Literature Review: Impact Of Temperature And Rainfall On Incident Malaria

Ladjumadil Ahmad Tiu¹, Waode Elfianti Wahid¹, Waode Yuli Andriani¹, Mirnawati¹, Ramadhan Tosepu¹*

¹Program Studi Kesehatan Masyarakat, Universitas Halu Oleo, Kendari, Indonesia
*Corresponding author Ramadhan Tosepu
Department of Environmental Health, Faculty of Public Health, Universitas Halu Oleo, Kendari, Indonesia.

Abstract: Malaria is a dangerous infectious disease that is transmitted through the bite of a female Anopheles mosquito. Malaria transmission is closely related to climatic conditions including temperature and rainfall. This article aims to review the impact of temperature and rainfall on the incidence of malaria. The method of this article is a systematic review. The search strategy was developed using the Pubmed, Google, and Google Scholar databases through the combination, terms and keywords "Temperature and malaria" and "Rainfall and malaria". The results obtained 14 articles that were reviewed. It can be conclude that high temperature and rainfall have an effect on the increase in malaria cases within a certain period of time. The results of the study support the need for an early warning system designed as a form of malaria prevention preparedness. Environmental factors, geographic conditions and regional spatial stratification, socio-economic factors and public health interventions related to incidents of malaria need to be investigated further.

1. Introduction

Malaria is a dangerous infectious disease that is transmitted through the bite of a female Anopheles mosquito. The mosquito bite contains the plasmodium parasite that causes malaria [1]. Parasitic species that cause malaria in humans include plasmodium falciparum, plasmodium vivax, plasmodium ovale and plasmodium malariae [2]. The Anopheles mosquito is found in tropical and sub-tropical regions of the world. This is because the climatic conditions in the area are suitable for the life cycle and development of the parasites that cause malaria [2]. So that countries in tropical and sub-tropical regions become endemic areas for malaria.

Globally, it is estimated that 3.4 billion people in 92 countries are at risk of contracting malaria. According to the 2018 World Malaria Report, there are more than 219 million cases of malaria in the world. The number of deaths due to malaria is almost 450,000 with a mortality rate of 28% [3]. A number of areas in malaria endemic countries such as Indonesia, China, Panama, Malawi and Eritrea have shown a decreasing trend in malaria cases from 2012 to 2016. However, the downward trend is sometimes followed by an increase in cases (outbreaks) in the following years [4,5,6,8,9]. In Indonesia, malaria cases have also decreased. The Annual Parasite Incidence (API) figure, which is an indicator of malaria morbidity in Indonesia, shows a decrease from 1.75‰ in 2011 to 0.85‰ in 2015 [4,17].
Malaria transmission to humans involves the role of mosquitoes as vectors, parasites that cause malaria and humans as hosts. The malaria life cycle consists of 2 phases, namely the sexual phase in the mosquito body and the asexual phase in the human body [1,2]. Environmental conditions influenced by climate also influence the reproduction of Anopheles vector mosquitoes and plasmodium parasites. Temperature, weather, humidity and rainfall include climatic conditions that affect the life cycle of mosquitoes and parasites that cause malaria [4,5,6,7,8,9]. Changing climatic and weather conditions can affect the life cycle of the vector spreading malaria which ultimately affects the incidence of malaria [13]. Changes in rainfall such as an increase in rainfall in a certain period, followed by a long dry season and an increase in temperature also affect the life cycle of mosquitoes and parasites that cause malaria [4]. Apart from climatic and environmental factors, the spread of malaria is also influenced by socio-economic factors in the community including changes in land use, public health interventions, changes in housing, human migration, knowledge, attitudes and community practices regarding malaria [2,8,10].

Several studies have examined the impact of climate change (rainfall, humidity and temperature) on malaria incidence. This systematic review aims to summarize previous research that elaborates on the effect of temperature and rainfall on malaria. This information can be useful for developing ideas about prevention strategies and interventions to reduce malaria in the future.

2. Methodology

Pubmed, Google and google scholar were used as the main sources, from a database accessed in October 2020 to extract research published in English that addresses the context of malaria worldwide. The search strategy was developed through a combination, terms and keywords "Temperature and malaria", "Rainfall and malaria", which were used to search for articles. We looked at research articles published during the period 2010 - 2020. Titles, abstracts and keywords were screened for the first step on relevant articles as well as articles that met the inclusion criteria that were included in the analysis. Inclusion criteria : peer-reviewed articles and in English; articles that evaluate the impact of various climatic conditions, temperature and rainfall on malaria incidence and articles discussing the impact of temperature and rainfall on malaria incidence.

![Figure 1. Flow diagram of study selection](image)

3. Result and Discussion

Literature review begins with a search for articles using the Pubmed, google and google scholar databases. Initial identification results obtained 26 articles. Furthermore, 12 articles were excluded because they did not meet the inclusion criteria. The remaining 14 articles that met the inclusion criteria were included in the review. Research studies were carried out in Malawi, Botswana, Ethiopia, Iran, Nigeria, South Africa, Indonesia, China, Panama and Eritrea. Of the 14 articles reviewed, 9 articles were conducted in the African region, 4 in Asia and 1 in South America.

All articles included study the relationship between temperature and rainfall to the incidence of malaria, whether it only involves temperature, rainfall, humidity or combining some of these climatic factors and their relationship with malaria. There are 4 articles looking at temperature, humidity and
rainfall factors against malaria [9,12,13,14], 3 articles looking at the relationship of temperature and rainfall to malaria [7,11,16]. Four articles looked at the impact of rainfall on malaria [6,8,15,17]. One article involved temperature and humidity factors against malaria [5] and two articles looked at rainfall and humidity factors against malaria [4,10]. Several statistical methods were used to determine the influence variable and correlation between temperature and rainfall on malaria. Three articles used Sperman analysis [12,13,15], two articles used Poisson model [4,16], one article used Autocorrelation and cross-correlation analyzes [8], one article used non-linear correlation test [9], two articles using the Pearson Correlation Test [10,11], one article using the Autoregressive integrated moving average (ARIMA) [14], 1 article using Distributed Lag Non-Linear Models (DLNM) [7], 1 article using the Negative Binomial Regression Model [5], and 1 article using cross wavelet coherence [6].

Table 1. Characteristics of the Study Discusses the Relationship Between the Impact of Temperature and Rainfall on the incidence of malaria

| Study | Area | Risk Factor | Disease/ Vector | Statistic method | Main Findings |
|-------|------|-------------|-----------------|-----------------|---------------|
| Hajison, Mwakukunga, Mathanga, & Feresu (2017) | Malawi | Temperature, humidity, rainfall | Malaria Anopheles sp. | Non-linear correlation test | Temperature and humidity are related to the incidence of malaria, rainfall is not significantly related. |
| Segun, Shohtaimi, Nallapan, Lamidi-Sarunmoh, & Salari (2020) | Nigeria | Rainfall and humidity | Malaria Anopheles sp. | Pearson correlation | Rainfall and humidity in are associated with malaria cases |
| Chirebvu, Chimbari, Ngwenya, & Sartorius (2016) | Botswana | Temperature and rainfall | Malaria Anopheles sp. | Pearson correlation | Rainfall, mean and minimum temperatures show a correlation with malaria cases |
| Sena, Deressa, & Ali (2015) | Ethiopia | Temperature, humidity, rainfall | Malaria Anopheles sp. Plasmodium falciparum | Spearman correlation | 1. Rainfall and relative humidity are driving factors for malaria |
| | | | | | 2. Temperature does not have a significant effect on the incidence of malaria |
| Mohammadkhani, Khanjani, Bakhhtiari, & Sheikhzadeh, (2016) | Iran | Temperature, humidity, rainfall | Malaria Anopheles sp. Plasmodium falciparum | Negative binomial correlation & Spearman Correlation | Temperature is the most associated factor with malaria incidence. |
| Akinobola & Omotosho (2013) | Nigeria | Temperature, humidity, rainfall | Malaria Anopheles sp. Plasmodium falciparum | Autoregressive integrated moving average (ARIMA) | Rainfall and maximum humidity and minimum temperature are predictors of malaria incidence in tropical rainforests and guinea savanna areas Nigeria. |
| Adeola, et al., (2019) | Afrika Selatan | Rainfall | Malaria Anopheles | Spearman correlation | Total monthly rainfall has a significant effect |
| Authors                          | Location    | Variables                  | Model                      | Findings                                                                 |
|----------------------------------|-------------|----------------------------|----------------------------|--------------------------------------------------------------------------|
| Rejeki, Nurhayati, Aji, Murhandarwati, & Kusnanto, (2018) | Indonesia   | Rainfall and humidity      | Poisson model, quasi-Poisson model, and negative binomial model          | Rainfall and humidity have no significant relationship with malaria cases |
| Wardrop, Barnett, Atkinson, & Clements, (2013) | China       | Temperature, rainfall      | Poisson model              | 1. Increased temperature resulted increased risk of malaria              |
|                                  |             |                            |                            | 2. Increased rainfall has had variable effects in some malaria-related areas |
| Hurtado, Calzada, Rigg, Castillo, & Chaves, (2018) | Panama      | Rainfall                   | Cross wavelet coherence analysis | Rainfall is related to the number of malaria cases                        |
| Mihreteab, et al., (2020)        | Eritrea     | Rainfall                   | Poisson regression model   | Significantly higher rainfall was associated with an increase in the number of malaria cases. Changes in rainfall patterns affect the incidence of malaria. |
| Kifle, Teklemarian, Tesfamariam, Tesfamariam, Andegiorgish, & Kidane, (2019) | Eritrea     | Rainfall                   | Autocorrelation and cross-correlation analyses |                                                                 |
| Chuang, et al. (2017)            | Swaziland   | Temperature, rainfall      | Distributed lag non-linear models (DLNM) | 1. Warmer temperatures and rainfall are more conducive to malaria transmission. 2. Risk of malaria increases in maximum temperature above 30 °C or monthly rainfall above 5 mm. |
| Li, Yang, & Wang (2013)          | China       | Temperature, humidity, sunshine | Negative binomial regression model | Each 1 °C increase in temperature equals an increase in monthly malaria numbers of 0.90% of cases. |

Most of the endemic research locations studied used the influence of climatic variables such as temperature, rainfall, humidity and sunlight on the incidence of malaria. Most of the research uses time series analysis to see weather data with climate in the observation time span between 1992 - 2018.

The effect of temperature on malaria incidence varies across countries. In Malawi in the period 2012 - 2016, the spread of malaria reaches its peak at an optimal temperature of 24° C. The study found that the ideal temperature for the spread of malaria is between 16-27° C. In this study, 24° C was
the peak of malaria [9]. Whereas in Malawi, the risk of malaria increases at maximum temperatures above 30° C [7]. The minimum temperature affects the incidence of malaria from a 0 month lag to 6 month lag. Research at Botswana for example states that minimum temperature affects malaria incidence from 0 month lag, while maximum temperature is positively correlated with malaria incidence at 2 month lag [11].

In some area in China, warmer temperatures increase the risk of malaria transmission. As the monthly mean, maximum, and minimum temperatures increased, the incidence rate increased significantly [16]. The multivariate negative binomial regression model showed that an increase in maximum temperature of 1° C in a given month led to a 15–19% increase in the incidence of malaria in the same month and the following month [5, 13]. In warmer weather, the increased temperature can lead to shorter periods of mosquito development thus increasing malaria transmission [16].

Most of the analysis of the research results supported the hypothesis that rainfall has an impact on malaria incidence. Higher rainfall has a significant impact on increasing the number of malaria cases. In years with high rainfall, a significant increase in malaria cases is immediately followed [12,15,17]. It is estimated that the transmission of malaria cases occurs when the rainfall intensity is estimated at 40–55 mm [15]. In Indonesia, using the data set for 2005 - 2014, rainfall ranges from 178 mm - 251 mm per year. An increase in rainfall of 1 mm was associated with a 0.08% increase in malaria cases after a 3 month lag [4].

Research in Panama using data sets from 1998 to 2016 shows that there is a relationship between the incidence of malaria cases and rainfall at 7 month log [6]. Meanwhile, in South Africa there was an increase in malaria cases from 2 to 5 month lag after heavy rainfall [15]. This is in line with research in Botswana using a 5-year data set showing that there is a relationship between the incidence of malaria cases and rainfall at 1 month lag [11]. The lag period of 1 - 7 months is the right period for the development of plasmodium parasites, the fertilization process and the development of anopheles mosquitoes from eggs to mosquitoes so that they can transmit malaria to humans [10,11,15]. In addition, high rainfall has an indirect impact on water availability as a medium for the development of Anopheles mosquitoes [4].

Meanwhile, research conducted in Iran shows that rainfall has less effect than other factors. This condition can be influenced by geographical and topographic conditions of an area. For example, in hot and dry climates, it causes rapid evaporation and absorption of water into the underground layers so that there is no appropriate medium for mosquito fertilization so that the risk of transmission decreases [13]. In addition, heavy rain or storms may destroy the breeding grounds for mosquitoes and interfere with the development of mosquito eggs or larvae [14].

4. Conclusion

This review indicate that temperature and rainfall influence the incidence and spread of malaria. High temperature and rainfall have an effect on the increase in malaria cases within a certain period of time. The results of the study support the need for an early warning system designed as a form of malaria prevention preparedness. Combination of environmental factors, geographic conditions and regional spatial stratification, socio-economic factors and public health interventions related to incidents of malaria need to be investigated further.

References
[1] Philips, M., Burrows, J., Manyando, C., Huijsduijnen , R., Voorhis, W., & Wells, T. (2017). Malaria. *Nature Reviews Disease Primer*, 1-24, doi: 10.1038/nrdp.2017.50.
[2] Rossati, A., Bargiacchi, O., Kroumova, V., Zaramella, M., Caputo, A., & Garavelli, P. (2016). Climate, environment and transmission of malaria. *Le Infezioni in Medicina*, 93-104. doi:
[3] WHO. (2020). Retrieved Oktober 22, 2020, from World Health Organization: [https://www.who.int/teams/global-malaria-programme](https://www.who.int/teams/global-malaria-programme)
Rejeki, D. S., Nurhayati, N., Aji, B., Murhardarwati, E. H., & Kusnanto, H. (2018). A Time Series Analysis: Weather Factors, Human Migration and Malaria Cases in Endemic Area of Purworejo, Indonesia, 2005–2014. *Iranian Journal of Public Health, 47*(4), 499-509.

Li, T., Yang, Z., & Wang, M. (2013). Temperature, relative humidity and sunshine may be the effective predictors for occurrence of malaria in Guangzhou, southern China, 2006–2012. *Parasites & Vectors*, 1-4.

Hurtado, L., Calzada, J., Rigg, C., Castillo, M., & Chaves, L. (2018). Climatic fluctuations and malaria transmission dynamics, prior to elimination, in Guna Yala, República de Panamá. *Malaria Journal, 17*(85), 1-12.

Chuang, T.W., Soble, A., Ntshalintshali, N., Mkhonta, N., Seyama, E., Mthethwa, S., et al. (2017). Assessment of climate-driven variations in malaria incidence in Swaziland: toward malaria elimination. *Malaria Journal, 16*(232), 1-10.

Kifle, M., Teklemariam, T., Teweldeberhan, A., Tesfamariam, E., Andegiorgish, A., & Kidane, E. (2019). Malaria risk stratification and modeling the effect of rainfall on malaria incidence in Eritrea. *Journal of Environmental and Public Health*, 1-11.

Hajison, P., Mwakukunga, B., Mathanga, D., & Feresu, S. (2017). Seasonal variation of malaria cases in children aged less than 5 years old following weather change in Zomba district, Malawi. *Malaria Journal, 16*(264), 1-12.

Segun, O., Shohaimi, S., Nallapan, M., Lamidi-Sarumoh, A., & Salari, N. (2020). Statistical Modelling of the Effects of Weather Factors on Malaria Occurrence in Abuja, Nigeria. *International Journal of Environmental Research and Public Health, 17*, 1-12.

Chirebvu, E., Chimbari, M., Ngwenya, B., & Sartorius, B. (2016). Clinical Malaria Transmission Trends and Its Association with Climatic Variables in Tubu Village, Botswana: A Retrospective Analysis. *PLON ONE, 11*(3), 1-16.

Sena, L., Deressa, W., & Ali, A. (2015). Correlation of climate variability and malaria: a retrospective comparative study, Southwes Ethiopia. *Ethiopia Journal Health Science, 25*(2), 129-140.

Mohammadkhani, M., Khanjani, N., Bakhtiari, B., & Sheikhzadeh, K. (2016). The relation between climatic factors and malaria incidence in Kerman, South East of Iran. *Parasite Epidemiology and Control*, 205-210.

Akinbobola, A., & Omotosho, J. (2013). Predicting Malaria occurrence in Southwest and North central Nigeria using Meteorological parameters. *Int J Biometeorol, 57*, 721-728.

Adeola, A., Ncongwane, K., Abiodun, C., Makgoale, T., Rautenbach, H., Botai, J., et al. (2019). Rainfall Trends and Malaria Occurrences in Limpopo Province, South Africa. *International Journal of Environmental Research and Public Health*, 1-15.

Wardrop, N., Barnett, A., Atkinson, J., & Clements, A. (2013). *Plasmodium vivax* malaria incidence over time and its association with temperature and rainfall in four counties of Yunnan Province, China. *Malaria Journal, 12*(452), 1-11.

Mihreteab, S., Lubinda, J., Zhao, B., Rodriguez-Morales, A., Karamtic-Muratovic, A., Goitom, A., et al. (2020). Retrospective data analyses of social and environmental determinants of malaria control for elimination prospects in Eritrea. *Parasites & Vectors, 13*(126), 1-11.