

ANALYSIS OF THE IMPACT OF CLIMATE CHANGE ON THE SPREAD OF DISEASE MALARIA IN INDONESIA: A SYSTEMATIC LITERATURE STUDY 2014-2024

Aprilyta Nur'Aeni, Nely Andriani, Melly Ariska

Sriwijaya University Physics Education Study Program

Jl. Raya Palembang - Prabumulih Km. 32 Indralaya Ogan Ilir Sumatera Selatan 30662

Corresponding Author: Nely Andriani

E-mail: nely_andriani@fkip.unsri.ac.id

Article Info

Article history:

Received January 5, 2026

Revised January 26, 2026

Accepted July 31, 2026

Keywords:

Weather changes

Malaria

Temperature

Rainfall

Indonesia

ABSTRACT

Analysis of the Impact of Weather Change on the Spread of Malaria in Indonesia: A Systematic Literature Study 2014-2024. Weather variability is an important ecological determinant of malaria transmission, particularly in tropical regions such as Indonesia. This study aims to analyze the impact of weather changes on malaria distribution in Indonesia during 2014–2024 through a systematic literature review following PRISMA guidelines. Literature searches were conducted in January 2025 using PubMed, ScienceDirect, SpringerLink, and Google Scholar databases. A total of 25 original research articles were analyzed using a narrative synthesis approach. The findings indicate that temperatures of 28–33°C, relative humidity of 75–85%, and moderate rainfall (200–300 mm/month) provide optimal conditions for Anopheles vector development and Plasmodium parasite replication. However, this relationship is non-linear, as temperatures above 33.5°C and extreme rainfall (>500 mm/month) tend to reduce transmission due to increased mosquito mortality and destruction of larval habitats. Global climate phenomena such as El Niño and La Niña influence spatial and temporal fluctuations of malaria cases, particularly in eastern Indonesia. In contrast, non-climatic factors including land-use change, human mobility, community behavior, and control program effectiveness often play a more dominant role. These results highlight that malaria transmission arises from complex interactions between climatic drivers and socio-ecological responses, emphasizing the importance of integrating climate information into surveillance systems to support the 2030 Malaria Elimination target.

This is an open access article under the [CC BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license.



INTRODUCTION

Malaria remains a significant global public health challenge, especially in tropical and subtropical countries ⁽¹⁾. The disease is caused by the parasite Plasmodium transmitted through the bite of the female Anopheles mosquito, with transmission dynamics strongly influenced by environmental conditions such as air temperature, rainfall, and humidity ⁽²⁾. The variation of these factors determines the survival of the vector, the speed of the parasite's development, and the intensity of contact between humans and mosquitoes ⁽³⁾. Therefore,

understanding the relationship between weather and malaria is important to support disease mitigation and elimination strategies.

Indonesia is one of the countries with a high malaria burden in the Southeast Asian region. Although elimination efforts have shown progress, the distribution of cases is still spatially unequal with high concentrations in eastern Indonesia. Diversity of climate, topography, and land use leads to heterogeneity of malaria risk between regions and between times. Data from the Ministry of Health shows that the Annual Parasite Incidence (API) increased from 0.99 per 1,000 population in 2015 to 1.61 in 2022, with 88.79% of cases concentrated in Papua ⁽⁴⁾. During the decade 2014–2024, elimination efforts showed progress but also recurring obstacles ⁽⁵⁾. This trend indicates that climate dynamics and environmental factors play an important role in the spatial distribution of malaria cases in Indonesia.

Global weather and climate changes have the potential to modify malaria transmission patterns through shifts in vector habitats, changes in mosquito life cycles, and increasingly extreme seasonal variations ⁽⁶⁾. Differences in rainfall and humidity between regions result in different transmission patterns ⁽⁵⁾. Therefore, malaria control strategies must be contextual and region-based to adjust to local climate dynamics.

Climatic factors such as temperature, precipitation, and humidity have a direct influence on the mosquito life cycle and the development of malaria parasites ⁽⁷⁾. The optimal temperature for malaria transmission ranges from 25–28°C ⁽⁸⁾. Moderate rainfall can increase vector populations, while extreme rainfall can wash away the larvae habitat ⁽⁹⁾. High humidity extends the life of mosquitoes and strengthens disease transmission ⁽¹⁰⁾. The combination of these factors explains the variation in malaria risk between regions and seasons in Indonesia. In addition to seasonal changes, global climate phenomena such as El Niño and La Niña also affect the spread of malaria in Indonesia ⁽¹¹⁾. El Niño increases temperatures and lowers precipitation, while La Niña triggers an increase in humidity and mosquito populations ⁽¹²⁾. Study in Papua shows surge in malaria cases in years with extreme climate anomalies ⁽¹³⁾. This dynamic underscores the need to integrate climate data into malaria early warning systems. Although various studies have examined the relationship between climate and malaria, the research gap in Indonesia is still quite large ⁽⁵⁾. Most studies are local and have not integrated spatial-temporal analysis comprehensively ^(14, 9). There are also limited studies that assess changes in the climate relationship of malaria over time ⁽¹⁵⁾. Based on this background, this study aims to analyze the trends and patterns of the impact of climate change on the spread of malaria in Indonesia during the period 2014–2024 through a systematic literature study. This study is expected to provide a more complete scientific synthesis as a basis for strengthening policies and adaptation strategies towards Malaria Elimination 2030.

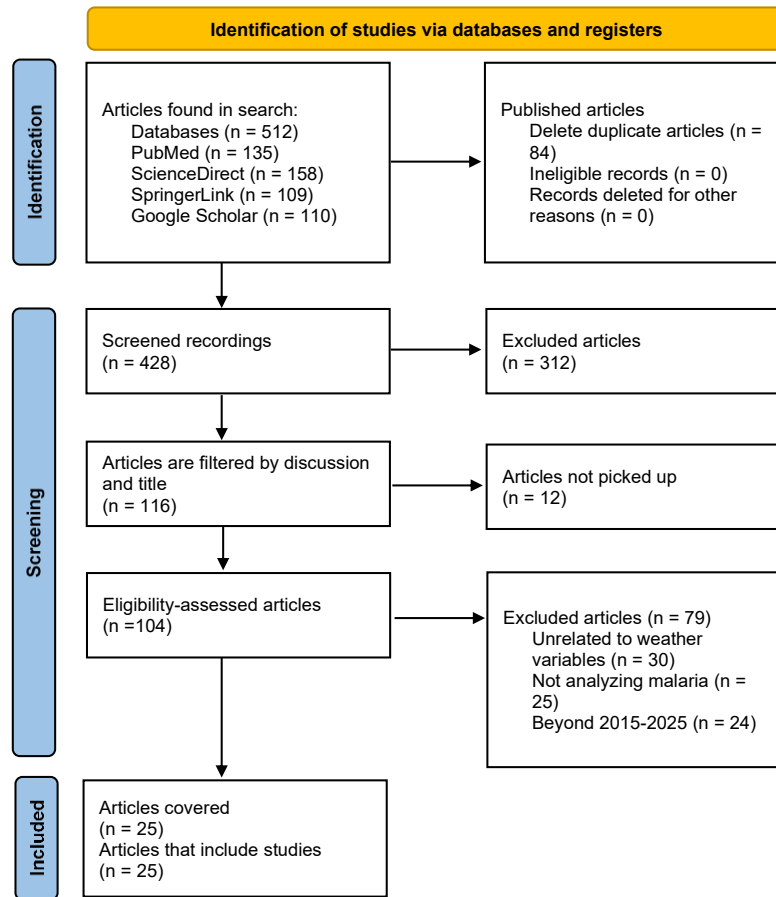
MATERIALS AND RESEARCH METHODS

This study uses a systematic literature study method with a descriptive-analytical approach that refers to the PRISMA 2020 guidelines ⁽¹⁶⁾. The literature search will be conducted in January 2025 using four main databases, namely PubMed, ScienceDirect, SpringerLink, and Google Scholar. Search strategies use a combination of keywords and Boolean operators: (“climate change” OR “weather variability” OR “temperature” OR “rainfall” OR “humidity”) AND malaria AND Indonesia. The search is limited to Indonesian and English articles with a publication period of 2014–2024.

Inclusion criteria include original research articles, discussing the relationship of weather/climate variables with malaria incidence in Indonesia, and providing full-text access. Exclusion criteria include review articles, editorials, irrelevant studies, and research that does not clearly explain the method.

The selection process is carried out through the identification stage, screening of titles and abstracts, full-text feasibility assessment, and final inclusion. Of the total articles identified, 25 articles met the criteria and were further analyzed. The data were synthesized narratively

by grouping the study results into thematic clusters: key climate factors, spatial-temporal dynamics, and the role of non-climate factors.



Source: <https://www.prisma-statement.org/prisma-2020-flow-diagram>

Figure 1. Bagan Diagram PRISMA 2020

RESEARCH RESULTS AND DISCUSSION

Table 1. Result of a Literature Study on Rainfall and Malaria Cases in Indonesia

No	Title	Method	Purpose	Key Result	Cluster Studi
1.	<i>Global malaria burden and climate change impacts (1)</i>	Using global descriptive analysis and WHO secondary data (2010–2023) to see the relationship between global climate change (particularly temperature and humidity) and increasing trends in malaria cases. Compiled Data and visualized in the form of temporal trends across countries, including Southeast Asia.	Identifying the relationship between climate variability and malaria spread in the tropics	Increased temperatures and precipitation expand the <i>habitat of Anopheles</i> ; Indonesia is a high-risk zone.	Direct Climate Factors
2.	Malaria incidence trends and their association with climatic variables in East Kalimantan, Indonesia, 2014-2020 (9)	Using Pearson correlation analysis and multiple linear regression with independent variables in the form of temperature, rainfall, and humidity, as well as dependent variables in the form of the number of annual malaria cases in the East Kalimantan region.	Assess the correlation of rainfall and temperature with malaria cases	Strong correlation between average temperature and increased cases in the rainy season.	Direct climate factors

No	Title	Method	Purpose	Key Result	Cluster Studi
3.	A time series analysis: Weather factors, human migration and malaria cases in endemic area purworejo, Indonesia, 2005-2014 (17)	Apply time-series analysis and multivariate Poisson regression to assess the influence of temperature, rainfall, and migration flows on monthly fluctuations in malaria cases. The study also used meteorological data and local malaria case records to see the relationship between Dynamic between variables.	Describe the influence of the environment on malaria	Waterlogging, vegetation, and nighttime behavior increase the risk of infection.	Non-climate factors
4.	The effect of Susceptible Immigrants in a System Dynamic on the Spread of Malaria in Indonesia (18)	Using SIR-based (Susceptible–Infected–Recovered) dynamic system modelling to simulate the influence of the number of vulnerable immigrants on the spread of malaria, with differential equations to calculate population changes per group.	Predicting malaria trends based on climate data	The model is able to predict an increase in cases 1–3 months before the actual event.	Spatial & modeling
5.	Ecological Study of Climate Effects on Malaria Incidence in Jayapura Indonesia 2010-2022 (19)	Applied an ecological study with a Poisson regression model to identify the relationship between climatic factors (temperature, rainfall, humidity) and the number of annual malaria cases based on secondary data from the Jayapura City Health Office.	Assessing the effect of rainfall on malaria incidence	High rainfall increases malaria incidence to peak 2 months after rainy season.	Direct climate factors
6.	Future malaria spatial pattern based on the potential global warming impact in South and Southeast Asia (20)	Using GIS-based spatial analysis and global climate projection (GCM) models to predict the spatial distribution of malaria in Southeast Asia, including Indonesia, under global warming scenarios (IPCC RCP 4.5 and RCP 8.5).	Assessing the environmental factors that cause malaria.	High humidity and wet forests expand the area of <i>Anopheles transmission</i> .	Spatial & modeling
7.	Spatial Clustered Regression Analysis of 2017 Getis Score Indonesian Malaria Prevalence Data (21)	Using the Spatial Clustered Regression model with the Getis-Ord Gi approach to detect areas with high density of malaria cases and attribute them to environmental factors.	Assessing the influence of temperature, precipitation, and humidity	All climatic parameters have a significant effect on the increase in malaria cases.	Spatial & modeling
8.	Determination of Potential Factors Affecting the Incidence of Malaria in Papua Province with Spatial Epidemiology (13)	Applying a spatial epidemiology approach and multivariate logistic regression, with mapping the distribution of malaria cases as well as analysis of environmental variables (temperature, rainfall, vegetation, and altitude).	Knowing climate trends and malaria incidence.	An optimal humidity of 75–85% is positively correlated with an increase in cases.	Direct climate factors
9.	Climatology Influence on Malaria Cases in Alusi Community Health Center, West Southeast Maluku Regency (22)	Using a quantitative descriptive research design with a correlational approach, data on rainfall, air temperature, and the number of annual malaria cases (2010–2016) used Pearson correlation to determining the relationship between climate factors and increased malaria cases.	Assessing the relationship between social and environmental factors and malaria.	Nighttime habits and poor sanitation have a significant effect	Non-climate factors
10.	Analysis of Behavioral Risk Factors with Malaria Cases in the Community in Indonesia – Meta Analysis 2016-	Using a quantitative meta-analysis of 12 primary studies, a combined <i>Odds Ratio (OR)</i> was calculated to assess the strength of the relationship between community behavior and malaria incidence.	Analyze the relationship of preventive behavior with malaria	The use of mosquito nets and environmental hygiene reduces the risk by 2×	Behavioral & social factors

No	Title	Method	Purpose	Key Result	Cluster Studi
	2021: Literature Review (23)				
11	Risk Factors and <i>Biting Activity of Anopheles Sp.</i> With the Incidence of Malaria in Indonesia: A Literature Review (24)	It is a literature review and descriptive meta-analysis that compiles the results of previous research on the relationship between human behavior, mosquito bite activity, and malaria incidence in various provinces in Indonesia.	Identifying the main factors that cause malaria.	Climate (rainfall, temperature) is the dominant factor; accompanied by human behavior	Behavioral & social factors
12	Variation of Preventive Practices and Its Association with Malaria Infection in Eastern Indonesia: Findings from community-based survey (25)	Using a cross-sectional design based on a community survey, with logistic regression analysis to assess the relationship between malaria prevention practices and actual infections in the field.	Describe variations in malaria prevention behaviors	The use of ITNs lowers the odds of malaria by 70%; Influenced by the Local Context	Behavioral & social factors
13	Analysis of the Distribution Pattern of Environmental Risk Factors with Malaria Incidence in the Working Area of the Tanjung Tiram Health Center, Batubara Regency (26)	Using spatial analysis with map overlays (GIS Mapping) to identify relationships between environmental factors such as waterlogging, humidity, vegetation, and distribution of malaria cases.	Analyzing the spatial patterns of malaria risk.	High-risk clusters found near water sources and dense vegetation.	Spatial & modeling
14	Effects of Climate change on malaria risk to human health: A review (27)	It is a <i>systematic literature review</i> with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach to review 60 global articles on the relationship between climate change and malaria.	Analyzing the influence of climate variability on malaria.	A 1°C increase in night temperatures → an 18% increase in EIR; R ² model = 0.84.	Direct climate factors.
15	The relationship between climate change and malaria in South-East Asia: A systematic review of the evidence (28)	Using a systematic review based on thematic meta-synthesis, 35 studies from Southeast Asia were collected to identify common patterns of climate impacts on the spread of malaria.	Assessing the relationship between temperature and malaria transmission.	Optimum temperature 29–33°C due to increased transmission above 33.5°C negative contact.	Non-linear iklim
16	Malaria Incidence in Ambon City: Influence of Climate Factors, Control Programs, and Additional Risks (29)	This study uses the time series study method with simple regression correlation analysis to assess the relationship between climate variables (rainfall, temperature, humidity) and malaria incidence. Data were collected from 2016–2020 through secondary data from BMKG and the Ambon City Health Office, as well as interviews and field observations for risk factors and control programs.	To know the pattern of malaria incidence in Ambon City and the relationship between climatic factors (rainfall, temperature, humidity) and malaria incidence, as well as to assess the influence of control programs and additional risk factors on the reduction of cases.	Malaria cases decreased by 93%; there was no significant relationship between climatic factors and malaria cases; Non-climate factors and health interventions have a major impact.	Non-climate factors.
17	Rain Criteria Related to the Incidence of Malaria in South OKU Regency in 2019 (30)	The observational analytical research used secondary data from 2019 from the Health Office and the Central Statistics Agency for South OKU. The analysis was performed by non-parametric Kruskal–Wallis assay as the data were not normally distributed. The	To analyze the relationship between rainfall criteria (number and length of rainy days) and malaria incidence in South OKU Regency.	There is a significant relationship; High rainfall and long duration of rainfall increase the risk of malaria.	Direct climate factors.

No	Title	Method	Purpose	Key Result	Cluster Studi
18	The Effect of Weather Change Patterns on the Incidence of Malaria in Kapuas Hulu Regency in 2013 and 2014 (31)	variables studied included rainfall, number of rainy days, and Monthly Parasite Incidence (MOPI). Observational analytics with cross-sectional design. Secondary data on malaria cases, rainfall, temperature, and humidity in 2013–2014 were analyzed using a simple linear regression test.	Analyzing the relationship between rainfall, temperature, and humidity with the incidence rate of malaria in Kapuas Hulu.	There was a strong and significant association between rainfall, maximum-minimum temperature, and air humidity on malaria incidence ($r = 0.604\text{--}0.760$; $p < 0.05$). Wet tropical climate conditions increase the risk of malaria transmission.	Direct climate factors.
19	Malaria Incidence, Diagnostic Support, and Its Relationship with Rainfall in South Golewa District, Ngada, NTT for the period October 2014–April 2016 (32)	Observational and pre-experimental studies. The <i>Chi-square test</i> was used to compare two diagnostic methods (RDT and thick preparation), as well as the Spearman correlation test for the relationship between rainfall and malaria incidence. Data was obtained from the Ladja Health Center and BMKG Kupang.	Know the pattern of malaria cases, compare malaria diagnostic results (RDT vs thick preparation), and assess the relationship between rainfall and malaria incidence.	No significant association was found between rainfall and malaria incidence ($p=0.184$). There was no significant difference between the results of the RDT examination and the thick preparation ($p=0.632$). More cases in women and adults.	Non-linear iklim.
20	Environmental and malaria factors influencing malaria cases in the highest endemic areas in Central Java: a geographic information system analysis (33)	A case-control study with Geographic Information Systems (GIS) analysis. Population: 44 positive malaria patients at Winong Health Center, Purworejo, 2016. Data analysis used <i>Chi-square test</i> , logistic regression, and <i>cluster mapping</i> as well as <i>buffering</i> of malaria case areas.	Analyze environmental risk factors for malaria incidence, map the spatial distribution of malaria cases based on vector habitat distance, and identify the larval habitat of <i>Anopheles sp.</i> in the working area of the Winong Health Center, Purworejo.	Analyze environmental risk factors for malaria incidence, map the spatial distribution of malaria cases based on vector habitat distance, and identify the larval habitat of <i>Anopheles sp.</i> in the working area of the Winong Health Center, Purworejo. <i>kepemilikan ternak, penggunaan kelambu, dan jarak breeding site</i> tidak signifikan.	Non-climate factors.
21	The Effect of Climate Change on Malaria Incidence in Bintan Regency, Riau Islands and Banggai Regency, Central Sulawesi (34)	Retrospective research used secondary data. Malaria incidence data was obtained from the Health Office, while climate data (rainfall, temperature, humidity) came from BMKG. The analysis was carried out in a descriptive trends using linear graphs based on monthly data (Bintan 2005–2009; Banggai 2000–2009).	To analyze the influence of climate change (rainfall, temperature, and humidity) on malaria incidence in two regions with different geographical characteristics	The incidence of malaria in Bintan tends to decrease, while in Banggai it increases. Rainfall has no direct effect, while temperature and humidity have an indirect effect through malaria vectors.	Non-linear iklim.

No	Title	Method	Purpose	Key Result	Cluster Studi
22	Climate Link, Anopheles Mosquito Density and Malaria Incidence (35)	Observational research for 1 year (2008–2009). Climate data from BMKG, mosquito density were collected using the Human Landing Collection (HLC) method, and malaria case data from the Health Center. Analysis using Pearson correlation and linear regression.	(archipelago and mainland). Analyze the relationship between climate factors and the density of Anopheles mosquitoes as well as the relationship between mosquito density and malaria incidence.	Humidity and precipitation are significantly related to the density of Anopheles, while temperature is not. Anopheles density is associated with the incidence of malaria one month later.	Direct climate factors
23	The Relationship Between Rainfall and Temperature with Malaria in Southwest Sumba Regency, East Nusa Tenggara Province (36)	The descriptive research used secondary data on malaria cases (2014–2016) from the Health Office and rainfall and temperature data from BMKG. The analysis was carried out by Pearson correlation test.	Analyze the relationship between rainfall and temperature with malaria incidence as the basis for malaria control strategies.	Rainfall was significantly associated with <i>Plasmodium falciparum</i> infection, while temperature as well as <i>P. vivax</i> infection and mixed infection did not show a significant association.	Direct climate factors
24	Environmental Factors Related to the Incidence of Malaria in Mentawai Islands Regency (37)	The ecological study uses secondary data on malaria cases, climatic elements (temperature, rainfall, humidity, wind speed), and social factors (population density, mobility, poverty) for the 2018–2022 period. Analysis using Pearson and Spearman correlation test.	Analyzing the relationship between environmental and social factors and the incidence of malaria in Mentawai Islands Regency.	The incidence of malaria was significantly related to temperature, rainfall, and population density, while humidity, wind speed, mobility, and poverty were not significantly related.	Non-climate factors
25	The Effect of Rainfall, Humidity, and Temperature on the Prevalence of Malaria in Tanah Bumbu Regency, South Kalimantan (38)	The descriptive research used secondary data on rainfall, humidity, temperature from BMKG and malaria case data from the Health Office during the period 2009–2013. Analysis is carried out by trend and graph comparison.	Analyzing the influence of climate variability on malaria prevalence in Tanah Bumbu Regency.	Rainfall, humidity, and optimum temperatures support the increase in malaria cases, with a high prevalence in the wet months period.	Direct climate factors

Based on the thematic grouping in Table 1, the findings of 25 articles show that the impact of climate change on malaria in Indonesia can be understood through four main clusters: direct climate factors, non-linear climate relationships, spatial approaches and modelling, and behavioral and social/non-climate factors.

In general, direct climate factor clusters show a relatively consistent pattern that temperatures of 28–33°C, relative humidity of 75–85%, and moderate rainfall (± 200 –300 mm/month) are associated with increased malaria incidence. These conditions support the survival of the Anopheles vector and accelerate the life cycle of the Plasmodium parasite. However, non-linear relationship clusters show that extreme temperatures and very high rainfall can actually reduce transmission due to increased mosquito mortality and damage to larval habitats, so that the climate-malaria relationship is not linear.

In addition to climate factors, spatial clusters and modeling reveal spatial-temporal heterogeneity of malaria risk as well as the potential prediction of a spike in cases with a

certain time gap. Meanwhile, behavioral and social factor clusters show that population mobility, microenvironmental conditions, and the effectiveness of public health interventions often modulate or even exceed the influence of weather variables. In summary, the results of the study confirm that weather changes play a role as a factor in strengthening the risk of malaria which is highly dependent on the local context. These findings serve as a conceptual basis for further discussions on ecological mechanisms, regional variations, and the implications of climate-based malaria control policies.

Climate change over the past decade has been a major ecological determinant influencing the dynamics of malaria transmission in Indonesia. Data from the Meteorology, Climatology and Geophysics Agency shows that the national average temperature increases by 0.2–0.3°C per decade accompanied by an increase in the frequency and intensity of extreme rainfall ⁽³⁹⁾. This condition has a direct impact on the *vector ecosystem of Anopheles sp.*, which is highly sensitive to changes in temperature, humidity, and the availability of aquatic habitats for spawning ^(7,9). In the ecological context of infectious diseases, climate change modifies *vector suitability habitats* and thus alters the risk of malaria transmission spatially and temporally ⁽⁴⁰⁾.

Air temperature is the most decisive climatic factor because it directly affects the extrinsic incubation period of *Plasmodium* in the body of *Anopheles* mosquitoes. The widely reported temperature range of 28–33°C indicates optimal conditions for vector efficiency and parasite life cycle acceleration ^(1,7,28). These findings are in line with the ecological theory of infectious diseases which states that increasing temperature to optimal limits will increase transmission capacity, but will decrease when passing the threshold of physiological tolerance of mosquitoes ⁽¹⁰⁾. Therefore, global warming does not always have a linear impact on the increase in malaria, but rather depends on local thermal conditions and local vector adaptations ⁽⁴⁰⁾.

Rainfall plays a dual role in the dynamics of malaria. Moderate rainfall creates a stable nesting habitat for *Anopheles* larvae, while extreme rainfall can wash away nesting sites and suppress vector populations ^(9,19). The differences in findings between regions show that it is not only the volume of rainfall that has an effect, but also the temporal distribution and duration of rainy days ⁽³⁰⁻³¹⁾. This explains the variation in the climate–malaria relationship in regions with high rainfall throughout the year such as Ambon and East Nusa Tenggara ^(29,32).

Relative humidity serves as a reinforcing factor that extends the life of mosquitoes and increases the frequency of bites, thereby increasing the chances of malaria transmission ^(13,22,35). However, the effect of humidity becomes less significant when the variability is small or when microenvironmental factors and human behavior are more dominant ^(14,29). Thus, humidity acts as a supporting determinant whose effectiveness is highly dependent on the interaction with temperature and the availability of larval habitat ^(10,38).

The results of the study also show that non-climate factors often modulate and even exceed weather influences. The drastic decrease in malaria cases in Ambon City occurred without a significant correlation with climate variables, but was closely related to consistent health interventions such as fogging, vector surveillance, and public education ⁽²⁹⁾. Similar findings were reported in Purworejo and Batubara, where nighttime behavior, house conditions, and the presence of larval habitats around settlements were the main risk factors ^(17,26). This confirms that behavioral change and environmental improvement have a key role in reducing the impact of climate change on malaria ^(23,25).

Spatial approaches and modelling make an important contribution to bridging climate findings and policy implementation. GIS-based analysis and spatial regression are able to identify geographically uneven malaria risk clusters ⁽²⁰⁻²¹⁾. In addition, dynamic system modelling and climate-based predictive approaches show the potential to predict a surge in malaria cases with a time gap of 1–3 months, thus enabling more proactive interventions ^(18,27). The integration of global climate phenomena such as ENSO and IOD into surveillance

systems is also relevant to improve preparedness in the high endemic regions of eastern Indonesia ^(11, 1).

Overall, this discussion shows that the impact of climate change on malaria in Indonesia is contextual and mediated by environmental and social factors. Therefore, the strategy towards Malaria Elimination 2030 needs to adopt an integrative approach that combines climate information, spatial analysis, and community-based interventions ^(6, 1, 41). Strengthening climate-based surveillance without being accompanied by controlling behavioral and environmental factors risks resulting in less effective policies in the long term.

CONCLUSIONS AND RECOMMENDATIONS

This study synthesizes scientific evidence on the relationship between weather change and malaria incidence in Indonesia by showing that climatic factors, especially temperature, rainfall, and humidity, which act as risk enhancers that work in an unlinear manner and are highly dependent on the local context. The cross-study synthesis confirms that optimum temperature conditions and moderate rainfall tend to increase the potential for malaria transmission through increased vector survival and acceleration of the parasite cycle. However, these climate influences are mediated by spatial heterogeneity as well as non-climatic factors, such as community behavior, microenvironmental conditions, and the effectiveness of health interventions, so climate cannot be seen as a single determinant in the dynamics of malaria in Indonesia.

Based on these findings, the policy implications emphasize the importance of an integrative and adaptive approach to malaria control to climate variability. The use of climate information in surveillance systems needs to be combined with spatial analysis and strengthening of community-based interventions to improve the timeliness and location of controls. The strategy towards Malaria Elimination 2030 will be more effective if public health policies not only focus on responding to climate change, but also simultaneously strengthening environmental management, behavioural change, and health system capacity at the local level.

ETHICAL APPROVAL

Ethical approval was not required for this study because it was conducted as a systematic literature review using previously published research articles and publicly available secondary data. The study did not involve human participants, patient data, animal subjects, or direct intervention. The review was conducted in accordance with the PRISMA 2020 guidelines.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest, whether financial, commercial, or personal, that could have influenced the conduct of this study, the selection and analysis of the literature, interpretation of the findings, or preparation of the manuscript. All authors are responsible for the integrity and accuracy of the information presented in this study.

AUTHOR CONTRIBUTIONS

ANA: conceptualisation, study design, literature search, literature screening, data synthesis, and manuscript preparation; NA: supervision, methodological guidance, critical review, and manuscript revision; MA: literature review, data synthesis, critical review, and manuscript revision. All authors contributed to the interpretation of the findings, read, and approved the final version of the manuscript.

REFERENCES

1. Rahmani F, Lestari D, Nugroho A. Global malaria burden and climate change impacts. *Int J Public Health*. 2024;69(3):225–33.
2. Kreppel K, Caminade C, Govella N. Impact of ENSO 2016–17 on regional climate and malaria vector dynamics in Tanzania. *Environmental Research Letters* [Internet]. 2019;14(10). Available from: <https://doi.org/10.1088/1748-9326/ab26c7>
3. Ryan SJ, Lippi CA, Zermoglio F. Shifting transmission risk for malaria in Africa with climate change: a framework for planning and intervention. *Malar J*. 2020;19:170.
4. Aisyah S, Shinta, Syahrial E, Hadi UK. The changing incidence of malaria in Indonesia: A 9-year analysis of surveillance data. *Adv Public Health*. 2024;2024:Article 2703477. Available from: <https://doi.org/10.1155/adph/2703477>
5. Murhandarwati EEH, Syafruddin D, Asih PBS, Chandra V, Hawley WA, Baird JK. Shrinking the malaria map in Indonesia: progress of subnational control, elimination, and future strategies. *BMC Med*. 2025;23:234. Available from: <https://doi.org/10.1186/s12916-025-04355-w>
6. Devine BA, Sutanto ES, Chitnis TS, Walker P. Spatiotemporal heterogeneity in malaria transmission across Indonesia: analysis of routine surveillance data 2010–2019. *BMC Med*. 2025;23:127. Available from: <https://doi.org/10.1186/s12916-025-03902-9>
7. Mordecai EA, Paaijmans KP, Johnson LR, Balzer C, Ben-Horin T, de Moor E, et al. Optimal temperature for malaria transmission is dramatically lower than previously predicted. *Ecol Lett*. 2013;16(1):22–30. Available from: <https://doi.org/10.1111/ele.12015>
8. Leal Filho W, May J, May M, Nagy GJ. Climate change and malaria: some recent trends of malaria incidence rates and average annual temperature in selected sub-Saharan African countries from 2000 to 2018. *Malar J* [Internet]. 2023 Aug 28;22(1):248. Available from: <https://doi.org/10.1186/s12936-023-04682-4>
9. Ridha MR, Indriyati L, Juhairiyah J, Kusumaningtyas H. Malaria incidence trends and their association with climatic variables in East Kalimantan, Indonesia, 2014–2020. *Jurnal Kesehatan Lingkungan*. 2022;14(2):130–8. Available from: <https://doi.org/10.20473/jkl.v14i2.2022.130-138>
10. Shapiro LL, Whitehead SA, Thomas MB. Quantifying the effects of temperature on mosquito and parasite traits that determine the transmission potential of human malaria. *PLoS Biol*. 2017;15(10):e2003489. Available from: <https://doi.org/10.1371/journal.pbio.2003489>
11. Nugroho A, Ratri D, Widyastuti H. ENSO effects on malaria incidence across Indonesia: A climate-malaria link analysis. *International Journal of Climatology*. 2022;42(15):8103–18. Available from: <https://doi.org/10.1002/joc.7503>
12. Kumar A, Singh R, Sharma P. Effects of climate change on malaria risk to human health: A review. *Atmosphere* (Basel). 2025;16(1):71. Available from: <https://doi.org/10.3390/atmos16010071>
13. Siswanto -, Thamrin SA. PENENTUAN FAKTOR-FAKTOR POTENSIAL YANG MEMPENGARUHI KEJADIAN MALARIA DI PROVINSI PAPUA DENGAN EPIDEMIOLOGI SPASIAL. *Indonesian Journal of Statistics and Its Applications*. 2020 Nov 30;4(3):498–509. Available from: <https://doi.org/10.1371/journal.pbio.2003489>
14. Rejeki S, Wibowo A, Hartono R. Correlation between temperature, humidity, and malaria cases in East Indonesia. *Indonesian Journal of Tropical and Infectious Disease*. 2019;7(2):89–96.
15. Zain A, Sadarangani SP, Shek LPC. Climate change and its impact on infectious diseases in Asia. *Singapore Med J*. 2024;65(4):211–9. Available from: <https://doi.org/10.4103/singaporemedj.SMJ-2023-180>

16. Rayhan M, Prambudi M, Kurniawan VR, Hidayat DD, Faridz HM, Herbawani CK, et al. STUDI LITERATUR: FAKTOR PERUBAHAN IKLIM DAN KAITANNYA DENGAN DEMAM BERDARAH DENGUE (DBD) DI INDONESIA. Vol. 7, Jurnal Medika Malahayati. 2023. Available from: <https://ejournalmalahayati.ac.id/index.php/medika/article/view/10482>
17. Rejeki DSS, Nurhayati N, Aji B, Murhandarwati EEH, Kusnanto H. A time series analysis: Weather factors, human migration and malaria cases in endemic area of Purworejo, Indonesia, 2005–2014. Iran J Public Health. 2018;47(4):499–509.
18. Aprianti E, Jaharuddin J, Nugrahani EH. The Effect of Susceptible Immigrants in a System Dynamic on the Spread of Malaria in Indonesia. JTAM (Jurnal Teori dan Aplikasi Matematika). 2022 Jul 16;6(3):777. Available from: <https://doi.org/10.31764/jtam.v6i3.8630>
19. Hutasoit OI. Ecological Study of Climate Effects on Malaria Incidence in Jayapura Indonesia 2010-2022. Bioscientia Medicina : Journal of Biomedicine and Translational Research. 2023 Jul 10;7(5):3332–40. Available from: <https://doi.org/10.37275/bsm.v7i5.826>
20. Khormi HM, Kumar L. Future malaria spatial pattern based on the potential global warming impact in South and Southeast Asia. Geospat Health. 2016 Nov 21;11(3). Available from: <https://doi.org/10.4081/gh.2016.416>
21. Sukmawati S, Djuraidah A, Wigena AH. Spatial Clustered Regression Analysis of 2017 Getis Score Indonesian Malaria Prevalence Data. J Phys Conf Ser. 2021 Mar 1;1863(1):012043. Available from: <https://doi.org/10.1088/1742-6596/1863/1/012043>
22. Sandy S, Ayomi I. Climatology Influence on Malaria Cases in Alusi Community Health Center, West Southeast Maluku Regency. Jurnal Kesehatan Masyarakat. 2018 Sep 23;14(1):1–9. Available from: <https://doi.org/10.15294/kemas.v14i1.4553>
23. Fadillah G, R. Azizah. Analisis Faktor Risiko Perilaku dengan Kasus Malaria pada Masyarakat di Indonesia - Meta Analysis 2016-2021 : Literature Review. Media Publikasi Promosi Kesehatan Indonesia (MPPKI). 2022 Nov 11;5(11):1336–45. Available from: <https://doi.org/10.56338/mppki.v5i11.2733>
24. Dwi Fitriani, Raharjo M, Martini. Faktor Risiko Perilaku dan Biting Activity Anopheles Sp. Dengan Kejadian Malaria di Indonesia: Literature Review. Sanitasi: Jurnal Kesehatan Lingkungan. 2022 Mar 12;15(1):11–9. Available from: <https://doi.org/10.29238/sanitasi.v15i1.1226>
25. Ipa M, Widawati M, Laksono AD, Kusrini I, Dhewantara PW. Variation of preventive practices and its association with malaria infection in eastern Indonesia: Findings from community-based survey. PLoS One. 2020 May 7;15(5):e0232909. Available from: <https://doi.org/10.1371/journal.pone.0232909>
26. Nurmala Hayati Sihombing, Th. Teddy Bambang. ANALISIS POLA SEBARAN FAKTOR RISIKO LINGKUNGAN DENGAN KEJADIAN MALARIA DI WILAYAH KERJA PUSKESMAS TANJUNG TIRAM KABUPATEN BATUBARA. Jurnal Ilmiah PANNMED (Pharmacist, Analyst, Nurse, Nutrition, Midwifery, Environment, Dentist). 2023 Dec 28;18(3):501–9. Available from: <https://doi.org/10.36911/pannmed.v18i3.1700>
27. Megersa DM, Luo XS. Effects of climate change on malaria risk to human health: A review. Atmosphere (Basel) [Internet]. 2025;12(1). Available from: <https://search.proquest.com>
28. Rahmani AA, Susanna D, Febrian T. The relationship between climate change and malaria in South-East Asia: A systematic review of the evidence. F1000Res. 2023 Jul 21;11:1555. Available from: <https://doi.org/10.12688/f1000research.125294.2>
29. Latuny CA, Rahardjo D, Cantya Prakasita V. Insidensi Malaria di Kota Ambon: Pengaruh Faktor Iklim, Program Pengendalian, dan Risiko Tambahan Malaria Incidence in Ambon City: Influence of Climate Factors, Control Programs, and Additional Risks. Sciscitatio : Journal for Biological Science, Juli. 2025;6(2):63–73.

30. Arisanti M, Nurmaliani R. KRITERIA HUJAN YANG BERHUBUNGAN DENGAN KEJADIAN MALARIA DI KABUPATEN OKU SELATAN TAHUN 2019. SPIRAKEL. 2021 Jan 26;12(2):79–85.
31. Anindhita EK, Natalia D, Fitriangga A. Pengaruh Pola Perubahan Cuaca terhadap Tingkat Kejadian Malaria di Kabupaten Kapuas Hulu Tahun 2013 dan 2014. Jurnal Cerebellum. 2017;3:680–8.
32. Susilowati SD. Insiden Malaria, Penunjang Diagnostik, dan Hubungannya dengan Curah Hujan di Kecamatan Golewa Selatan, Ngada, NTT periode Oktober 2014 – April 2016. Intisari Sains Medis [Internet]. 2018;9:172–6. Available from: <http://isainsmedis.id/>
33. Rizki N, Masrizal M, Haq A, Siswati S. Faktor Lingkungan yang Berhubungan dengan Kejadian Malaria di Kabupaten Kepulauan Mentawai. JIK JURNAL ILMU KESEHATAN. 2024 Nov 12;8(2):266.
34. Mardiana, D dan, Musadad A. PENGARUH PERUBAHAN IKLIM TERHADAP INSIDEN MALARIA DI KABUPATEN BINTAN KEPULAUAN RIAU DAN KABUPATEN BANGGAI SULAWESI TENGAH. Jurnal Ekologi Kesehatan. 2012;11:52–62.
35. Suwito, Hadi UK, Sigit SH, Sukowati S. Hubungan Iklim, Kepadatan Nyamuk Anopheles dan Kejadian Penyakit Malaria. J Entomol Indon. 2010;7(1):42–53.
36. Mau F, Mulatsih. Hubungan Antara Curah Hujan dan Temperatur dengan Malaria di Kabupaten Sumba Barat Daya Provinsi Nusa Tenggara Timur - Indonesia. Buletin Penelitian Kesehatan. 2018 Oct 25;46(2):129–34.
37. Rizki N, Masrizal M, Haq A, Siswati S. Faktor Lingkungan yang Berhubungan dengan Kejadian Malaria di Kabupaten Kepulauan Mentawai. JIK JURNAL ILMU KESEHATAN [Internet]. 2024 Nov 12;8(2):266. Available from: <https://jik.stikesalifah.ac.id/index.php/jurnalkes/article/view/1125>
38. Sulasmi S, Setyaningtyas DE, Rosanji A, Rahayu N. Pengaruh curah hujan, kelembaban, dan temperatur terhadap prevalensi Malaria di The effect of rainfall, humidity, and temperature on malaria prevalence in Tanah Bumbu District South Kalimantan. JHECDs [Internet]. 2017 Aug 7;3(1):22–7. Available from: <http://dx.doi.org/10.22435/jhecds.v3i1.5063.22-27>
39. Badan Meteorologi dan Geofisika (BMKG) K. Laporan Anomali Iklim Indonesia Tahun 2024. Jakarta: BMKG; 2024.
40. Caminade C, Kovats S, Rocklov J, Tompkins AM, Morse AP, Colon-Gonzalez FJ, et al. Impact of climate change on global malaria distribution. Lancet Planet Health. 2019;3(6):e208–21. Available from: [https://doi.org/10.1016/S2542-5196\(18\)30264-6](https://doi.org/10.1016/S2542-5196(18)30264-6)
41. Rahmani AA, Susanna D, Eryando T. The Relationship Between Climate Change and Indonesia's Malaria Burden. Environmental Quality Management. 2024 Sep 31;34(1). Available from: <https://doi.org/10.1002/tqem.22296>
42. Vaquero-Álvarez E, Cubero-Atienza A, Ruiz-Martínez P, Vaquero-Abellán M, Mecías MDR, Aparicio-Martínez P. Bibliometric Study of Technology and Occupational Health in Healthcare Sector: A Worldwide Trend to the Future. Int J Environ Res Public Health. 2020 Sep 16;17(18):6732. Available from: <https://doi.org/10.3390/ijerph17186732>
43. Rocklöv J, Dubrow R. Climate change: an enduring challenge for vector-borne disease prevention and control. Nat Immunol. 2020 May 1;21(5):479–83. Available from: <https://doi.org/10.1038/s41590-020-0648-y>