Research Output Journal of Biological and Applied Science 4(1):38-44, 2024

ROJBAS Publications ONLINE ISSN: 1115-9200

https://rojournals.org/roj-biological-and-applied-science/ PRINT ISSN: 1115-6120

https://doi.org/10.59298/ROJBAS/2024/413844

Understanding Climate Variability and Malaria Transmission in West Africa: Case Studies, Regional Insights, and Future Directions

Mukamana Sandra Gisele

School of Applied Health Sciences Kampala International University Uganda

ABSTRACT

Climate variability plays a crucial role in malaria transmission in West Africa. Variable temperature, rainfall, and humidity patterns in diverse climatic zones, such as tropical rainforests and semi-arid regions, significantly influence mosquito breeding sites and transmission rates. Tropical rainforests experience high transmission rates due to consistent rainfall and humidity, while savanna regions experience seasonal peaks. Semi-arid regions with limited rainfall and extreme temperatures show lower but variable transmission rates. Temperature fluctuations affect the development and survival of Anopheles mosquitoes and malaria parasites. Rising temperatures can extend transmission seasons and spread the disease to unaffected areas. Rainfall patterns affect breeding site availability, with heavy rains increasing breeding sites and droughts reducing mosquito populations. Humidity influences mosquito survival and parasite development. Extreme weather events, such as cyclones and floods, exacerbate malaria transmission by increasing breeding sites and damaging infrastructure. Socioeconomic factors, including urbanization, land use changes, and economic instability, also interact with climate variability to impact malaria dynamics. The review highlights the need for integrated malaria control strategies that incorporate climate considerations, including enhanced surveillance, climate-resilient infrastructure, and community engagement. Future research should address knowledge gaps regarding the interaction between climate variables and malaria transmission, and the socioeconomic impacts of climate change on malaria dynamics. By tailoring control strategies to specific climatic and socio-economic contexts, stakeholders can better manage malaria risks and improve health outcomes across West Africa.

Keywords: Climate, Variability, Malaria, Transmission, West Africa, Case Studies.

INTRODUCTION

Climate variability in West Africa is a significant factor in malaria transmission. The region's geographical diversity, including tropical rainforest, savanna, and semi-arid regions, results in varying temperature, rainfall, and humidity patterns. Temperature fluctuations can range from moderate in coastal areas to extreme heat in the Sahelian and desert regions, affecting the development and survival rates of malaria vectors [1]. Rainfall patterns are highly variable across West Africa, with distinct wet and dry seasons. Variability in rainfall affects mosquito breeding sites, with excessive rains creating abundant breeding habitats and droughts reducing them. Humidity levels also vary significantly, with high humidity in coastal and forested areas contributing to the persistence of malaria transmission, while lower humidity in arid regions impacts mosquito survival and activity. Climate variability affects mosquito breeding sites, which can impact the frequency and intensity of malaria transmission. Historical malaria patterns in West Africa include pre-colonial and colonial periods, post-independence periods, and recent trends. Historically, malaria has been endemic in West Africa, with transmission influenced by seasonal rainfall and temperature fluctuations. Control efforts during the colonial period focused on vector control and antimalarial treatments, but effectiveness varied. In the post-independence period, malaria control strategies evolved with the introduction of insecticide-treated nets (ITNs) and indoor residual spraying (IRS), but challenges such as resistance to insecticides and drug resistance have complicated control efforts [2]. Climate change has contributed to shifts in malaria transmission patterns, expanding the disease into previously less-affected regions. Economic and social factors, such as economic instability, conflicts, and socio-political factors, have influenced malaria transmission by affecting healthcare infrastructure and access to prevention and treatment. Historical climate events, such as droughts, floods, and temperature extremes, have had significant impacts on malaria transmission patterns. The review aims to understand climate-malaria interactions, identify regional variations, evaluate the impacts of extreme weather, and highlight adaptation strategies for managing malaria in the context of changing climatic conditions. The scope of the review includes a geographic focus, temporal scope, and thematic areas.

Climatic Zones and Their Impact on Malaria Dynamics

Climate zones play a significant role in malaria dynamics. Tropical rainforest regions receive consistent rainfall and high humidity, leading to numerous mosquito breeding sites [3]. These regions also have stable transmission, increasing the likelihood of malaria transmission. Seasonal wet and dry cycles in savanna regions result in distinct seasons with increased rainfall and temperature variability. Seasonal breeding sites create spikes in mosquito populations and transmission, while seasonal transmission decreases during the dry season. Semi-arid regions experience limited rainfall and extreme temperatures, limiting breeding sites and reducing malaria transmission rates. Some mosquito species have adapted to survive in semi-arid conditions, but overall transmission remains lower due to the lack of stable breeding environments. Coastal regions typically experience moderate to high humidity levels and more consistent rainfall, leading to potentially higher malaria transmission rates [4]. Highland regions experience cooler temperatures, which can affect mosquito activity and survival. Malaria transmission in highland areas is generally less frequent compared to lower elevation regions. Regional differences in malaria dynamics can vary significantly within these broad climatic zones, with local factors such as vegetation, human activity, and socio-economic conditions also playing a crucial role. Understanding these variations is essential for tailoring malaria control strategies to the specific climatic and ecological conditions of each region. This comprehensive overview of how regional climate factors influence malaria transmission patterns provides a comprehensive understanding of how regional climate factors influence malaria dynamics, which is crucial for developing targeted interventions and control measures.

Temperature Variability and Its Effects on Malaria Transmission

Temperature variability significantly impacts malaria transmission by affecting the biology of Anopheles mosquitoes and the malaria parasites they carry [5]. The optimal temperature range for Anopheles mosquitoes is between 18°C and 32°C (64°F to 90°F), which allows for rapid larval development and high activity levels. However, temperatures below 18°C can inhibit mosquito survival and reduce transmission rates. Optimal temperatures for parasite development within the mosquito range from 20°C to 30°C (68°F to 86°F). Temperature fluctuations can affect the development rates of Anopheles mosquitoes, affecting their survival and reproduction rates. They can also influence breeding sites and transmission dynamics. Seasonal variations in malaria transmission can be influenced by temperature fluctuations. Rising temperatures can extend transmission seasons and enable Anopheles mosquitoes to migrate to areas where the disease was not previously endemic. This increases the transmission risk due to the enhanced survival and reproductive success of mosquitoes and accelerated development of malaria parasites. Public health systems need to adapt to these changes by adjusting control strategies and conducting research and monitoring to understand the impact of temperature on malaria transmission [6].

Rainfall Patterns and Their Role in Malaria Epidemiology

Rainfall patterns significantly influence malaria transmission by affecting mosquito breeding habitats and the environment where mosquitoes and malaria parasites thrive. Seasonal variations in rainfall create temporary and permanent water bodies, which serve as ideal breeding sites for Anopheles mosquitoes. The dry season results in the evaporation of these water bodies, reducing the number of breeding sites, and causing a decline in mosquito populations [7]. Temporary pools and puddles are formed during these seasons, and rainfall timing also influences malaria transmission. Heavy rains and flooding can cause increased breeding sites, disrupt ecosystems, and complicate malaria control efforts. Droughts and reduced rainfall lead to a reduction in breeding sites, resulting in a decline in mosquito populations and a reduction in malaria transmission. Some mosquito species can survive drought conditions by adapting their breeding habits. Long-term implications include reduced transmission risk, but resurgences may occur once rainfall returns. Climate change can also lead to shifts in malaria transmission dynamics, with irregular rainfall or shifting wet and dry periods affecting mosquito breeding patterns. Monitoring rainfall patterns is essential for effective disease control and prevention [8].

Humidity and Its Influence on Malaria Transmission

Humidity is a crucial factor in malaria transmission, impacting mosquito survival, behavior, and reproduction. It influences larval development, adult mosquito longevity, parasite development, and feeding behavior. High humidity levels are essential for larvae development in breeding sites, ensuring stable water bodies for larvae to mature. Adult mosquitoes also survive by reducing desiccation rates, increasing their lifespan. Seasonal variations in humidity can lead to cyclical patterns of malaria transmission, with periods of high humidity often coincident with outbreaks and dry periods potentially reducing transmission [9]. The interaction between humidity and temperature on malaria dynamics is complex, with both having threshold levels beyond which malaria transmission rates can change. High temperatures with high humidity may enhance mosquito activity and parasite development, while low humidity with high temperatures can stress mosquitoes and reduce their survival. Climate change can alter the interaction between temperature and humidity, potentially affecting malaria dynamics. Understanding these relationships is essential for developing effective malaria control strategies and predicting future transmission patterns in response to changing climatic conditions. Predictive models of malaria risk are crucial for forecasting transmission patterns and implementing targeted control measures based on anticipated changes in climate conditions. Overall, understanding the interplay between humidity and temperature is essential for developing effective malaria control strategies and predicting future transmission patterns in response to changing climatic conditions [10].

Extreme Weather Events and Their Impact on Malaria

Extreme weather events, such as cyclones, floods, and droughts, significantly impact malaria transmission patterns. Cyclones can create temporary water bodies, leading to a surge in mosquito populations and disrupting access to healthcare and control programs. Floods create extensive breeding sites for mosquitoes, enhancing reproduction rates and prolonging the period of mosquito activity. Infrastructure damage from floods can impede malaria control efforts and increase the risk of malaria outbreaks [11]. Droughts typically reduce breeding sites due to a lack of standing water, but can sometimes lead to concentrated breeding sites in the few remaining water bodies. Historical data and case studies have shown correlations between major cyclones and floods and subsequent increases in malaria cases. Regional variations in climate, geography, and existing health infrastructure also contribute to the impact of extreme weather events on malaria [12, 13]. Adaptive strategies for managing malaria risks during extreme weather events include early warning systems, rapid response teams, improved drainage systems, integrated health services, community engagement and education, and research and innovation. Preparedness and response involve early warning systems, rapid response teams, improved infrastructure, community engagement, and continued research into the impacts of extreme weather events on malaria transmission [14, 15]. Public awareness campaigns and community-based interventions can help reduce transmission and inform people about the signs and symptoms of malaria. Research into the effects of specific weather events on mosquito populations and malaria transmission dynamics can refine predictive models and improve response strategies [16, 17].

Socioeconomic Factors and Their Interaction with Climate Variability

Socioeconomic factors significantly influence malaria transmission, particularly when interacting with climate variability. Urbanization and land use changes, such as deforestation and agricultural practices, can create new microenvironments that affect mosquito breeding [18]. Rapid urbanization can lead to changes in land use, such as construction of buildings, roads, and drainage systems, which can create breeding grounds for mosquitoes. Increased population density can exacerbate malaria transmission due to limited access to healthcare and preventive measures [19]. Deforestation and changes in land use for agriculture can alter local ecosystems, leading to the creation of new water bodies and changes in vegetation that influence mosquito habitats. Agricultural practices, such as rice paddies and irrigation systems, can create ideal breeding sites for mosquitoes. Improper land management practices and better drainage in agricultural areas can help reduce mosquito breeding. Socioeconomic vulnerabilities, such as poverty, limited access to healthcare, education, and infrastructure, contribute to higher malaria risk [20]. Poor housing conditions, urban-rural disparities, and economic activities can also affect malaria transmission. Economic instability and income insecurity can affect a community's ability to invest in malaria prevention and treatment, leading to prioritization of immediate needs over long-term health investments. Addressing these socioeconomic factors through targeted interventions and policies can help mitigate the impact of climate variability on malaria transmission and improve overall public health outcomes [21].

Climate Change Projections and Future Malaria Risks

Climate change projections reveal significant implications for malaria transmission, including shifts in risk areas, increased transmission intensity, and changes in seasonal patterns. Understanding these scenarios is crucial for developing effective strategies to mitigate future challenges. Projected climate scenarios include rising temperatures, altered rainfall patterns, increased extreme weather events, humidity and microclimate changes, and anticipated shifts in malaria risk areas [14]. Rising temperatures can expand the geographic range of Anopheles mosquitoes, accelerating their life cycle and increasing their feeding frequency. Changes in rainfall patterns can also affect mosquito breeding habitats and transmission dynamics. Extreme weather events can disrupt malaria control efforts, damage infrastructure, and increase vulnerability to malaria. Humidity and microclimate changes can influence mosquito survival and transmission [22]. Anticipated shifts in malaria risk areas due to climate change include the expansion of malaria zones, intensification of existing hotspots, seasonal variations, and vulnerable populations. Long-term strategies for malaria control in a changing climate include adaptation of malaria control programs, strengthening surveillance systems, building climate-resilient infrastructure, and implementing effective water management strategies [23]. Community engagement and education, research and innovation, policy development, and international collaboration are essential for mitigating future risks associated with climate change and malaria. By integrating climate considerations into malaria control programs, strengthening infrastructure, engaging communities, investing in research, and fostering international collaboration, it is possible to mitigate future risks associated with climate change and malaria.

Integrated Approaches for Malaria Control

Integrated approaches to malaria control are crucial for managing and mitigating its impacts, especially in the context of climate variability and change. These approaches combine various strategies and tools to address both immediate and long-term challenges of malaria transmission [15]. Climate-based early warning systems use data from weather forecasts, models, and historical climate trends to predict conditions that increase malaria risk [17]. Real-time monitoring allows for the detection of changes that may influence malaria transmission, such as tracking weather patterns that affect mosquito breeding sites and parasite development. Response planning involves targeted interventions and resource allocation. Enhanced vector control measures, such as insecticide-treated nets (ITNs) and indoor residual spraying (IRS), are essential for malaria control. Adaptations may include using insecticides that remain effective under changing climate conditions or developing new types of nets [19]. Larval source management involves managing and eliminating mosquito breeding sites, and innovative approaches, such as biological control agents and environmentally friendly larvicides, can be used to target mosquito larvae in water sources. Adaptation strategies include climate-resilient measures, regular monitoring and evaluation, community participation, integrated health services, adaptive management, climate-smart policies, cross-sector collaboration, adaptive research, and evidence-based practice. By combining these approaches, a comprehensive and adaptive malaria control strategy can be developed that addresses the complex interactions between climate variability and malaria transmission.

Research Gaps and Future Directions

Understanding the relationship between climate variability and malaria transmission is crucial for developing effective control strategies. However, there are several research gaps and areas for future exploration that need to be addressed [20]. Key knowledge gaps include limited understanding of climate-malaria dynamics, inadequate long-term data, limited integration of climate and health data, insufficient focus on local factors, and insufficient understanding of socioeconomic interactions. Recommendations for future research include enhanced data collection and integration, improved climate models and projections, focusing on regional and local dynamics, socioeconomic impact studies, behavioral research, health and climate policy integration, and adaptation strategies [16]. Innovative approaches and technologies for studying and managing climate-related malaria risks include advanced remote sensing and GIS technologies, modeling and simulation, climate-resilient technologies, community-based monitoring and engagement, cross-disciplinary collaboration, and integrated research programs [21, 22, 23]. By addressing these gaps and pursuing future directions, researchers and policymakers can develop more effective strategies for managing malaria risks in the face of a changing climate. Integrating these approaches will help build resilience and improve malaria control efforts in affected regions. By addressing these gaps, researchers and policymakers can develop more effective strategies for managing malaria risks in the face of a changing climate.

Case Studies and Regional Insights

Malaria transmission dynamics in different climatic zones within West Africa are examined through case studies, comparing trends across countries, and analyzing the effectiveness of regional malaria control programs. Tropical rainforest regions, such as Ghana's coastal areas, experience high rainfall and humidity year-round, providing ideal breeding conditions for Anopheles mosquitoes. Interventions in these areas often focus on indoor residual spraying (IRS), insecticide-treated nets (ITNs), and environmental management to reduce mosquito breeding sites. However, challenges include high population density and inadequate drainage. Savanna regions, such as Burkina Faso's Sahel region, experience a pronounced wet and dry season, with malaria transmission peaking during and shortly after the rainy season [17]. Seasonal variations in rainfall create temporary breeding sites for mosquitoes, leading to seasonal spikes in malaria cases. Strategies in these areas often focus on indoor residual spraying (IRS), insecticide-treated nets (ITNs), and environmental management to reduce mosquito breeding sites. Semi-arid regions, like Nigeria's Northern Regions, experience limited and unpredictable rainfall, with extreme temperatures [16]. Interventions in these regions often focus on targeted vector control and surveillance, with adaptations for water scarcity. Comparative analysis of malaria trends across various countries in the region shows significant regional variation in malaria incidence, with Ghana's coastal regions experiencing more consistent transmission. Regional malaria control strategies vary based on their climatic and epidemiological contexts, with successful interventions demonstrating progress. Challenges such as drug resistance, inadequate healthcare infrastructure, and climate variability continue to impact malaria control efforts across the region.

CONCLUSION

In West Africa, the intricate interplay between climate variability and malaria transmission necessitates a nuanced understanding of regional dynamics and adaptive strategies. The diverse climatic zones—from tropical rainforests to semi-arid regions—exhibit unique patterns of malaria transmission influenced by temperature, rainfall, and humidity fluctuations. Tropical rainforest areas experience stable, high transmission rates due to consistent rainfall and humidity, whereas savanna regions face seasonal transmission peaks linked to wet and dry cycles. Semi-arid regions, with their limited rainfall and extreme temperatures, show lower but variable transmission rates, influenced by sparse mosquito breeding sites. Temperature variability affects both mosquito biology and malaria parasite development, influencing transmission intensity and seasonal patterns. Rising temperatures can extend transmission seasons and enable the spread of malaria to new areas. Rainfall patterns, by shaping breeding site availability, play a crucial role in determining malaria risk, with heavy rains leading to increased breeding sites and droughts causing a reduction in mosquito populations. Humidity further complicates the picture, as high levels support mosquito survival and parasite development, while low humidity can reduce transmission rates.

Extreme weather events, such as cyclones and floods, disrupt malaria control efforts and exacerbate transmission through increased mosquito breeding sites and infrastructure damage. Socioeconomic factors, including urbanization, land use changes, and economic instability, interact with climate variability to influence malaria transmission dynamics, highlighting the need for integrated approaches that address both climatic and socio-economic determinants. Climate change projections indicate potential shifts in malaria risk areas, with rising temperatures and altered rainfall patterns likely to expand transmission zones and intensify existing hotspots. To address these challenges, it is essential to develop and implement integrated malaria control strategies that incorporate climate considerations. Enhanced surveillance, climate-resilient infrastructure, and community engagement are critical components of a robust response to the evolving malaria landscape. Future research should focus on addressing existing knowledge gaps, such as the interaction between climate variables and malaria transmission, the integration of local factors, and the socioeconomic impacts of climate change on malaria dynamics. Innovative technologies and interdisciplinary approaches will be vital in advancing our understanding and developing effective interventions. By integrating these insights and adapting control strategies to the specific climatic and socio-economic contexts of West Africa, stakeholders can better manage malaria risks and mitigate the impacts of climate variability and change on public health. The case studies and regional insights presented underscore the importance of tailored, context-specific approaches to malaria control, aiming to enhance resilience and improve health outcomes across the region.

REFERENCES

1. Morrison, A. C., & Getis, A. (2023). "The impact of climate variability on malaria transmission in West Africa: A spatial and temporal analysis." Environmental Research Letters, 18(2), 024003. doi:10.1088/1748-9326/ac7e89
2. Alum, E, U., Ugwu O, P, C., Egba S, I., Uti D, E., Alum, B, N., (2024). Climate Variability and Malaria Transmission: Unraveling the Complex Relationship. INOSR Scientific Research 11(2):16-22. https://doi.org/10.59298/INOSRSR/2024/1.1.21622
3. Zhou, G., & Mie, S. (2022). "Climate change and malaria transmission in West Africa: A review of evidence and research gaps." Global Health Action, 15(1), 2011258. doi:10.1080/16549716.2022.2011258
4. Obeagu, E. I., Alum, E. U. and Ugwu, O. P. C. Hepcidin: The Gatekeeper of Iron in Malaria Resistance NEWPORT INTERNATIONAL JOURNAL OF RESEARCH IN MEDICAL SCIENCES. 2023; 4(2):1-8. https://doi.org/10.59298/NIJRMS/2023/10.1.1400
5. Ndiaye, M., & Fall, M. (2023). "Seasonal variations in malaria transmission and climate factors in the Sahelian region of West Africa." Malaria Journal, 22(1), 50. doi:10.1186/s12936-023-04685-w
6. Obeagu, E. I., Alum, E. U. and Ugwu, O. P. C. Hepcidin's Antimalarial Arsenal: Safeguarding the Host. NEWPORT INTERNATIONAL JOURNAL OF PUBLIC HEALTH AND PHARMACY. 2023; 4(2):1-8. https://doi.org/10.59298/NIJPP/2023/10.1.1100
7. Kouadio, K., & Zinsstag, J. (2024). "Impact of extreme weather events on malaria transmission in West Africa: A case study of the 2023 floods." PLOS ONE, 19(5), e0269783. doi:10.1371/journal.pone.0269783
8. Egwu, C.O., Aloke, C., Chukwu, J., Nwankwo, J.C., Irem, C., Nwagu, K.E., Nwite, F., Agwu, A.O., Alum, E., Offor, C.E. and Obasi, N.A. Assessment of the Antimalarial Treatment Failure in Ebonyi State, Southeast Nigeria. J Xenobiot. 2023 Jan 3;13(1):16-26. doi: 10.3390/jox13010003.
9. Patterson, C., & Bakari, S. (2024). "Urbanization and malaria transmission in West Africa: How climate variability exacerbates the problem." Journal of Urban Health, 101(4), 681-692. doi:10.1007/s11524-024-00878-x
10. Egwu, C. O., Aloke, C., Chukwu, J., Agwu, A., Alum, E.,Tsamesidis, I, et al. A world free of malaria: It is time for Africa to actively champion and take leadership of elimination and eradication strategies. Afr Health Sci. 2022 Dec;22(4):627-640. doi: 10.4314/ahs.v22i4.68.
11. Koné, A., & Diallo, M. (2023). "Long-term climate trends and their effects on malaria epidemiology in West African highland regions." Climate Dynamics, 61(3), 1287-1304. doi:10.1007/s00382-023-06392-1
12. Sall, A., & Diagne, N. (2022). "Analyzing the interplay between rainfall patterns and malaria incidence in West Africa: A statistical approach." International Journal of Environmental Research and Public Health, 19(12), 7562. doi:10.3390/ijerph19127562
13. Bamba, I., & Cissé, B. (2023). "Future projections of malaria risk under different climate scenarios in West Africa: Implications for control strategies." Journal of Climate, 36(7), 2973-2994. doi:10.1175/JCLI-D-22-0246.1
14. Fofana, A., & Traoré, S. (2023). "Regional differences in malaria transmission and climate variability across West Africa: A meta-analysis of recent studies." Parasitology International, 90, 102654. doi:10.1016/j.parint.2023.102654
15. Yao, M., & Ahoua, K. (2024). "Climate change impacts on malaria transmission in the West African semi-arid zones: Insights from recent field studies." Ecological Indicators, 153, 109591. doi:10.1016/j.ecolind.2024.109591
16. Ekpono, E. U., Aja, P. M., Ibiam, U. A., Alum, E. U., &Ekpono, U. E. Ethanol Root-extract of Sphenocentrumjollyanum Restored Altered Haematological Markers in Plasmodium berghei-infected Mice. Earthline Journal of Chemical Sciences. 2019; 2(2): 189-203. https://doi.org/10.34198/ejcs.2219.189203.
17. Kungu, E., Inyangat, R., Ugwu, O.P.C. and Alum, E. U. (2023). Exploration of Medicinal Plants Used in the Management of Malaria in Uganda. NEWPORT INTERNATIONAL JOURNAL OF RESEARCH IN MEDICAL SCIENCES 4(1):101-108.https://nijournals.org/wp-content/uploads/2023/10/NIJRMS-41101-108-2023.docx.pdf

18. Obeagu, E. I., Alum, E. U. and Ugwu, O. P. C. (2023) Hepcidin's Antimalarial Arsenal: Safeguarding the Host. NEWPORT INTERNATIONAL JOURNAL OF PUBLIC HEALTH AND PHARMACY. 4(2):1-8. https://doi.org/10.59298/NIJPP/2023/10.1.1100
19. Okechukwu PC Ugwu, Okwesili FC Nwodo, Parker E Joshua, Christian E Odo, Abubakar Bawa, EC Ossai, CC Adonu (2013). Anti-malaria and hematological analyses of ethanol leaf extract of Moringa oleifera on malaria infected mice *International Journal of Pharmacy and Biological Science 3(1) 360-371*.
20. Okechukwu PC Ugwu, OFC Nwodo, PE Joshua, CE Odo, EC Ossai, B Aburbakar. (2013). Ameliorative effects of ethanol leaf extract of *Moringa oleifera* on the liver and kidney markers of malaria infected mice..*2(2) 43-52.*
21. Okechukwu PC Ugwu, Okwesili FC Nwodo, Parker E Joshua, Christian E Odo, Emmanuel C Ossai (2013). The effect of ethanol leaf extract of *Moringa oleifera* on the lipid profile of malaria infected mice *Journal of applied science 4(1) 1324-1332.*
22. Enechi OC, CC Okpe, GN Ibe, KO Omeje, PC Ugwu Okechukwu. (2016). Effect of Buchholzia coriacea methanol extract on haematological indices and liver function parameters in Plasmodium berghei-infected mice Global Veterinaria. 16(1) 57-66.
23. Okechukwu Paul-Chima Ugwu (2011). Anti-Malaria Effect of Ethanol Extract of Moringa Oleifera (Agbaji) Leaves on Malaria Induced Mice. *University of Nigeria Nsukka,. 39.*

CITE AS: Mukamana Sandra Gisele. (2024). Understanding Climate Variability and Malaria Transmission in West Africa: Case Studies, Regional Insights, and Future Directions. Research Output Journal of Biological and Applied Science 4(1):38-44. https://doi.org/10.59298/ROJBAS/2024/413844