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Analysis of Ecological and Socio-Demographic Variations on the Incident of Malaria in Manokwari District, Province of West Papua in 2019-2023

Komariah Abdullah[1*], A. Arsunan Arsin[1], Nur Nasry Noor[1], Abdul Salam[2]
[1]*Department of Epidemiology, Faculty of Public Health, Hasanuddin University, Indonesia*
[2]*Department of Nutritionist, Faculty of Public Health, Hasanuddin University, Indonesia*

Abstract

Malaria is a major infectious disease affecting tropical and subtropical regions, particularly in low-income countries. Manokwari Regency reports the highest number of malaria cases in West Papua Province, with 7,325 cases and a malaria parasite incidence rate of 20.81 per 1,000 population, far from the national elimination target by 2028. This study analyzed the ecological and socio-demographic variations of malaria cases in Manokwari Regency from 2019 to 2023 using a quantitative study with an ecological design. The study was conducted from September to October 2024, analyzing nine districts. Secondary data were collected from various agencies covering the period of 2019-2023. Data analysis included univariate, bivariate, and spatial analyses. No significant association was found between population density (p=0.380; r=0.067), poverty (p=0.380; r=-0.333), geographical characteristics (p=0.380; r=-0.100), and rainfall (p=0.112; r=0.482) with malaria incidence. A negative correlation was observed between average temperature and malaria incidence (p=0.027; r=-0.648), while humidity showed a positive correlation (p=0.022; r=0.649). Spatial analysis revealed inconsistent patterns; densely populated or low-poverty areas often recorded high malaria cases, with coastal and lowland areas tending to have higher malaria incidence compared to highlands. Malaria distribution in Manokwari shows varied and complex patterns. Temperature and humidity were significantly associated with malaria incidence, whereas population density, poverty, geographical characteristics, and rainfall showed no consistent relationship. These findings highlight the complexity of malaria dynamics, suggesting the need for further detailed analysis.

Keywords : *Climate, Malaria Incidence, Spatial, Socio-Demographic.*

Introduction

Malaria remains one of the most significant public health challenges globally. The disease is predominantly found in tropical and subtropical regions, particularly in low-income countries. In many nations, malaria is endemic, disproportionately affecting populations facing adversity, poverty, limited access to healthcare services, and an inability to afford the recommended treatments [1]. Globally, in 2022, an estimated 249 million cases of malaria occurred across 85 countries and malaria-endemic regions [1]. In South-East Asia, three countries account for 98% of the reported cases, with India contributing 58%, followed by Indonesia 30%, and Myanmar 10% [2].

West Papua is a province in Indonesia with a high endemicity stratification, as indicated by its Annual Parasite Incidence (API) of 12.68 per 1,000 population. West Papua ranks second in terms of the highest malaria cases in Indonesia. 2020, the province reported 254,050 malaria cases, which increased to 304,607 in 2021. In 2023, the number of malaria cases in West Papua was 13,079, with an API of 13.12 per 1,000 population. Notably, 56% of the cases in West Papua originate from Manokwari Regency [3].

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****Corresponding Author: komariah.a@gmail.com***

In 2022, Manokwari Regency reported the highest number of malaria cases in West Papua, with 7,325 cases. This number decreased to 4,178 cases in 2023. Manokwari, a tropical region, provides a favorable environment for the survival of Anopheles mosquitoes. These mosquitoes are widespread in the area and transmit both tertian malaria and tropical malaria, with a relatively high incidence rate [4].

Malaria transmission is influenced by factors such as population density, migration trends from non-endemic areas, and the recent impact of global warming, which has been linked to an increase in malaria cases. The transmission of malaria is highly sensitive to climatic conditions, including temperature, rainfall, and humidity [5]. The geographical location significantly impacts malaria incidence, with various ecological and climatic factors playing a crucial role in the disease's transmission and prevalence. Coastal areas with moderate temperature, humidity, and regular rainfall provide a stable environment for mosquito breeding and malaria transmission.

In endemic areas such as Manokwari, malaria remains a significant public health issue, particularly for high-risk groups such as pregnant women and young children [6]. The central government pursues efforts to eliminate malaria by 2030 to encourage regional governments' commitment, especially in high-endemic areas. Malaria control efforts are also actively supported by all sectors to contribute significantly to malaria prevention and maintain malaria-free status in areas that have already achieved elimination [7].

This study focuses on ecological and socio-demographic aspects as risk factors for malaria incidence. Understanding the malaria situation and its risk factors has motivated researchers to examine the socio-ecological factors of malaria incidence in Manokwari Regency, West Papua. Therefore, this study aims to analyze the ecological and socio-demographic variations in malaria cases in Manokwari Regency from 2019 to 2023.

Materials and Methods:

Research Design

This quantitative study employs an ecological study design.

Population and Sample

The population in this study consists of all sub-districs in Manokwari Regencey, totaling 9 sub-districts. The sample in this study includes the number of malaria cases that occurred in these 9 sub-districts of Manokwari Regency over five-year period, from 2019 to 2023.

Research Variables

The dependent variable in this study is malaria incidence. The independent variables include population density, poverty, regional characteristics, temperature, rainfall, and humidity.

Analysis Data

This study employs statistical analysis using Spearman's correlation test, which was conducted using STATA software and presented as tables and graphs. Additionally, QuantumGIS software was utilized for spatial analysis techniques. The spatial analysis included overlay and buffering analyses. After conducting the analysis, the p-value will be obtained to determine the existence of a relationship between variables.

Ethical Approval

This study was approved by the Health Research Ethics Committee of Hasanuddin University with the ethical approval recommendation number 1858/UN4.14.1/TP.01.02/2024.

Result

The incidence of malaria by gender in Manokwari Regency from 2019 to 2023 shows a higher frequency among males than females. The highest number of male malaria cases occurred in 2020 (67%), while the highest among females occurred in 2019 (42%). The age group most affected by malaria is the 0-9 years age group. Regarding occupation, the highest malaria incidence in Manokwari Regency from 2019 to 2023 was observed unemployed. (Table 1).

Tabel 1. Demographic Characteristics of Malaria Incidence in Manokwari Regency from 2019 to 2023

Variables	**Years**				
	2019	**2020**	**2021**	**2022**	**2023**
Total Cases	3642	5200	4409	7825	6826
Malaria incidence rate (per 10.000)	193	270	226	394	338
Gender (%)					
Male	58	67	62	63	62
Female	42	33	38	37	38
Age (%)					
0-9	37.20	27.30	26.20	25.40	21.80
10-19	17.70	15.80	15.30	16.40	16.80
20-29	16.90	21.90	22.80	22.40	24.40
30-39	12.60	16.60	16.40	16.80	18.10
40-49	7.70	10.90	11.40	10.70	10.50
50-59	5.00	5.04	5.58	5.50	5.76
60-60	1.90	2.00	1.79	2.07	1.93
>70	0.90	0.46	0.48	0.75	0.72
Occupation (%)					
ASN/TNI/POLRI	7.58	6.50	4.69	9.60	3.81
Farmer	10.10	24.13	15.58	16.91	13.10
Fisherman	2.06	1.92	1.68	1.47	0.76
Irt	11.45	10.10	12.86	12.13	13.14
Wiraswasta	1.84	1.60	1.38	1.61	6.55
Student	30.89	25.02	24.59	24.45	22.75
Unemployed	35.97	27.65	24.61	33.15	27.06
Other	0.14	3.08	14.61	0.69	2.53

The results of this study indicate that the average incidence of malaria in Manokwari Regency from 2019 to 2023 was 333.05 per 10,000 population. The average population density was 250.10 individuals/km², the average poverty percentage was 52.60%, and the average elevation above sea level was 41.11 meters. Climatic variability was also examined in this study, with findings showing the average annual rainfall from 2019 to 2023 was 215.43 mm, the average temperature was 27.87°C, and the average humidity was 81.25% (Tabel 2).

Tabel 2. Distribution of Research Variables

Variables	**2019-2023**		
	Mean	**Min**	**Max**
Malaria Incidence 2019-2023	333.05	172.38	897.88
Socio Demographic			
Population Density (Ha/Population)	250.10	13.86	1413.08

Poverty (%)	52.60	33.87	70.79
Regional Characteristic (masl)	41.11	5	120
Weather			
Rainfall (mm)	215.43	100.12	358.5
Temperature (°C)	27.87	27.36	28.38
Humidity (%)	81.25	79.2	82.6

Source: The Health Office of Manokwari Regency, BPS (Central Statistics Agency), BMKG (Meteorological, Climatological, and Geophysical Agency), 2020-2024.

The peak malaria incidence over the past five years occurred in 2022, reaching 394 cases per 10,000 population (Figure 1). The malaria incidence exhibited a clear fluctuating pattern throughout the year, with peaks occurring in specific months. Generally, malaria incidence was higher during the early to mid-months of the year (January to June). The peak malaria cases in 2019 occurred in January, 2020 in February, 2021 in March, and 2022 and 2023 in January (Figure 2).

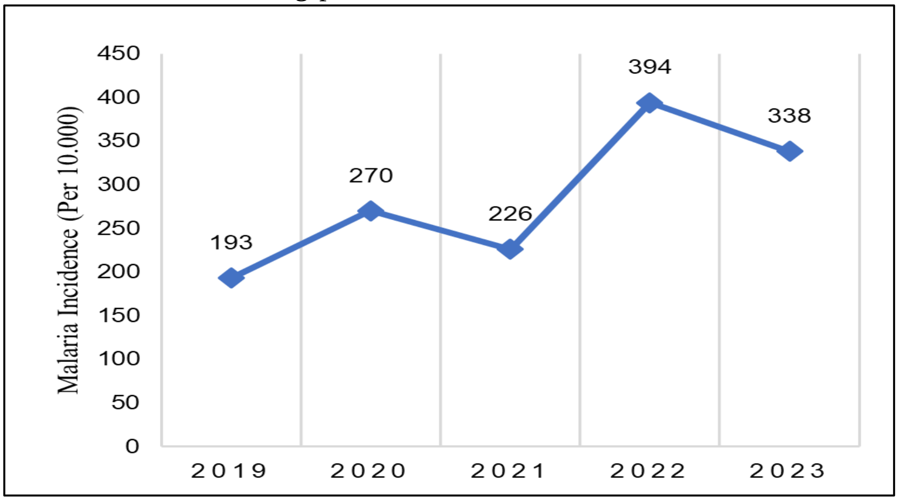

Figure 1. Graphic of Malaria Incidence by Year

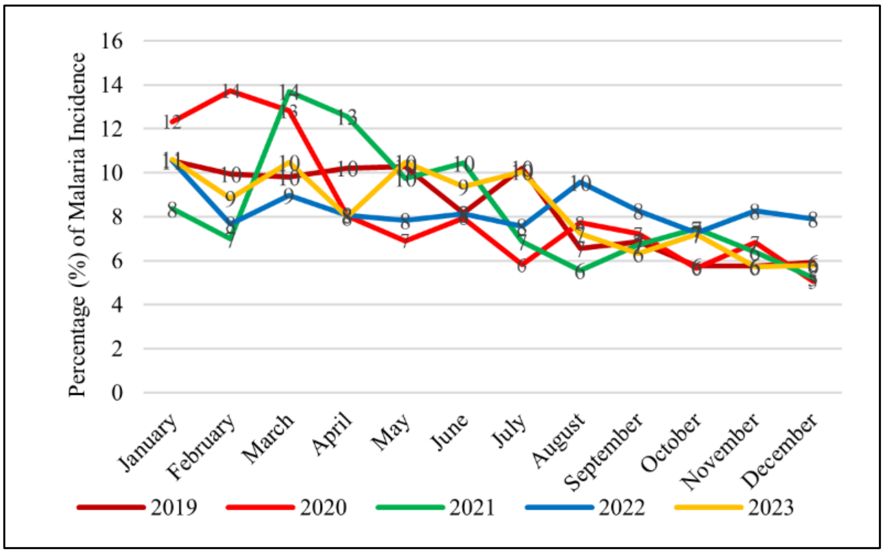

Figure 2. Graphic of Malaria Incidence by Month

North Manokwari Subdistrict has the highest malaria incidence rate (IR) per 10,000 population compared to other subdistricts. This indicates that the region has a high risk of transmission. In contrast, Warmare and Sidey Subdistricts exhibited relatively low incidence rates throughout the study period (Figure 3).

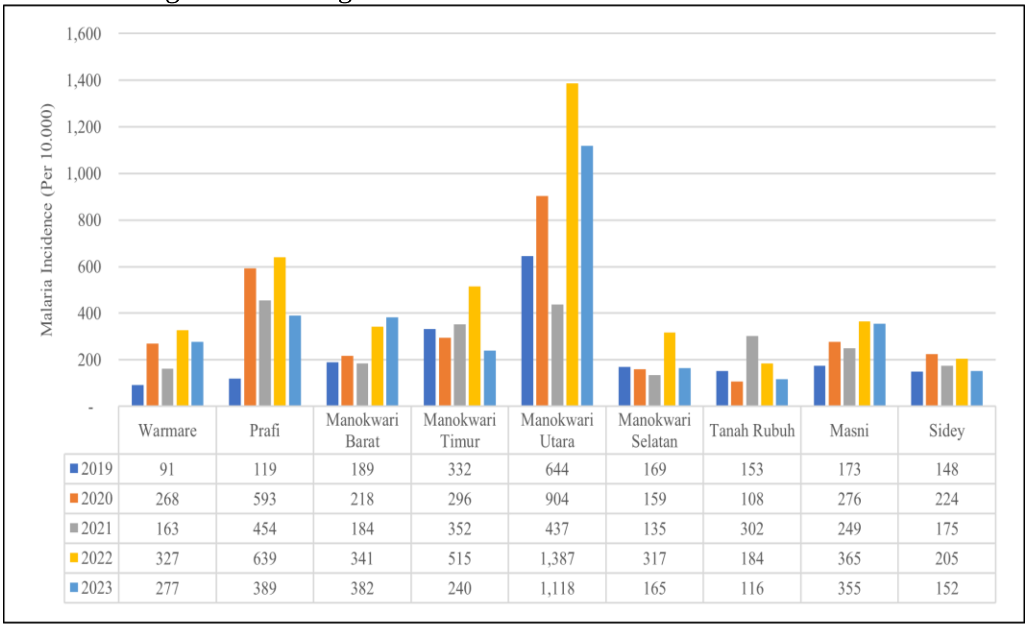

Figure 3. Graphic of Malaria Incidence Distribution by Subdistrict in Manokwari Regency

The results of the Spearman rank correlation analysis indicate that temperature and humidity are statistically significant factors associated with malaria incidence. Temperature had a p-value of 0.027 and a correlation coefficient of -0.648, indicating a strong negative relationship. This suggests that as temperature increases, malaria incidence tends to decrease. Conversely, humidity had a p-value of 0.022 and a correlation coefficient of 0.649, indicating a strong positive relationship, meaning that higher humidity levels are associated with an increase in malaria cases. In contrast, other variables such as population density (p = 0.864; r = 0.067), poverty (p = 0.380; r = -0.333), regional characteristics (p = 0.380; r = -0.100), and rainfall (p = 0.112; r = 0.482) did not show statistically significant associations with malaria incidence, although rainfall demonstrated a moderate positive correlation.These findings emphasize the important role of climatic factors particularly temperature and humidity in influencing malaria transmission dynamics in the study area (Table 3).

Table 3. Correlation between Population Density, Poverty, Regional Characteristic, Rainfall, Temperature, Humidity with the Malaria Incidence in Manokwari Regency in 2019-2023

Variables	**Malaria Incidence 2019-2023**	
	Spearman'R	**p-Value**
Population Density (Ha/Population)	0.067	0.864
Poverty (%)	-0.333	0.380
Regional Characteristic (masl)	-0.100	0.042
Rainfall (mm)	0.482	0.112
Temperature (°C)	-0.648	0.027
Humidity	0.649	0.022

The spatial analysis using the overlay technique in Manokwari Regency revealed an inconsistent pattern between population density and malaria incidence. In certain years, such as 2019, 2022, and 2023, areas with high population density such as East and West Manokwari tended to report high malaria incidence. However, in 2020 and 2021, areas with low population density, such as North Manokwari, recorded very high malaria incidence, while densely populated areas like South Manokwari reported relatively low incidence.

Additionally, areas with moderate population density, such as Prafi and Tanah Rubuh, also showed high malaria incidence in specific years. These findings suggest that population density is not the sole determining factor in the spatial distribution of malaria. Other factors, such as environmental conditions, access to healthcare services, and community behavior, also contribute significantly (Figure 4).

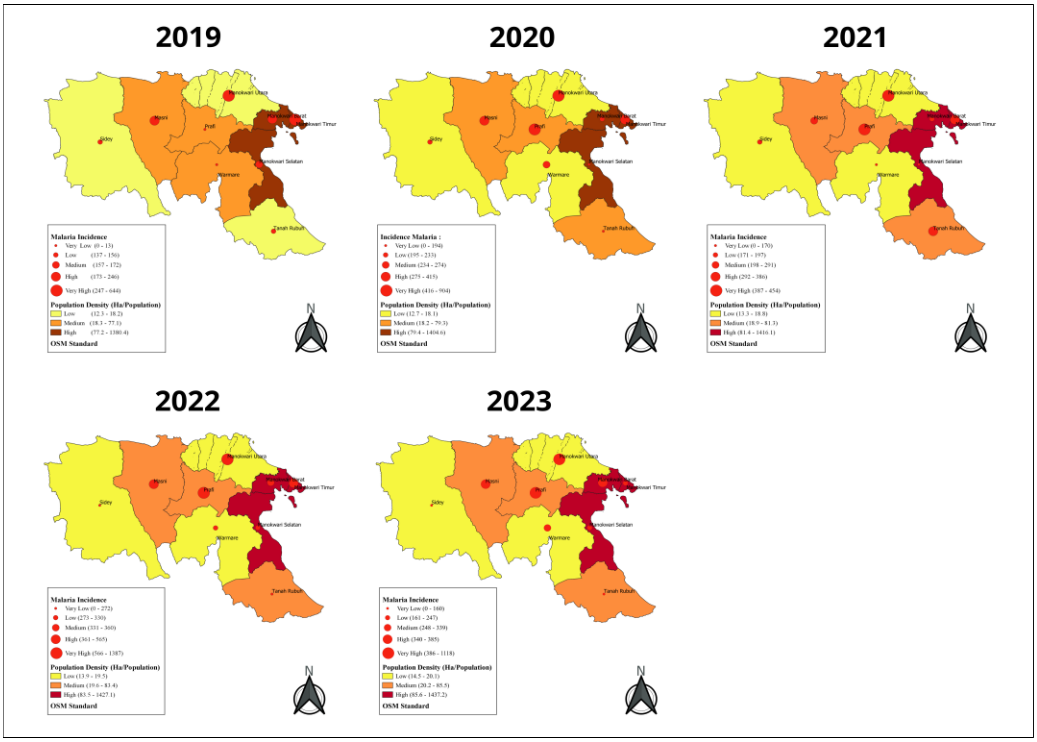

Figure 4. Population Density Map with Malaria Incidence in Manokwari Regency from 2019 to 2023

The spatial analysis using the overlay technique in Manokwari Regency from 2019 to 2023 revealed a varied and inconsistent pattern between poverty levels and malaria incidence. In certain years, such as 2020 and 2021, there was a tendency for areas with high poverty rates such as North Manokwari, Masni, and Tanah Rubuh to experience high malaria incidence. However, in 2019, 2022, and 2023, areas with a high percentage of impoverished residents, such as Sidey and Tanah Rubuh, reported low malaria incidence. In contrast, areas with lower poverty levels, such as West and East Manokwari, recorded higher malaria incidence Figure 5.

These findings indicate that while poverty may act as a risk factor, the distribution of malaria in Manokwari is also influenced by other variables, including geographical conditions, environmental factors, community behavior, and access to healthcare facilities.

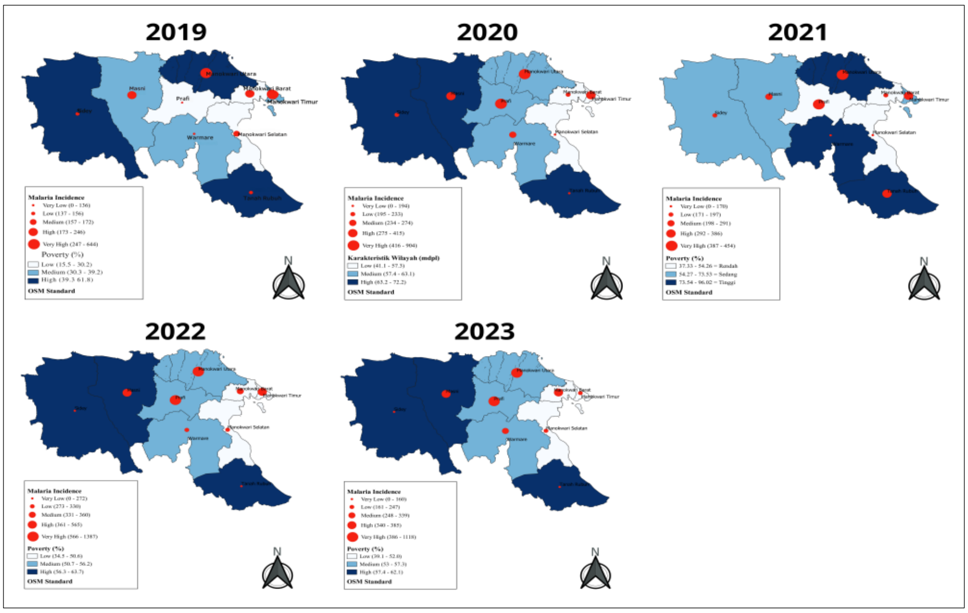

Figure 5. Poverty Map with Malaria Incidence in Manokwari Regency from 2019 to 2023

During the 2019-2023 period, spatial overlay analysis of regional characteristics and malaria incidence in Manokwari Regency indicated that coastal areas (0-5 meters above sea level) and lowland regions (6-100 meters above sea level) consistently tended to experience high to very high malaria incidence, as observed in districts such as East Manokwari, North Manokwari, and Prafi. In contrast, highland areas (101-120 meters above sea level), such as Warmare District, generally exhibited lower malaria incidence, although it was categorized as moderate in 2023. This pattern suggests that areas closer to sea level are at greater risk of malaria, likely due to environmental conditions that favor the life cycle of malaria vector mosquitoes–such as higher humidity, stagnant water, and more stable temperatures (Figure 6).

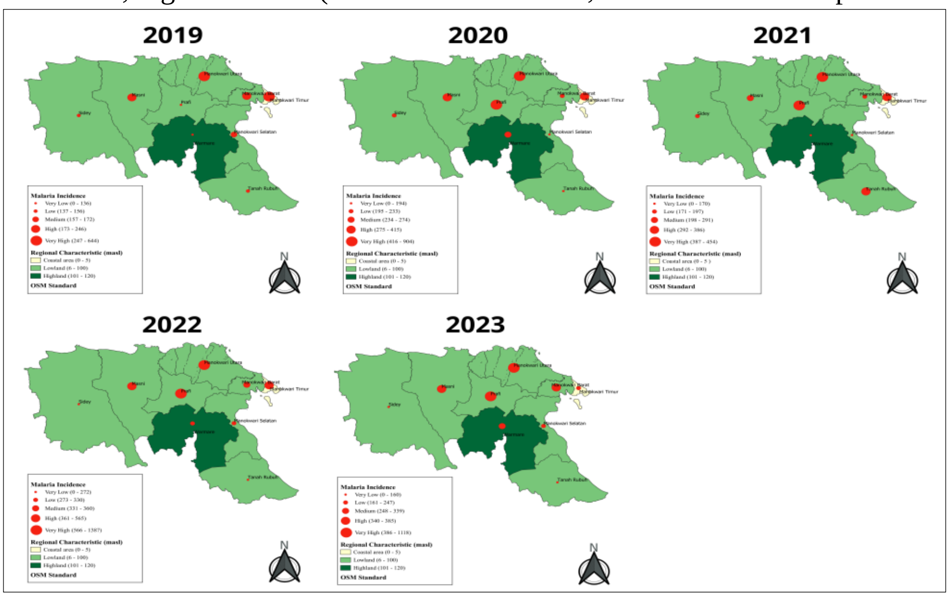

Figure 6. Regional Characteristics Map with Malaria Incidence in Manokwari Regency from 2019 to 2023

During the 2019-2023 period, the graph illustrating the relationship between temperature and malaria incidence in Manokwari showed a negative correlation pattern, where an increase in malaria cases tended to occur when average temperatures decreased–particularly at the beginning (January-April) and end of the year (October-December), when temperatures renged between 27-28°C. Conversely, when temperatures rose, especially in the middle of the year (May-August) reaching aroung 29.5°C, the number of malaria cases declined. This pattern suggests that lower temperatures create more favorable conditions for malaria vector activity, thereby increasing the risk of transmission (Figure 7).

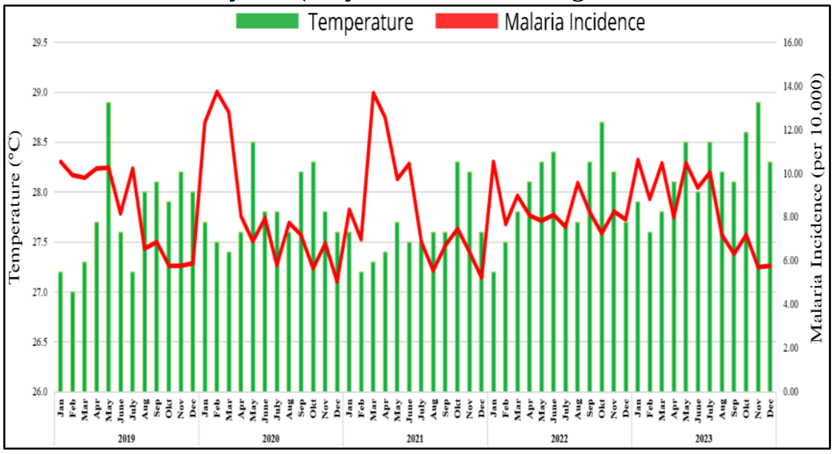

Figure 7. Time Series of Temperature and Malaria Incidence

During the 2019-2023 period, the correlation between rainfall and malaria incidence in Manokwari exhibited a fluctuating and inconsistent pattern. However, there was a tendency for malaria cases to increase several weeks to 1-2 months after periods of heavy rainfall, particularly at the beginning and end of the year (January-March and November-December). High rainfall creates humid conditions and standing water that support the breeding of Anopheles mosquitoes, the primary vectors of malaria. Nevertheless, extreme rainfall can wash away mosquito larvae and may not immediately lead to an increase in cases. Consequently, the period following moderate rainfall—when standing water persists but conditions are less disruptive presents the highest risk for malaria transmission, especially between February and April and from December to January (Figure 8).

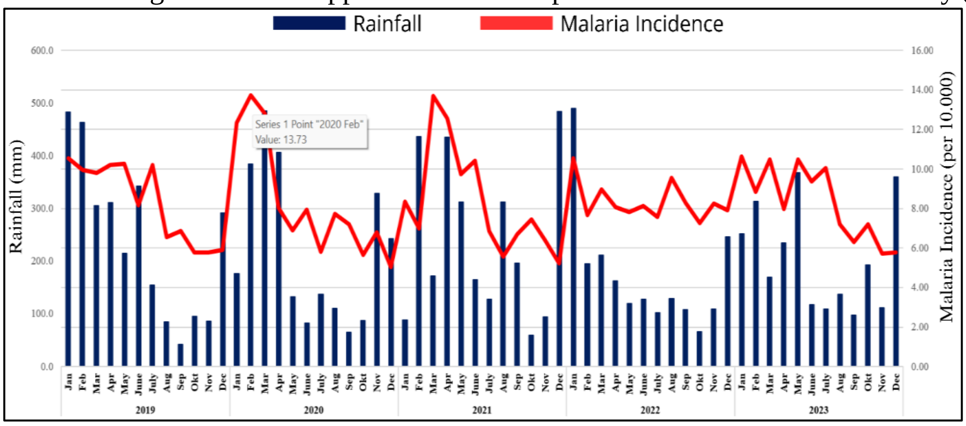

Figure 8. Time Series of Rainfall and Malaria Incidence

During the 2019–2023 period, the relationship between humidity and malaria incidence in Manokwari demonstrated a relatively consistent pattern, in which increases in air humidity (typically ranging from 78% to 85%) were often followed by a rise in malaria cases within the subsequent 1–2 months particularly during the early part of the year (January–March). Figure 9 illustrates that spikes in humidity, especially following the rainy season, create more humid environmental conditions that are ideal for Anopheles mosquitoes to breed and survive longer, thereby increasing the risk of malaria transmission. This pattern is further supported by correlation analysis, which reveals a strong positive relationship between humidity and malaria incidence, identifying periods of high humidity as critical windows for malaria prevention efforts.

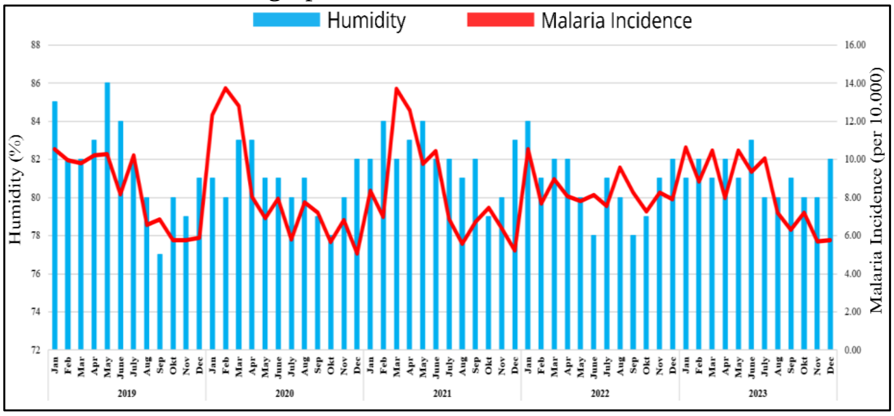

Figure 9. Time Series of Humidity and Malaria Incidence in Manokwari Regency from 2019 to 2023

The study's results on malaria incidence in Manokwari Regency from 2019 to 2023 show that malaria cases were predominantly observed in males over the five years. This finding is supported by research conducted in Dembiya District, Northwest Ethiopia, which reported that males were 2.6 times more likely to be infected with malaria than females (AOR=2.6, 95% CI 1.04, 6.41) [8]. In contrast, a study in Selayar Island showed that malaria incidence from 2016 to 2019 was predominantly among females [9]. It has been suggested that males are at higher risk of malaria infection due to frequent outdoor activities influenced by male-dominated occupations such as farming, livestock farming, plantation workers, and military personnel who often have assignments outside the city, while females are more likely to engage in indoor activities as housewives [10].

The age group most affected by malaria is the 0-9 year age group. This indicates that malaria incidence in Manokwari Regency is exceptionally high among children. These results align with research conducted in Nkongho-Mbeng, Southwest Cameroon, which showed that malaria infections were most common in infants (0-2 years) compared to other age groups. Children are more vulnerable than other age groups, contributing to 67% of all malaria-related deaths globally (272,000) in 2018 [11]. Similar findings were reported in the Urban Community of Ibadan, Southwest Nigeria, regarding the age-specific prevalence patterns of malaria and average parasite density, showing that the 5-year age group had the highest malaria infections. The decline in immunity in mothers and the lower immunity in children compared to adults are significant causes. As individuals age and gain more exposure, the risk of malaria infection decreases, except among the elderly and immunocompromised individuals. Therefore, special attention should be given to children under five years old. Measures to prevent mosquito bites, such as providing bed nets for families with young children, should be enhanced [12].

Work conducted in malaria-endemic areas can influence the risk of contracting the disease, as workplaces in malaria-endemic regions tend to increase the likelihood of exposure to malaria [13]. The results of this study indicate that malaria incidence in Manokwari Regency from 2019 to 2023 was most prevalent among those who were unemployed. Individuals who are not working tend to spend more time at home or in their residential environment, which often carries a higher risk, especially if located in malaria-endemic areas [14].

The findings also show that malaria incidence in Manokwari Regency fluctuated over the years, with the highest peak in cases occurring in 2022. According to the average temperature measurements by the BMKG in Manokwari Regency from 2019 to 2023, the average temperature was 27°C, with maximum and minimum temperature boundaries still within the range that supports the survival of malaria mosquitoes. Malaria cases tend to spike at the beginning of the year. The peak of malaria cases in 2019 occurred in January 2020, February 2021 in March, and 2022 and 2023 in January, coinciding with the peak of rainfall. During the rainy season, the population of Anopheles mosquitoes tends to increase due to the proliferation of breeding sites outdoors caused by inadequate environmental sanitation, which results in a higher incidence of malaria [15].

The highest malaria incidence by location during 2019-2023 was consistently recorded in the Manokwari Utara District. Spatial analysis of the distribution of malaria incidence over the five years reveals that malaria cases were present across all districts in Manokwari Regency. The high malaria incidence in Manokwari Utara may be linked to its geographic location, which is relatively close to sea level (25 meters above sea level). In addition to the geographical factors examined in this study, other factors that could contribute to the high malaria incidence in a given area include access to healthcare services. According to Manokwari Regency Health Office data, access to healthcare services in this region remains relatively low. This is attributed to various factors, ranging from inadequate infrastructure to a shortage of healthcare personnel [16]. Delayed treatment is associated with a higher risk of severe malaria. In malaria-endemic areas, the primary factors contributing to delays in seeking healthcare are low levels of education and traditional beliefs [17].

Population density refers to the number of individuals residing per square kilometer of a given area. This factor is closely related to the flight range of mosquitoes and malaria transmission, as higher population density facilitates easier spread of the disease by mosquitoes. The results of the Spearman correlation test indicate no significant relationship between population density and malaria incidence in Manokwari Regency over the past five years. Spatially, malaria case distribution patterns do not consistently align with areas of high population density. Similar findings were reported in a study which found that population density had a weak positive correlation with P. falciparum malaria in Africa [18]. Corresponding results were also observed in a study conducted in Malawi, which showed no significant relationship between population density and malaria incidence [19]. These findings contrast with results from Rwanda, where population density was found to be associated with malaria endemicity. The probability of malaria endemicity increased with higher population density [20].

The relationship between malaria and poverty is reciprocal. Malaria contributes to poverty, and poverty, in turn, contributes to the spread of malaria [21]. However, the results of the Spearman correlation test indicate that there is no statistically significant relationship between poverty and malaria incidence in Manokwari. Spatial analysis further supports this finding, showing that districts with high poverty levels (e.g., Sidey) actually reported low malaria incidence, while districts with lower poverty levels (such as West Manokwari, East Manokwari, and South Manokwari) experienced higher malaria incidence. Therefore, this study found no significant association between poverty and malaria incidence. These findings are consistent with a study conducted in the Mentawai Islands Regency [22], which investigated environmental factors associated with malaria incidence. That study also found no statistically significant relationship between poverty and malaria incidence. In contrast, contradictory results were reported in a study conducted in Africa [23], which found a strong association between wealth index and malaria infection. As household income increased, the risk of malaria infection tended to decrease. In Mountong Parigi District, malaria is prone to occur in areas with extreme poverty [24].

As elevation increases and distance from sea level grows, ambient temperatures tend to decrease, which can in turn influence the dynamics of infectious disease transmission. Additionally, the geographical shift of Anopheles mosquito habitats due to climate change has facilitated malaria transmission in areas that were previously considered non-endemic [25]. The results of the Spearman correlation test indicate that there is no statistically significant relationship between geographical characteristics and malaria incidence in Manokwari. However, spatial analysis shows that areas with consistently low malaria incidence are located in highland regions, such as Warmare District. These findings are consistent with a study conducted in Uganda, which reported that spatial variation in malaria incidence showed higher case numbers in lowland areas of the Kween District [26]. In contrast, mid- and high-altitude areas in the district recorded relatively lower malaria incidence. This contrasts with the findings from Hainan, where malaria incidence increased monotonically from the northern lowlands to the southern hill regions of moderate elevation and the central highlands, reaching altitudes up to 1800 meters [25].

The presence and transmission of malaria are highly dependent on climatic factors such as rainfall, humidity, and temperature [27]. Rainfall has a generally positive effect on malaria incidence. When annual rainfall intensity is high, it is often followed by an increase in reported malaria cases. Rainfall affects local ecosystems and creates favorable breeding conditions for disease vectors such as Anopheles mosquitoes. In Ethiopia, malaria transmission has been shown to vary and remain unstable depending on rainfall patterns [8]. In this study, average annual rainfall in Manokwari Regency between 2019 and 2023 was recorded at 215.43 mm, with a minimum of 100.12 mm and a maximum of 358.5 mm. However, the Spearman correlation analysis revealed no statistically significant relationship between rainfall and malaria incidence in Manokwari. Malaria case peaks often occurred following periods of high rainfall. A similar positive correlation between rainfall and malaria was reported in Odisha, India [28], where the highest malaria incidence occurred during the monsoon season and immediately afterward. In contrast, a study conducted in Iran [29] found a more complex relationship, where increased rainfall was associated with a decrease in malaria incidence.

At temperatures of 30°C, Anopheles mosquito eggs will hatch within 1-2 days, whereas at temperatures around 16°C, hatching can take up to a week. For female mosquitoes, the pupal phase lasts about 1 to 2 hours longer than for males. During this pupal stage, temperatures between 25°C and 27°C are required, with a duration of 2 to 4 days [30]. The results of this study show that the average temperature in Manokwari Regency from 2019 to 2023 was 27.87°C, with a minimum of 27.36°C and a maximum of 28.38°C, which falls within the optimum temperature range for Anopheles mosquito development. Spearman correlation testing reveals a strong and significant negative correlation between temperature and malaria incidence, indicating that higher temperatures are associated with fewer malaria cases. However, the time series graph shows an inconsistent pattern, with a tendency for higher malaria incidence at lower temperatures during specific periods. Similar findings were observed in a study conducted in West Africa, which described a negative association between average temperature and malaria incidence [31]. Contrasting results were found in a study in the Tiko Health District, Cameroon, where the seasonal correlation between average temperature and malaria cases showed a moderate positive correlation (r = 0.599, p = 0.024) [32].

Another climatic factor, humidity, has also been found to play a significant role in malaria transmission. Low humidity shortens the lifespan of mosquitoes. Evidence has shown that malaria transmission is hindered when the average relative humidity is below 60%, but relative humidity levels above 60% may no longer be a limiting factor for malaria transmission. At higher humidity levels, mosquitoes are more active and bite more frequently, thereby increasing malaria transmission [5]. Spearman correlation analysis reveals a strong and significant positive correlation between humidity and malaria incidence, where an increase in humidity is followed by a rise in malaria cases, as observed in the time series graph. A significant relationship between malaria incidence and humidity was found in a study emphasizing that adequate humidity is crucial for mosquito survival, as these insects are highly vulnerable to drought [33]. However, the opposite result was observed in cities of the Sistan–Baluchestan Province, where malaria incidence decreased significantly as humidity levels increased [29].

Conclusion

The results of this study indicate that temperature and humidity have a statistically significant relationship with malaria incidence. Temperature exhibited a strong negative correlation, while humidity showed a strong positive correlation. In contrast, other variables such as rainfall, population density, poverty, and geographical characteristics did not demonstrate statistically significant associations with malaria incidence. However, spatial analysis revealed that coastal and lowland areas consistently experienced higher malaria incidence, whereas highland regions tended to report lower case numbers. The relationships between poverty and population density with malaria incidence appeared inconsistent across different years, suggesting that malaria distribution in Manokwari is influenced by a complex interplay of factors, including geographical conditions, environmental factors, access to healthcare services, and community behavior.

Conflict of Interest

We have no conflict of interest.

Acknowledgements

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