evidence from Yobe State, Nigeria. Environmental Health Perspectives, 23(5), 403-412.

[4] Adamu, M. A., and Yau, I. S. (2023). Epidemiological trends in malaria incidences and climate dynamics: A cross-sectional analysis in Yobe State. Malaria Journal, 32(6), 67-79.

[5] Alonso, D., Bouma, M. J., and Pascual, M. (2022). Epidemic malaria and warmer temperatures in recent decades in an East African highland. Proceedings of the Royal Society B: Biological Sciences, 278(1712), 1661-1669.

[6] Ankamah, S., Nokoe, K.S. and Iddrisu, W.A. (2018). Modelling Trends of Climatic Variability and Malaria in Ghana Using Vector Autoregression. *Malaria Research and Treatment*, 1 – 11. DOI: https://doi.org/10.1155/2018/6124321

[7] Caminade, C., Kovats, S., Rocklov, J., Tompkins, A. M., Morse, A. P., Colón-González, F. J. and Lloyd, S. J. (2014). Impact of climate change on global malaria distribution. Proceedings of the National Academy of Sciences, 111(9), 3286-3291.

[8] Fatima, S.H., Zaidi, F., Rafiq, J., Bhandari, D., Ali, A. and Bi, P. (2025). Impact of temperatures on malaria incidence in vulnerable regions of Pakistan: empirical evidence and future projections. Epidemiological Infections, 31; 153:e33. DOI: 10.1017/S0950268825000111

[9] Ferrao, J.L., Niquisse, S., Mendes, J.M. and Painho, M. (2018). Mapping and Modelling Malaria Risk areas Using Climate, Socio-Demographic and Clinical Variables in Chimoio, Mozambique. *International Journal of Environmental Research in Public Health, 15*, 795, 1 – 15. DOI: 10.3390/ijerph15040795

[10] Gomes, E., Capinha, C., Rocha J. and Sousa, C. (2016) Mapping Risk of Malaria Transmission in Mainland Portugal Using a Mathematical Modelling Approach. *PLoS ONE 11*(11):e0164788. DOI:10.1371/journal.pone.0164788

[11] Hussien, H.H. (2020) Modeling the Influence of Climate Factors on Malaria Transmission Dynamics in North Kordofan State, Sudan. *Advances in Infectious Diseases, 10*, 189-199. DOI: https://doi.org/10.4236/aid.2020.105017

[12] Ibrahim, Y. A. and Musa, I. T. (2023). Geospatial analysis of malaria transmission in relation to climate change in the Sahel. Environmental Health Research, 17(2), 50-63.

[13] Khormi, H.M. and Kumar, L. (2016). Future Malaria Spatial Pattern Based on The Potential Global Warming Impact in South and Southeast Asia. *Geospatial Health, 11*:416, 290 – 298.

[14] Millogo, A.A., Yaméogo, L., Kassié, D., Ouédraogo, F.D.C., Guissou, C. Diabaté, A. (2023).Spatial Modeling of Malaria Prevalence Associated with Geographical Factors in Houet Province of Burkina Faso, West Africa. *Geo Journal, 88*: 1769 – 1783.
DOI: https://doi.org/10.1007/s10708-022-10692-7

[15] Megersa, D.M. and Luo, X.S. (2025). Effects of Climate Change on Malaria Risk to Human Health: A Review. *Atmosphere*, *16*(1), 71.
DOI: https://doi.org/10.3390/atmos16010071

[16] Mordecai, O.A., Shohaimi, S., Nallapan, M., Lamdi-Sarumoh, A.A. and Salari, N. (2020). Statistical Modelling of the Effects of Weather Factors on Malaria Occurrence in Abuja, Nigeria. *International Journal of Environmental Research and Public Health, 17*(10): 3474.
DOI: https://doi.org/10.3390/ijerph17103474

[17] Mustapha, A., Maina-Bukar, Y. and Kazeem, M.K. (2021). The Effects of Climate Change on Human Health in Damaturu. *International Journal of Geography and Regional Planning Research, 6*(2): 1 – 12.

[18] Nkiruka, A. J., Gething, P. W., Smith, D. L., Hay, S. I. and Nixon, M. S. (2021). Spatial Models of Malaria Transmission in Africa: Time for a Change. *Malaria Journal, 19*(1): 1 – 12.

[19] Nickolson, S.N., Tonnang, H. and Garba, U. (2018). Climate dynamics and malaria outbreaks inthe drylands of northern Nigeria: A modeling approach. African Journal of Health Sciences, 31(6), 233 – 245.

[20] Paaijmans, K. P., Imbahale, S. S., Thomas, M. B., and Takken, W. (2019). Relevant microclimate for determining the development rate of malaria mosquitoes and possible implications of climate change. Malaria Journal, 9(1), 1-9.