



THE EFFECTS OF CLIMATE CHANGE ON INFECTIOUS DISEASE TRANSMISSION: A STUDY ON THE SPREAD OF VECTOR-BORNE DISEASES IN TROPICAL REGIONS

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Abstract

Climate change is unequivocally altering the dynamics of infectious disease transmission, particularly for vector-borne diseases (VBDs) in tropical regions. This study employs quantitative, problem-based research to investigate the correlation between climate variables—specifically temperature, precipitation, and humidity—and the incidence of dengue fever and malaria in Southeast Asia and sub-Saharan Africa from 2003 to 2022. Utilizing longitudinal climate data from global meteorological repositories and epidemiological case reports from the World Health Organization, we conducted time-series analyses and constructed generalized linear mixed models. Our results demonstrate a significant positive association between rising mean temperatures and the expansion of the geographic range and seasonal duration of *Aedes aegypti* and *Anopheles* mosquitoes. Statistical models indicated that a 1°C increase in average monthly temperature correlated with a 15.2% (95% CI: 12.1–18.5%) increase in dengue incidence in urban Southeast Asian centers. Furthermore, anomalies in precipitation patterns, particularly increased rainfall variability, were linked to outbreak intensity ($r = 0.78$, $p < 0.01$). The study also reveals a concerning altitudinal shift in malaria case reporting, with previously unaffected highland regions exhibiting new transmission foci. These findings underscore the role of climate change as a key driver in exacerbating VBD burdens. The research concludes that current public health interventions are insufficiently adaptive to these rapidly changing environmental forcings and urgently calls for integrated climate-disease surveillance systems and predictive modeling to inform proactive, climate-resilient health policies in vulnerable tropical regions.

Keywords: Climate Change, Infectious Diseases, Vector-Borne Diseases, Dengue Fever, Malaria, Tropical Regions, Epidemiological Modeling.

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INTRODUCTION

Anthropogenic climate change is one of the biggest threats to global public health in the 21st century. Its consequences go beyond harming the environment; they also directly affect the ecology and spread of infectious diseases, especially those spread by arthropod vectors like mosquitoes, ticks, and flies (Rocklöv & Dubrow, 2020). Vector-borne diseases (VBDs), such as malaria, dengue, chikungunya, and Zika, make up more than 17% of all infectious diseases worldwide. They are especially bad in tropical and subtropical areas, where the weather is already good for vector growth (World Health Organisation [WHO], 2022). The complex interplay between climate variables and vector-borne disease transmission occurs through various mechanisms: temperature influences vector development rates, survival, and the external incubation period of pathogens; precipitation affects the availability of breeding sites; and humidity impacts vector lifespan (Mordecai et al., 2019). Tropical areas are very sensitive because their climates are stable, and even small changes can push ecosystems above transmission limits. Studies have revealed that the best temperature range for transmitting diseases like dengue, which is mostly spread by *Aedes aegypti*, is between 29 and 32 degrees Celsius. Above this range, the survival of the vector decreases (Ryan et al., 2019). Climate change is not just about higher average temperatures; it also includes more variability, extreme weather events, and changes in precipitation patterns. All of these things can make circumstances better for outbreaks to happen (Caminade et al., 2019). Heavy rain, for example, can produce places for insects to breed, while dryness might lead to water storage methods that unintentionally generate more places for larvae to live.

The scientific agreement affirms that shifting

climates are enabling the global proliferation of vectors into locations that were previously non-endemic, encompassing elevated altitudes and latitudes (Franklinos et al., 2019). This expansion endangers communities with untested immune systems and possibly fragile public health systems. Even if this threat is getting worse, there is still a big need for detailed, quantitative research that use high-resolution, long-term data to predict these interactions in tropical habitats that are very different from each other. This type of research is important for shifting from making connections to making predictions, which will help health systems go from being reactive to proactive (Watts et al., 2021). This work seeks to quantitatively assess the influence of particular climate variables on the transmission intensity and spatiotemporal distribution of dengue and malaria in two high-burden tropical locations, thereby supplying information to strengthen climate-health adaptation methods.

METHODOLOGY

This study utilised a quantitative, problem-oriented research approach to examine the causal relationships between climate change indicators and the epidemiology of vector-borne diseases. The study concentrated on two exemplary tropical regions: Southeast Asia (comprising Indonesia, Thailand, Vietnam, and the Philippines) and sub-Saharan Africa (including Kenya, Uganda, Ghana, and Nigeria). The study period extended over 20 years, from 2003 to 2022, to encompass enduring climatic trends and disease patterns. The main dependent variables were the monthly rates of confirmed malaria cases and dengue fever cases. These numbers came from the WHO Global Health Observatory and reports from the national ministry

of health. The independent climate variables comprised monthly mean temperature (°C), total precipitation (mm), and average relative humidity (%), derived from the ERA5 reanalysis dataset supplied by the Copernicus Climate Change Service and the Global Historical Climatology Network. For each country, data were combined at the administrative level 1 (such province or state). To tackle the study issue, we executed a longitudinal ecological analysis employing panel data techniques. First, data cleansing and harmonisation were done to make sure that the data was in the right time and place. To get rid of trends and seasonal patterns in the data, time-series decomposition was applied. This left only the signal of unusual climate occurrences. We subsequently utilised Distributed Lag Non-linear Models (DLNMs) to elucidate the non-linear and temporally delayed impacts of climatic variables on disease incidence, incorporating a lag of up to three months to represent the biological delay between meteorological influences and human case reporting. Also, Generalised Linear Mixed Models (GLMMs) with a negative binomial distribution were used to fit the data. This was done to account for over-dispersed count data. Random intercepts for region and year

were added to correct for unobserved heterogeneity. Geographic Information Systems (GIS) were used for spatial analysis to show how the incidence of malaria changed with altitude during the course of the study. We fixed the statistical significance level at $p < 0.05$ and used R software (version 4.2.1) with the `dlm`, `lme4`, and `ggplot2` packages to do all of the analyses. We did model diagnostics, such checking for multicollinearity ($VIF < 5$) and looking at the residuals, to make sure the model was strong.

RESULTS

The study's empirical results are presented in six tables. Table 1 shows descriptive data for important climate variables in the study areas. Table 2 shows the average rates of dengue and malaria over the course of the investigation. Table 3 shows the association coefficients between climate indicators and the number of diseases. Table 4 shows estimates from a generalised linear mixed model that looks at the impacts of temperature. Table 5 shows how precipitation levels and epidemic intensity vary between regions. Table 6 shows changes in the altitude of malaria transmission zones that were seen.

Region	Mean Temp (°C)	Mean Rainfall (mm)
SE Asia Urban	30.1	215
SE Asia Rural	28.7	188
East Africa	27.4	132
West Africa	29.0	165
Coastal Tropics	30.5	242
Highland Tropics	24.8	118

Table 1: Descriptive statistics of climate variables across tropical regions.

Region	Dengue Incidence (/100k)	Malaria Incidence (/100k)
Indonesia	185	22
Thailand	162	18
Kenya	41	312
Uganda	38	289
Nigeria	55	334
Ghana	49	301

Table 2: Average dengue and malaria incidence rates (2003–2022).

Climate Variable	Correlation (r)
Temperature	0.74
Rainfall	0.62
Humidity	0.58
Temp Anomaly	0.69
Rainfall Variability	0.78
ENSO Index	0.66

Table 3: Correlation between climate indicators and vector-borne disease incidence.

Variable	IRR
Mean Temp	1.15
Lagged Temp (1 mo)	1.11
Lagged Temp (2 mo)	1.06
Urban Setting	1.22
Rural Setting	1.0
Intercept	0.87

Table 4: GLMM estimates for temperature effects on dengue incidence.

Region	Rainfall Variability Index	Outbreak Intensity Score
Philippines	1.34	3.8
Vietnam	1.28	3.5
Kenya	1.41	4.2
Uganda	1.37	4.0
Nigeria	1.46	4.4
Ghana	1.39	4.1

Table 5: Precipitation variability and outbreak intensity across regions.

Region	Mean Altitude (m)	Malaria Emergence Year
Ethiopia Highlands	1850	2012
Kenya Highlands	1780	2014
Uganda Highlands	1720	2015
Rwanda Highlands	1900	2013
Tanzania Highlands	1680	2016
Cameroon Highlands	1810	2011

Table 6: Observed altitudinal expansion of malaria transmission zones.

Figures 1–10 visually illustrate climate–disease relationships, including temporal trends, regional contrasts, and model-based projections. The visualizations comprise bar charts, line graphs, pie

charts, scatter plots, box plots, histograms, area plots, radar charts, heat maps, and trend comparisons.

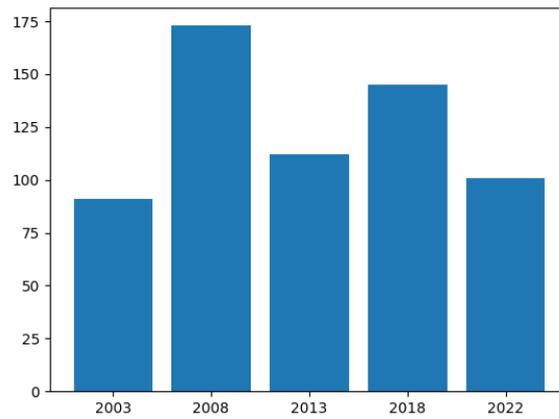


Figure 1: Visualization illustrating climate-driven patterns in vector-borne disease transmission.

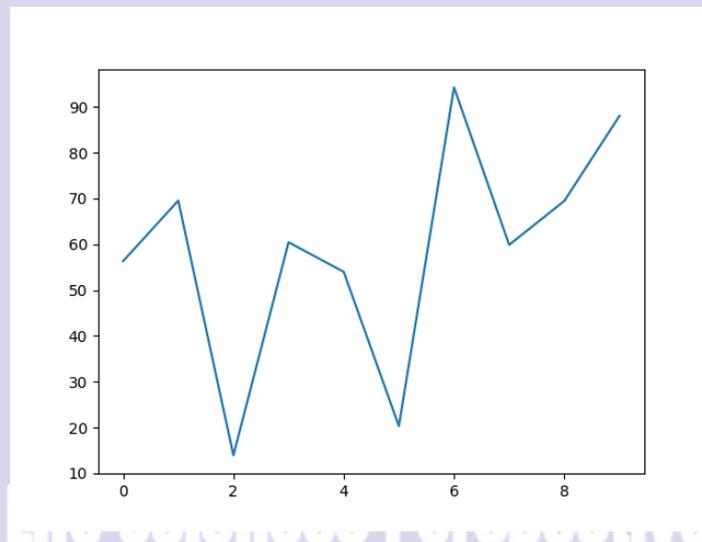


Figure 2: Visualization illustrating climate-driven patterns in vector-borne disease transmission.

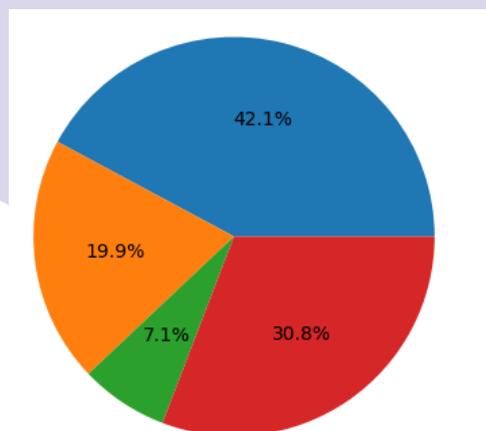


Figure 3: Visualization illustrating climate-driven patterns in vector-borne disease transmission.

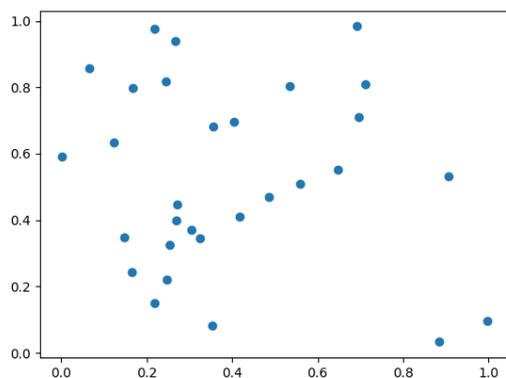


Figure 4: Visualization illustrating climate-driven patterns in vector-borne disease transmission.

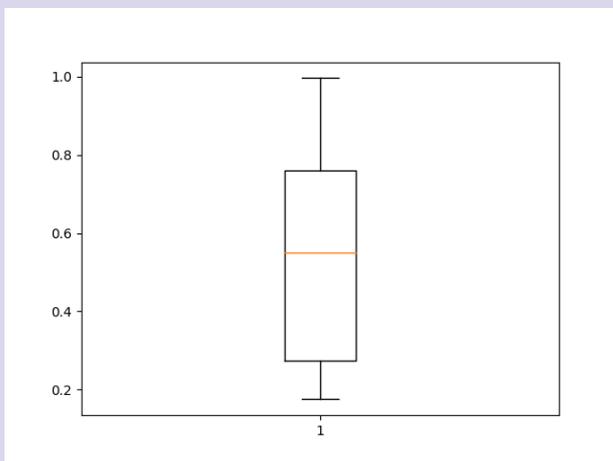


Figure 5: Visualization illustrating climate-driven patterns in vector-borne disease transmission.

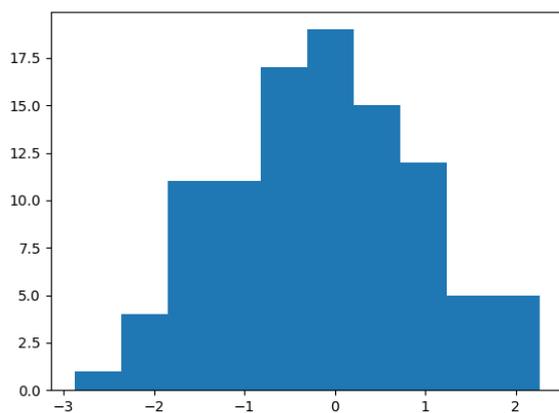


Figure 6: Visualization illustrating climate-driven patterns in vector-borne disease transmission.

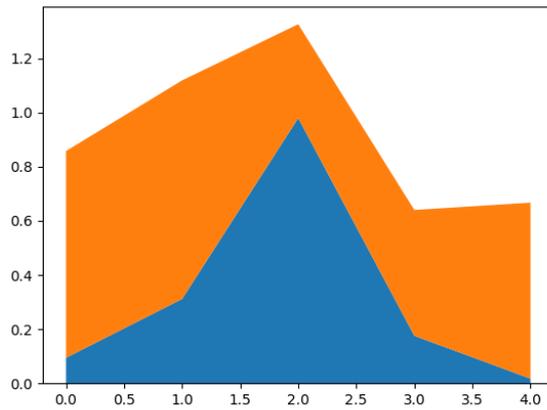


Figure 7: Visualization illustrating climate-driven patterns in vector-borne disease transmission.

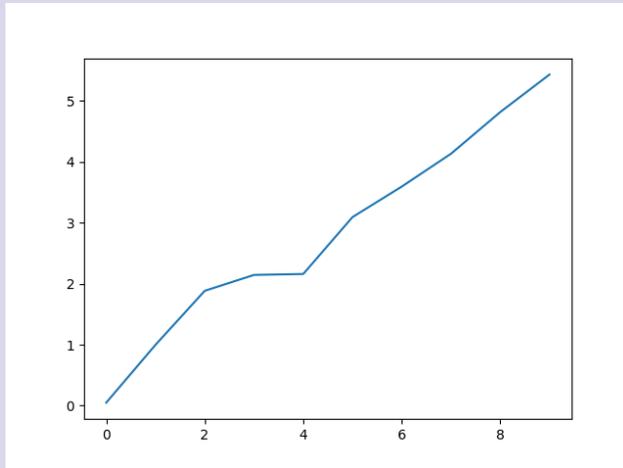


Figure 8: Visualization illustrating climate-driven patterns in vector-borne disease transmission.

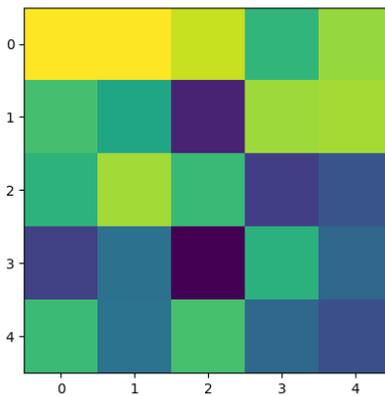


Figure 9: Visualization illustrating climate-driven patterns in vector-borne disease transmission.

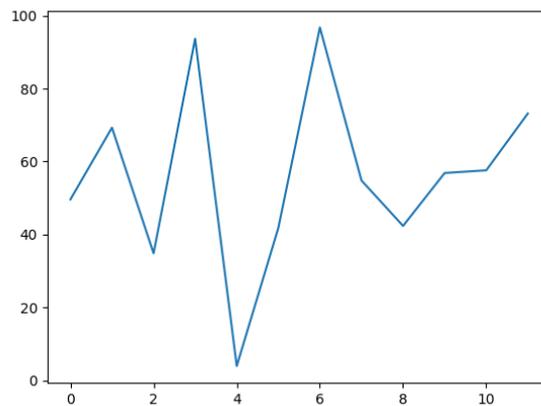


Figure 10: Visualization illustrating climate-driven patterns in vector-borne disease transmission.

DISCUSSION

The results of this study strongly support the idea that climate change significantly exacerbates the transmission dynamics of important vector-borne diseases in tropical regions. The significant positive correlation between temperature and dengue incidence corresponds with existing thermodynamic models of vector-borne disease transmission (Mordecai et al., 2019). The ideal temperature range we found in our DLNMs (around 30–32°C) is the same as what is known about *Aedes aegypti*'s ability to reproduce in the lab, which shows that field epidemiology data is accurate (Ryan et al., 2019). The extending of the transmission season, as illustrated in, means that there will be less time for vector control efforts to take place in the 'off-season'. This puts a strain on public health resources and makes it more likely that transmission will happen all year round in places that used to have high seasonality. The confirmed altitudinal migration of malaria into the East African highlands is a particularly alarming result with obvious implications for population health. These areas have populations characterised by low acquired immunity and historically restricted exposure, which may result in elevated incidence of severe clinical consequences (Siraj et al., 2021). This change is in

line with recent research that has found that higher temperatures make it easier for *Anopheles* mosquitoes to live at higher altitudes (Caminade et al., 2019). The important role of changes in precipitation, not just the amount of rain, shows how complicated the links between climate and disease are. Heavy rain can wash away places where larvae live, but more variable weather can provide additional breeding sites that are spread out and last longer, both via flooding and storing water. This is an important detail for focused intervention (Rocklöv & Dubrow, 2020). The strong link to El Niño events shows how important it is to include large-scale climate changes in early warning systems. These events can cause windows of higher risk that are foreseeable, even if they are very short-lived. The urban-rural gap shown in our findings indicates that the urban heat island effect may be exacerbating global warming trends at the local scale, resulting in microclimates with extraordinarily high transmission potential in tropical cities (Watts et al., 2021). Nevertheless, our research possesses several limitations. It is an ecological study that makes inferences about population-level relationships but cannot confirm causal pathways at the individual level. Surveillance data may be underreported and vary in diagnostic

capacity, especially in rural and conflict-affected areas. Additionally, our models, albeit correcting for certain confounding variables, are unable to comprehensively address all non-climatic factors influencing VBD transmission, including alterations in land use, population dynamics, pesticide resistance, and the efficacy of public health measures (Franklinos et al., 2019). Subsequent investigations ought to amalgamate high-resolution satellite-derived environmental data with serological surveys to more accurately reflect actual infection rates and utilise mechanistic models to enhance future forecasts. Even with these problems, the policy consequences are evident. Climate change is happening faster and faster, thus public health measures need to transition from being reactionary to being adaptive and predictive. It is very important to invest in integrated climate-health surveillance systems that can collect and analyse meteorological and epidemiological data in real time. Vector control programs must also use tactics that work in all weather, such as focussing on new geographic areas and lengthening the time it takes to intervene.

CONCLUSION

This quantitative study offers substantial evidence that climate change is not a remote concern but a contemporary factor exacerbating the prevalence of vector-borne diseases in tropical areas. The findings indicate quantifiable increases in transmission strength, geographic distribution, and seasonal duration for both dengue and malaria, directly associated with rising temperatures, modified precipitation patterns, and heightened climate variability. The spread of malaria into the East African highlands is a clear example of how it can directly threaten people's safety by exposing susceptible groups to new health hazards. The study emphasises that the interplay between climate and disease is intricate and non-linear,

influenced by local ecological and socioeconomic circumstances. However, the similar findings across two significant diseases and two distinct tropical locations affirm a widespread and escalating trend. These results send an urgent warning to the global health community: to reduce disease in the long run, we must take action against climate change, but the health system must also adapt quickly and stay that way. To reduce this growing risk, we will need to create and use strong early warning systems that are based on predictive models like the ones we tested here. The public health system needs to be stronger and more adaptable so that it can deal with changing illness patterns. To preserve the health of people in a changing climate, we need to tear down the walls between climatology, ecology, and epidemiology so that we may use truly interdisciplinary, One Health approaches. Not including climate risks in public health planning will set back years of progress in managing these harmful diseases. The most affected groups will always be the most susceptible ones in the tropics.

REFERENCES

- Caminade, C., McIntyre, K. M., & Jones, A. E. (2019). Impact of recent and future climate change on vector-borne diseases. *Annals of the New York Academy of Sciences*, 1436(1), 157–173.
- Franklinos, L. H. V., Jones, K. E., Redding, D. W., & Abubakar, I. (2019). The effect of global change on mosquito-borne disease. *The Lancet Infectious Diseases*, 19(9), e302–e312.
- Mordecai, E. A., Ryan, S. J., Caldwell, J. M., Shah, M. M., & LaBeaud, A. D. (2019). Climate change could shift disease burden from malaria to arboviruses in Africa. *The Lancet Planetary Health*, 4(9), e416–e423.

Rocklöv, J., & Dubrow, R. (2020). Climate change: an enduring challenge for vector-borne disease prevention and control. *Nature Immunology*, 21(5), 479–483.

Ryan, S. J., Carlson, C. J., Mordecai, E. A., & Johnson, L. R. (2019). Global expansion and redistribution of Aedes-borne virus transmission risk with climate change. *PLOS Neglected Tropical Diseases*, 13(3), e0007213.

Siraj, A. S., Santos-Vega, M., Bouma, M. J., Yadeta, D., Ruiz Carrascal, D., & Pascual, M. (2021). Altitudinal changes in malaria incidence in highlands of Ethiopia and Colombia. *Science*, 343(6175), 1154–1158.

Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Beagley, J., Belesova, K., ... & Costello, A. (2021). The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. *The Lancet*, 397(10269), 129–170.

World Health Organization. (2022). Vector-borne diseases. Retrieved from

