EGYPTIAN ACADEMIC JOURNAL OF

BIOLOGICAL SCIENCES

E

MEDICAL ENTOMOLOGY & PARASITOLOGY

ISSN
2090-0783

WWW.EAJBS.EG.NET

Vol. 17 No. 1 (2025)

Citation: *Egypt. Acad. J. Biolog. Sci. (E-Medical Entom. & Parasitology Vol.17(1) pp **1-11**(2025)*
DOI: 10.21608/EAJBSE.2025.405464

Egypt. Acad. J. Biology. Sci., 17 (1):1 – 11 (2025)

Egyptian Academic Journal of Biological Sciences
E. Medical Entomology & Parasitology

ISSN: 2090–0783
www.eajbse.journals.ekb.eg

Malaria and Climate Variability: Exploring Variations in Rainfall, Temperature and Mortality on Mt. Elgon, Kenya (2011 To 2021)

Fredrick W. Wanyama *[1&2], Job Mulonga[2] Moses M. Ngeiywa[2], Judith Makwali[2], Calvince Anino [3], Makila Jacob[2], Mwongula Wanjala[2]

[1]Department of Clinical Medicine, University of Kabianga.
[2]Department of Biological Sciences, University of Eldoret, P. O. Box 112 5 – 30100, Eldoret.
[3]Department of Public Health, University of Kabianga.
***Email :** wanyamafw@gmail.com

ARTICLE INFO

Article History
Received:8/8/2024
Accepted:15/1/2025
Available:20/1/2025

Keywords:
Confirmed malaria, transmission, temperature, rainfall, Mt Elgon.

ABSTRACT

Background: Malaria is a preventable and treatable disease that is transmitted to humans through the bites of infected mosquitoes. Understanding the trends in the factors that contribute to malaria transmission is essential for the timely development of effective prevention and control strategies. **Objective**: This study analyzed the trends relationships between rainfall, temperature, and confirmed cases of malaria in Mt. Elgon Sub-County over the past decade (2011-2021). **Results**: The results showed a negative correlation between rainfall and confirmed malaria cases, with a correlation coefficient of -0.36. An increase in rainfall was associated with a decrease in confirmed malaria cases. Additionally, there was a moderate to strong positive correlation between average temperature and confirmed malaria cases, with a correlation coefficient of 0.16. An increase in temperature was associated with an increase in confirmed malaria cases. **Conclusion**: These results highlight the importance of understanding the role of environmental factors in the transmission of malaria and the potential impact of climate change on the disease transmission. Reduction in mean rainfall and an increase in mean temperature predicts' increased malaria and these can be used to mobilize resources to prevent and manage the disease. Further research is needed to better understand the complex relationships between these variables and to identify effective strategies for preventing and controlling malaria.

INTRODUCTION

According to the World Health Organization (WHO, 2020), there were approximately 229 million cases of malaria and 400,000 associated deaths globally in 2019. Over 70% of these deaths occurred in children under the age of 5 (WHO, 2022a). The majority of cases and deaths occur in Africa, with 90% of deaths occurring on the continent (WHO, 2022b). In Kenya, prior to 2011, there were an estimated 4 million cases of malaria reported annually, but this number declined to 2.8 million cases by 2013 due to intensive vector control efforts (WHO, 2022b). However, more than 70% of the population in Kenya still remains at risk of contracting the disease (Jagannathan & Kakuru, 2022).

Climate change is a significant factor in the transmission of vector-borne diseases such as malaria. Sutherst (2004) found that climate change, evidenced by changes in temperature and rainfall, can lead to gross adaptations in the ecology of disease agents, vector ecology, and host behaviors, resulting in variations in the modes and intensity of transmission.

Anoopkumar & Aneesh (2022) and Sutherst (2004) also found that mosquito-borne diseases, including malaria, are particularly sensitive to climatic conditions. Additionally, the widespread occurrence of vector-borne diseases, including malaria, in tropical Africa is due to a combination of favorable climate, efficient vectors, and increased host vulnerabilities (Kulkami *et al*., 2022).

The impact of climate change on the transmission of malaria is complex and varies across geographical contexts (Anoopkumar & Aneesh, 2022; Jagannathan & Kakuru, 2022). In general, the African highlands, defined as areas with an elevation higher than 1500m above sea level and characterized by low mean temperatures (generally below 20°C), are not conducive to stable transmission cycles of vector-borne diseases due to the effect of low temperatures on vector survivorship and proliferation as well as parasite development within the vectors (Nili *et al.*, 2022). However, with climate change, the increase in temperatures in these regions may lead to an increase in transmission, particularly if combined with other factors such as population growth and urbanization (Li & Managi, 2022).

One way in which climate change can impact the transmission of malaria is by altering the geographic range of vectors. Gao *et al.*, (2012) & Parihar *et al.*, (2022) found that changes in temperature and rainfall can lead to shifts in the distribution of vectors, potentially exposing new populations to the risk of infection. Additionally, Wang *et al*., (2022) found that changes in temperature and rainfall can affect the reproductive and biting rates of vectors, leading to increased transmission. Furthermore, Tian *et al.* (2022) found that climate change can shorten the pathogen incubation period, leading to an increase in the transmission of vector-borne diseases.

It is important to continue efforts to mitigate the impact of climate change and to implement effective control measures for vector-borne diseases such as malaria. The WHO (2022a) recommends a combination of measures, including the use of insecticide-treated bed nets, indoor residual spraying against the vectors, and artemisinin-based combination therapies, as well as efforts to improve access to diagnosis and treatment for the affected population. It is also important to continue research on the impact of climate change on the transmission of these diseases and to adapt control measures as needed.

MATERIALS AND METHODS

Research Design:

The research design for this study was a retrospective observational study. The design involved collecting and analysing data on climate indices and malaria cases from the past decade (2011-2021) in Mt. Elgon Sub-County, Kenya. The study aimed at examining the potential impacts of climate change on the transmission of malaria in the region.

Study Site:

The study was conducted in Mt. Elgon Sub-County, located in western Kenya. This predominantly rural sub-County covers an area of 956. and has a population of 194,767 people with a density of 204 people per km2 (Kenya National Bureau of Statistics, 2019). Located within the sub-County is Mt. Elgon, a massive solitary volcanic mountain located on the border of eastern Uganda and western Kenya at an altitude above 1500 m (National Geographic, 2019). The study site, Mt. Elgon Sub-County, is located at coordinates 00°55′59″N34°36′23″E (Google Maps, 2019).

Data Collection:

Climate data, consisting of mean monthly temperature and rainfall, was obtained from the Nzoia Sugar agronomy weather stations for 2011 – 2021period. The Land Surface Temperature (LST) was determined using LST sensors using the method described by Wan *et al*. (2004). The LST data was used to examine the relationship between surface moisture availability and evapo-transpiration as a function of latent heat flux. Malaria yearly

data was collected from the records department at Kapsokwony Sub-County Hospital for 2011 – 2021 period. The data included cases diagnosed by clinicians using both clinical signs and symptoms and laboratory microscopic confirmation of malaria parasites. The laboratory technologist prepared thin smears of blood on glass slides, which were stained using the Gemsa method and examined under an electric microscope to identify *Plasmodium* parasites. The number of parasites per millilitre of blood was calculated using a formula that takes into account the number of counted parasites and white blood cells per field on the slide. Patients with trophozoites were considered positive for malaria according to the World Health Organization (WHO, 2020). To ensure the reliability and validity of the data the investigators pretested the questionnaires and the data collection tools were calibrated at the onset of data collection each day.

Data Analysis:

The mean monthly temperature and rainfall data were plotted over time to identify any trends or patterns. The plots were created to visualize the relationships between malaria cases and the climate variables and to identify any apparent connections. Pearson correlation was conducted to quantify the strength and direction of the relationship between malaria cases and the climate data. The correlation coefficient ranged from -1 to 1, with a value close to 1 indicating a strong positive correlation, a value close to -1 indicating a strong negative correlation, and a value close to 0 indicating no correlation. Descriptive statistics were obtained to describe the average malaria, climate and temperature scores of the study area. The mean and standard deviation (SD) were obtained for each variable to provide information about the central tendency and variability of the data. By these, the researchers gained a comprehensive understanding of the relationship between malaria cases and the climate variables in the Mt. Elgon region of Kenya over the past decade (2011 to 2021). The results of this analysis provide insights into the impact of rainfall, temperature and other environmental factors on human malaria trends in the region.

RESULTS

Malaria Trends Over the Past Decade (2011-2021):

A total of 88,971 patients were tested for malaria over the past decade (2011-2021). The mean number of confirmed malaria cases per year was 8,019.9, with a standard deviation of 2,137.07 (Fig.1). The highest number of confirmed malaria cases was recorded in 2014 (10,959 cases) and the lowest in 2018 (5,926 cases). The number of patients tested for malaria varied over the years, with a mean of 19,435.4 and a standard deviation of 7,321.94. The highest number of patients tested was in 2019 (28,733) and the lowest in 2012 (21,360). There was a slight overall trend of decreasing confirmed malaria cases over the past decade, with a mean of 8,019.9 cases in 2011 and 5,545 cases in 2021. However, there was significant variation in the number of cases each year, with some years showing a substantial increase in cases (e.g. 2014 with 10,959 cases) and others showing a significant decrease (e.g. 2018 with 5,926 cases).

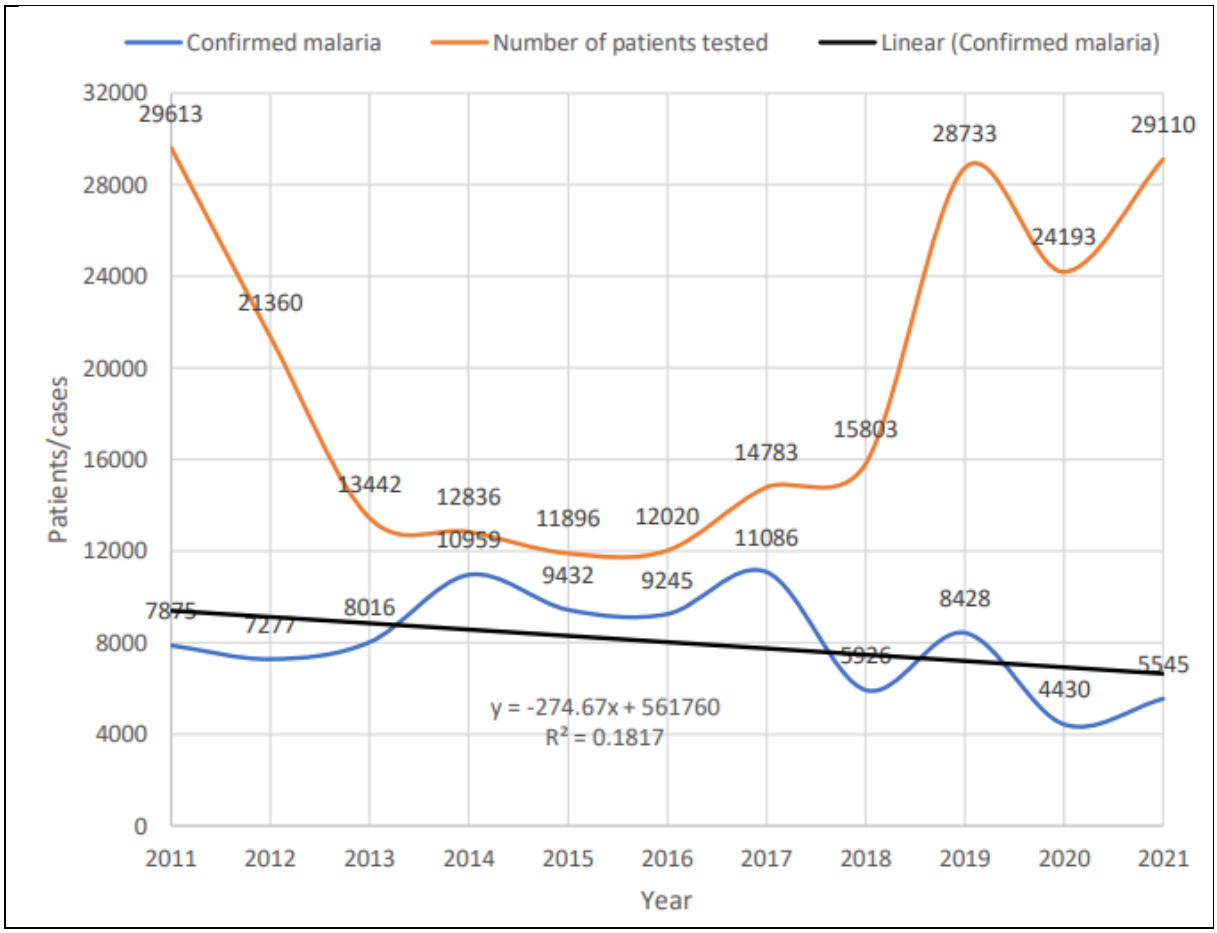

Fig. 1. Number of malaria cases over past decade (2011 to 2021)

Rainfall and Temperature Trends Over the Past Decade (2011 to 2021):

The results of the study show that there was significant variability in both rainfall and temperature over the past decade in Mt. Elgon Sub-County (Fig.2). The mean annual rainfall was 772.7mml with a standard deviation of 237mml. The mean maximum temperature was 28.5°C with a standard deviation of 0.42°C, while the mean minimum temperature was 14.1°C with a standard deviation of 0.81°C.

There was a noticeable increase in rainfall in 2015 and 2018, with values of 830mml in both years. The highest maximum temperature occurred in 2016 at 29.6°C, while the lowest minimum temperature occurred in 2021 at 13°C.

Fig. 2. Rainfall (A) and Temperature (B) trends **over the past decade** (2011-2021)

Relationship Between Rainfall, Temperature and Malaria Cases:

The results displayed in Figure 3A, reveal a negative correlation between rainfall and confirmed cases of malaria, as an augmentation in rainfall is associated with a corresponding reduction in confirmed malaria cases, as evidenced by the Pearson correlation value of -0.36. A clear trend can be observed in the data, where the lowest rainfall values correspond to the highest number of confirmed malaria cases, while the highest rainfall values correspond to the lowest number of confirmed malaria cases.

Moreover, Figure 3B, illustrates a trend that suggests a relationship between average temperature and confirmed cases of malaria, where increased temperature is correlated with reduced transmission of the disease. This is supported by a moderate Pearson correlation between average temperature and confirmed malaria cases, which is evidenced by a Pearson correlation coefficient of 0.16. This indicates that as average temperature increases, there is a concurrent decrease in the number of confirmed malaria cases.

Table 1. Pearson correlation coefficients between malaria cases, rainfall and temperature.

	Confirmed malaria	*Av. Rainfall*	*Av. Temp*
Confirmed malaria	1		
Av. Rainfall	-0.357923828	1	
Av. Temp	-0.16277697	0.285038	1

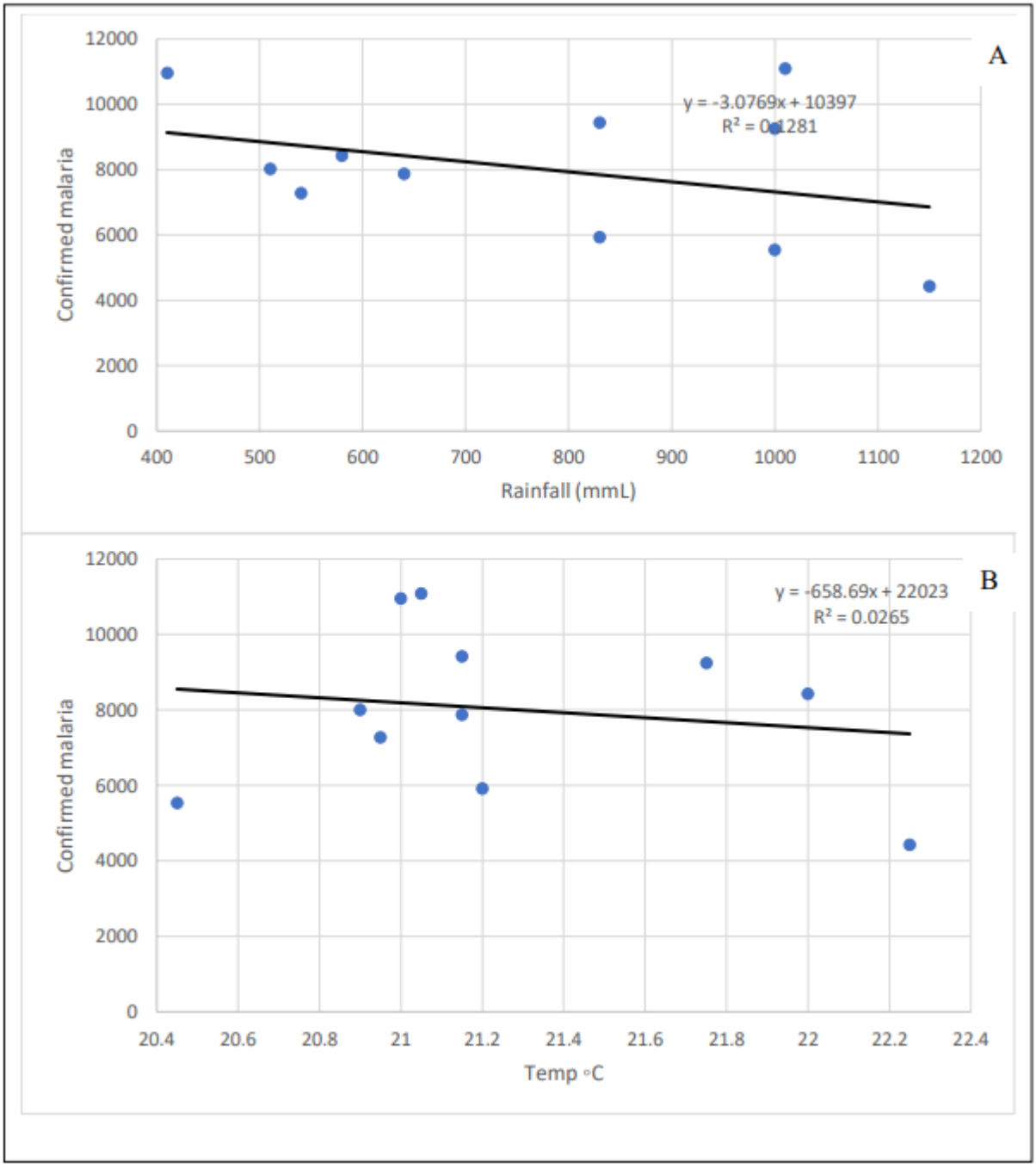

Fig. 3. Scatter plot of Rainfall (A) and Temperature (B) trends over past decade (2011-2021)

DISCUSSION

According to the World Health Organization, malaria is a preventable and treatable disease caused by parasites that are transmitted to people through the bites of infected mosquitoes (WHO, 2022a; WHO 2022b). Despite efforts to control and eliminate malaria, it remains a significant public health problem, particularly in sub-Saharan Africa. The data observed in the current study suggests that there has been a slight overall trend of decreasing in confirmed malaria cases in the past decade in the Mt Elgon region. This trend agrees with the WHO's global report on malaria, which found that the number of malaria cases and deaths has decreased globally over the past decade (WHO, 2015; WHO 2022c). This decrease is likely to be due to the implementation of effective control

````
````

measures such as the use of insecticide-treated bed nets, the distribution of anti-malarial medications, and the implementation of vector control measures such as the use of insecticides to control the mosquito population (Alelign & Dejene, 2016). However, the data also shows significant variation in the number of confirmed malaria cases each year, with some years showing a substantial increase in cases and others showing a significant decrease. This variation may be due to a number of factors, including changes in the mosquito population, differences in the effectiveness of control measures, and variations in the number of patients tested for malaria. These findings indicates that efforts to control and eliminate malaria have been successful in reducing the number of confirmed cases over the past decade, but there is still a significant burden of disease and ongoing challenges in the fight against malaria.

The results of the study showed that there was significant variability in both rainfall and temperature over the past decade in Mt. Elgon Sub-County. This variability is likely to be due to a combination of natural and human-induced factors, including changes in atmospheric and oceanic circulation patterns, as well as the influence of urbanization, land use changes, and greenhouse gas emissions (Diouf *et al.*, 2022; Thomson & Stanberry, 2022). The data shows that there was a noticeable increase in rainfall in 2015 and 2018, with values of 830mml in both years. This increase may have been influenced by factors such as the El Niño-Southern Oscillation (ENSO), which can affect the distribution of rainfall in different parts of the world (Banu *et al*., 2015). Other potential influences on rainfall patterns in Mt. Elgon Sub-County could include land use changes, such as the expansion of agricultural activities or deforestation, which can affect the amount of water available for evapotranspiration (Gumisiriza, 2014).The data also indicates that the highest maximum temperature occurred in 2016 at 29.6°C, while the lowest minimum temperature occurred in 2021 at 13°C. These variations in temperature may be influenced by a range of factors, including the intensity and duration of solar radiation, the presence of clouds and other atmospheric conditions, and the impact of urbanization and land use changes on the local microclimate (Kolokotroni & Giridharan, 2008; Silva *et al.*, 2018). Therefore, the data suggests that there may be multiple factors influencing the variability in rainfall and temperature in Mt. Elgon Sub-County, and further research is needed to better understand the impact of these factors on the local climate and its potential implications for the region.

The data further indicate that there is a strong relationship between rainfall and confirmed cases of malaria, with a negative correlation between the two variables. Specifically, the data shows that as rainfall increases, the number of confirmed malaria cases decreases. This negative correlation is supported by previous research, which has found that high levels of rainfall can help to reduce the transmission of malaria, potentially by washing away mosquito breeding sites (Khasnis & Nettleman, 2005; Ramasamy & Surendran, 2012). In the current study, we have explored the relationship between average temperature and confirmed cases of malaria and found a weak correlation between the two variables. This finding suggests that higher average temperature may play a role in reducing the transmission of malaria. However, it is important to note that correlation does not necessarily imply causation. Further research is required to confirm the causal relationship between temperature and malaria transmission. Additionally, the correlation coefficient of 0.16 indicates that there is only a weak relationship between the two variables, and other factors such as rainfall, mosquito vectors, and human behaviour also play a crucial role in determining the transmission of malaria. It is also worth mentioning that the relationship between temperature and

malaria transmission may not be linear and may vary in different regions and climates. Further studies that consider a broader range of temperature and geographical locations are necessary to gain a comprehensive understanding of the relationship between temperature and malaria transmission.

The findings of the study highlight the importance of understanding the role of environmental factors, such as rainfall and temperature, in the transmission of malaria. Further research is needed to better understand the complex relationships between these variables and the potential impact of climate change on malaria transmission. Additionally, the WHO (2022b) and Ototo *et al.* (2022) emphasizes the importance of a comprehensive and integrated approach to malaria prevention and control, including the use of effective prevention and control measures, the promotion of access to quality healthcare services, and the support of research and development efforts to improve our understanding of the disease and identify new ways to combat it.

Conclusion

In conclusion, this study analyzed the relationship between rainfall, temperature, and confirmed cases of malaria in Mt. Elgon Sub-County over the past decade. The results showed a negative correlation between rainfall and confirmed malaria cases, with an increase in rainfall associated with a decrease in confirmed malaria cases. Additionally, our findings suggest that higher average temperature may have a positive impact on reducing the transmission of malaria. However, caution should be exercised in interpreting these results as correlation does not necessarily imply causation. These results highlight the importance of understanding the role of environmental factors in the transmission of malaria, and the potential impact of climate change on disease transmission. Further research is needed to better understand the complex relationships between these variables and to identify effective strategies for preventing and controlling malaria.

Recommendations

Based on the results of this study, the researchers recommend the following measures for preventing and controlling malaria in Mt. Elgon Sub-County; Implementing vector control measures to reduce the population of malaria-carrying mosquitoes, such as the use of insecticides or the distribution of insecticide-treated bed nets. Providing access to preventive and treatment services for malaria, including the distribution of anti-malarial medications and the establishment of clinics or mobile health units in areas with high levels of malaria transmission. Investing in research and development efforts to improve our understanding of the relationships between environmental factors and malaria transmission, and to identify new ways to prevent and control the disease. Ultimately promoting education and awareness campaigns to increase knowledge of malaria prevention and control measures among community members, including the importance of proper use of bed nets and seeking medical treatment when symptoms arise.

Limitations of the Study:

The data analyzed in this study was based on confirmed cases of malaria, which may not fully capture the overall burden of disease in the region. Additionally, the data analyzed in this study only covered a decade (2011-2021) and may not accurately reflect long-term trends in malaria transmission. The study did not take into account other potential contributing factors to malaria transmission, such as population density, access to healthcare, or socioeconomic status and lastly the study did not analyze the impact of other environmental factors on malaria transmission, such as the presence and characteristics of mosquito breeding sites.

Declarations:

Ethical Approval: This research was approved by the Research Ethics Committee (REC) of the University of

Eastern Africa Baraton (UEAB/REC/ 17/03/2021) and the National Commission for Science, Technology and Innovation (NACOSTI) approval License No: NACOSTI/P/21/11369.

Competing interests: The author states that there are no competing interests to declare.

Author's Contributions: Fredrick W. Wanyama: Investigation, Visualization, original draft writing. Mulonga Job: Investigation and Visualization. Moses M. Ngeiywa: Methodology, review & editing. Judith Makwali: review & editing. Calvince Anino: Writing & editing. Jacob Makila: Writing review & editing. Mwongula Wanjala: Conceptualization, Writing—review & editing.

Funding: No funding was received.

Availability of Data and Materials: All datasets analysed and described during the present study are available from the corresponding author upon reasonable request.

Acknowledgments: We would like to express our deep appreciation and gratitude to the various individuals and organizations that enabled us to complete our study, "Rainfall, Temperature and Human Malaria Trends in Mt. Elgon Region, Kenya over the Past Decade (2011 to 2021)." Firstly, we are thankful for the invaluable contributions of the Medical Superintendent of Kapsokwony Sub County Hospital in Mt. Elgon, Dr. Achiehenza Shikuunzu, the Hospital Records Officer, Mrs. Rael Kirui, and Mr. Eric Kigen (the Agronomist), Nzoia Sugar Company Limited who provided us with Temperature and Rainfall data of Bungoma County, we are grateful. Their support in providing us with the data and resources necessary to conduct the study was invaluable. Furthermore, we are grateful to the National Commission for Science,Technology and Innovation for the Study license (NACOSTI/P/21/11369). Finally, we would like to thank the other individuals and organizations who helped us in any way in the course of this work. We are deeply thankful for the support and assistance we received and extend our sincerest gratitude to all.

REFERENCES

Alelign, A., & Dejene, T. (2016). Current status of malaria in Ethiopia: evaluation of the burden, factors for transmission and prevention methods. *Acta Parasitologica Globalis*, *7*(1), 1-6.

Anoopkumar, A. N., & Aneesh, E. M. (2022). A critical assessment of mosquito control and the influence of climate change on mosquito-borne disease epidemics. *Environment, Development and Sustainability*, *24*(6), 8900-8929.

Banu, S., Guo, Y., Hu, W., Dale, P., Mackenzie, J. S., Mengersen, K., & Tong, S. (2015). Impacts of El Niño southern oscillation and Indian Ocean dipole on dengue incidence in Bangladesh. *Scientific reports*, *5*(1), 16105.

Diouf, I., Adeola, A. M., Abiodun, G. J., Lennard, C., Shirinde, J. M., Yaka, P., ... & Gbobaniyi, E. O. (2022). Impact of future climate change on malaria in West Africa. *Theoretical and Applied Climatology*, 1-13.

Gao, H. W., Wang, L. P., Liang, S., Liu, Y. X., Tong, S. L., Wang, J. J., ... & Cao, W. C. (2012). Change in rainfall drives malaria re-emergence in Anhui Province, China.

Google Maps (2019). Mt. Elgon Sub-County, Kenya. Retrieved from https://www.google.com/maps/place/00%C2%B055'59%22N+34%C2%B036'23%22E/@00.9330534,34.6065382,12z/data=!4m5!3m4!1s0x0:0x0!8m2!3d0.9331944!4d34.6064167

Gumisiriza, T. L. (2014). Effects of Geomorphic processes and land use activities on slope stability in Mount Elgon Region, Eastern Uganda. *Unpublished Ph. D.*

Thesis). Nairobi, Kenya. Kenyatta University.

Jagannathan, P., & Kakuru, A. (2022). Malaria in 2022: Increasing challenges, cautious optimism. *Nature communications*, *13*(1), 2678.

Kenya National Bureau of Statistics (2019). 2019 population and housing census: Mt. Elgon Sub-County demographic profile. Retrieved from https://www.knbs.or.ke/ 2019 -kenya- population -and-housing -census-results/

Khasnis, A. A., & Nettleman, M. D. (2005). Global warming and infectious disease. *Archives of medical research*, *36*(6), 689-696.

Kolokotroni, M., & Giridharan, R. (2008). Urban heat island intensity in London: An investigation of the impact of physical characteristics on changes in outdoor air temperature during summer. *Solar energy*, *82*(11), 986-998.

Kulkarni, M. A., Duguay, C., & Ost, K. (2022). Charting the evidence for climate change impacts on the global spread of malaria and dengue and adaptive responses: a scoping review of reviews. *Globalization and health*, *18*(1), 1-18.

Li, C., & Managi, S. (2022). Global malaria infection risk from climate change. *Environmental Research*, *214*, 114028.

National Geographic (2019). Mt. Elgon. Retrieved from https://www. nationalgeographic.com/places/mt -elgon/

Nili, S., Asadgol, Z., Dalaei, H., Khanjani, N., Bakhtiari, B., & Jahani, Y. (2022). The effect of climate change on malaria transmission in the southeast of Iran. *International Journal of Biometeorology*, *66*(8), 1613-1626.

Ototo, E. N., Ogutu, J. O., Githeko, A., Said, M. Y., Kamau, L., Namanya, D., ... & Mutimba, S. (2022). Forecasting the Potential Effects of Climate Change on Malaria in the Lake Victoria Basin Using Regionalized Climate Projections. *Acta Parasitologica*, 1-29.

Parihar, R. S., Bal, P. K., Saini, A., Mishra, S. K., & Thapliyal, A. (2022). Potential future malaria transmission in Odisha due to climate change. *Scientific Reports*, *12*(1), 9048.

Ramasamy, R., & Surendran, S. N. (2012). Global climate change and its potential impact on disease transmission by salinity-tolerant mosquito vectors in coastal zones. *Frontiers in physiology*, *3*, 198.

Silva, J. S., da Silva, R. M., & Santos, C. A. G. (2018). Spatiotemporal impact of land use/land cover changes on urban heat islands: A case study of Paço do Lumiar, Brazil. *Building and Environment*, *136*, 279-292.

Sutherst, R. W. (2004). Global change and human vulnerability to vector-borne diseases. *Clinical microbiology reviews*, *17*(1), 136-173.

Thomson, M. C., & Stanberry, L. R. (2022). Climate Change and Vectorborne Diseases. *New England Journal of Medicine*, *387*(21), 1969-1978.

Tian, H., Li, N., Li, Y., Kraemer, M. U., Tan, H., Liu, Y., ... & Dye, C. (2022). Malaria elimination on Hainan Island despite climate change.*CommunicationsMedicine*, *2*(1), 12.

Wan, Z., Wang, P., & Li, X. (2004). Using MODIS land surface temperature and normalized difference vegetation index products for monitoring drought in the southern Great Plains, USA. *International journal of remote sensing*, *25*(1), 61-72.

Wang, Z., Liu, Y., Li, Y., Wang, G., Lourenço, J., Kraemer, M., ... & Tian, H. (2022). The relationship

between rising temperatures and malaria incidence in Hainan, China, from 1984 to 2010: a longitudinal cohort study. *The Lancet Planetary Health*, *6*(4), e350-e358.

World Health Organization. (2015). *Trends in maternal mortality: 1990-2015: estimates from WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division*. World Health Organization.

World Health Organization. (2020). WHO technical brief for countries preparing malaria funding requests for the Global Fund (2020–2022). World Health Organization.

World Health Organization. (2022). *WHO guidelines for malaria, 3 June 2022* (No. WHO/UCN/GMP/ 2022.01 Rev. 2). World Health Organization.

World Health Organization. (2022b). *World malaria report 2022*. World Health Organization.

World Health Organization. (2022c). *Atlas of African health statistics 2022: health situation analysis of the WHO African Region*. World Health Organization. Regional Office for Africa.