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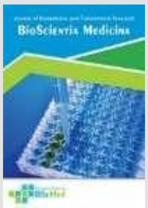

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Ecological Study of Climate Effects on Malaria Incidence in Jayapura Indonesia 2010-2022

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A B S T R A C T

Background: Malaria is still a health problem in Indonesia with high geography, rainfall and humidity. Malaria infects people living in endemic areas, especially in tropical and subtropical countries. Malaria can be a public health threat in remote areas. Jayapura is one of the cities in Indonesia with a high incidence of malaria. This event is supported by the geographical position and dominant topography in the form of swamp areas, sago forests, forests, mountains, and environmental influences such as temperature, rainfall, and air humidity. This study aimed to determine the effect of climatic factors consisting of monthly cumulative rainfall, average air temperature monthly average and monthly average relative humidity on the number of monthly malaria cases in Jayapura. **Methods:** This study uses observation by using ecological-based studies and ecological time-trend design. **Results:** This study found that rainfall and the incidence of malaria in the city of Jayapura in 2010-2022 had a significant relationship and had a positive relationship at lag 2 in 2010. Air temperature and malaria in the city of Jayapura in 2010-2022 had a significant relationship and had a positive lag 2 in 2010 and 2011. The relative humidity and incidence of malaria in Jayapura in 2010-2022 had a significant relationship and had a negative relationship at a 2-month lag in 2011 and 2015 while in 2013 and 2014 it had a strong and positive relationship. **Conclusion:** Ecological studies found a significant relationship between climate and malaria incidence in Jayapura.

1. Introduction

Several cases of malaria in Indonesia were found throughout the archipelago, especially in Eastern Indonesia, namely Papua, West Papua, Maluku, North Maluku, and East Nusa Tenggara. The proportion of malaria incidence in Indonesia is 7.9. National Annual Parasite Incidence (API) data decreased, namely 4.68 per thousand population in 1990, decreased sharply to 1.96 per thousand population in 2010, and fell to 1.75 per thousand population in 2011, then 1.69 per -a thousand inhabitants in 2012, to 0.99 in 2014, and in 2015 to 0.85. API in 2016 was 0.8 per thousand population.[1] Epidemiological data estimates that 35% of Indonesia's population lives in areas at risk of Indonesia currently consist of 497 Regencies/Cities, and 54% of them are malaria-endemic areas. Routine reports on national data on malaria cases for the period 2005-2011, the incidence rate tended to decrease, namely from 4.10% (2005) to 1.3% (2013). Eastern Indonesia is the area with the most cases of malaria, where the incidence rate reaches almost 80%.1. Based on data World the Health Organization in 2015 Globally, the economic burden of malaria cases was approximately US$ 300 million per year, and the cost of funding for the disease in 2014 was US$ 2.5 billion.[2] In Indonesia, the economic calculation due to malaria in 2015 is Rp. 4.65 trillion, and funding for activities related to malaria in the amount of Rp. 664 billion.[3]

The intergovernmental panel on climate change (IPCC) stated that human activities have caused an increase of 1.1°C global warming since the pre-industrial period. This can lead to climate change, thereby affecting a wide range factor environments, resulting in increases in temperature, rainfall, and extreme weather events such as heat waves and floods.[4] The world's average surface air temperature has increased by 0.6°C since the era of 1850. As well as, world rainfall in the mainland area has increased by 2% since the early 20th century, especially in mid and high latitudes.[5] Factor climate, such as temperature and rainfall, are closely related to the biology and transmission of diseases that are transmitted through vectors.[6] Climate change is likely to affect malaria risk. These impacts on malaria can occur both directly, due to optimal climatic ranges and critical thresholds for vector and parasite development, and indirectly, as society grapples with the disruptive effects of changing weather patterns and seasonal cycles.[7] Cases of endemic areas of malaria in Indonesia are generally in the regional rural, remote areas, and the average socio-economic population is low, and transportation and communication are relatively difficult to reach. The increase in malaria affects not only morbidity and mortality but also the socio-economic community. There are several factors that increase malaria cases and extraordinary events (KLB), namely changes in the physical environment, especially rainfall, temperature, humidity, and changes in land use, including environmental damage, poverty, economic crisis, and population movements. Climate change and its close relationship with the distribution of malaria is related to the effect of temperature, so many areas have become new endemic sites for malaria cases. The area becomes too dry for the life of mosquitoes, causing the mosquito population to decrease so there is no risk of transmitting disease.[8]

The incidence of malaria in Jayapura Regency is a disease that has been around for a long time, and some people have suffered from malaria. This event is supported by the geographical position and dominant topography in the form of swamp areas, sago forests, forests, mountains, and environmental influences such as temperature, rainfall, and humidity.[9] Climatic conditions in Jayapura Regency are wet tropical, where the air temperature ranges from 26-33°C, and humidity air temperature ranges from 75-84%. Rainfall conditions are quite high and not evenly distributed, so these conditions are ideal for malaria vector habitat and the cycle and development of malaria vectors, and the life cycle of the plasmodium parasite.[10] The incidence of malaria in Jayapura Regency is quite high, where the prevalence reaches 45.4%.[11] The Jayapura Regency Health Office's annual report in 2010 recorded 15,113 cases of malaria. In 2014 it increased to 22,165 sufferers. Positive malaria sufferers in 2017 were 14,839 and increased in 2018 to 18,514 sufferers10. During the period 2010-2022, the highest number of malaria cases in the whole province of Indonesia was dominated by the province of Papua, represented by the Jayapura.

2. Methods

This ecological study research uses an observational-based design ecological time-trend design in the period January 2010 to December 2022 in Jayapura. The population consists of all regencies/cities of Jayapura, which consist of 28 regencies and 1 city. The research sample was screened using inclusion and exclusion criteria. All regencies/cities in whose administrative areas there are meteorology, climatology, and geophysics agency (BMKG) weather monitoring stations and all of their administrative areas are within a radius area 15 km from the location of the BMKG weather monitoring station were included in this study. Exclusion criteria if outside the radius 15 km from the location of the BMKG weather monitoring station. Data is taken from data secondary obtained from Data of the Directorate General of Prevention and Control of Infectious Diseases of the Ministry of Health of the Republic of Indonesia. Monthly cumulative rainfall data, monthly average air temperature, and humidity relatively monthly average, obtained from the meteorology, climatology, and geophysics agency (BMKG) of the Republic of Indonesia, which can be downloaded on the website http://dataonline.bmkg.go.id/data_iklim. The process of processing data through data checking, data entry, and data cleaning. Univariate data analysis is presented in graphical form, and bivariate analysis uses parametric statistical tests, while non-parametric statistical tests are used if the data is not normally distributed. The test was used using Spearman or Pearson test.

3. Results

The analyzed Jayapura data amounted to 156 rows of data covering one dependent variable, namely the incidence of Malaria, and three independent variables consisting of air temperature (Tavg), relative humidity (RH_avg), and rainfall (CH_RR) as in Table 1.

Table 1. Distribution of Jayapura data for 2010-2022.

Variable	**Total**	**Min-Max**	**Mean**	**Median**	**SD**	**95% CI**	**Kolmogorov-Smirnov**	**Skewness**
							P-value	
Malaria	156	0 -5663	2001	1869	884.19	1861.3–2141	0.014	1.137
Air temperature (Tavg)	156	26.5- 29.2	28.12	28.11	0.422	28.05-28.18	0.884	-0.221
Relative humidity (RH_avg)	156	75.6-90.9	82.84	82.58	3.16	82.34-83.34	0.647	-0.063
Rainfall (CH_RR)	156	47.3 - 841.8	233.8	205	1.27	213.6 - 254.1	0.047	1.518

The results of the normality test for the Malaria case variables, rainfall, air temperature, and relative humidity for the city of Jayapura show that the malaria variable is not normally distributed where the P value = 0.014 (below 0.05), the air temperature variable is normally distributed where the P value is = 0.084 (above 0.05)), the humidity variable shows a p-value = 0.647 (above 0.05) which indicates that the relative humidity data is normal and the rainfall variable shows a p-value 0.047 (below 0.05) which means that the rainfall data is not normal. The type of statistical test used for variables that are not normally distributed is a statistical test non-parametric with the Spearman correlation test method. Spearman correlation is used to determine whether or not there is a relationship, the strength of the relationship, and the direction of the relationship between two numerical variables that are not normally distributed. The Spearman correlation test was carried out on the dependent variable, namely malaria cases, and the independent variables, namely rainfall (mm), air temperature (ºC), and relative humidity (%), which were carried out separately in the cities studied. Then it is analyzed by considering the lag time (lag *time*) Independent variable to the dependent variable.

Based on the bionomics of Anopheles spp mosquitoes which are required for adult mosquitoes for 35 days, a correlation test was carried out between rainfall and malaria in Jayapura City for 12 years (2010-2022) using lag 1 and lag 2 the number of malaria cases (Figure 1).

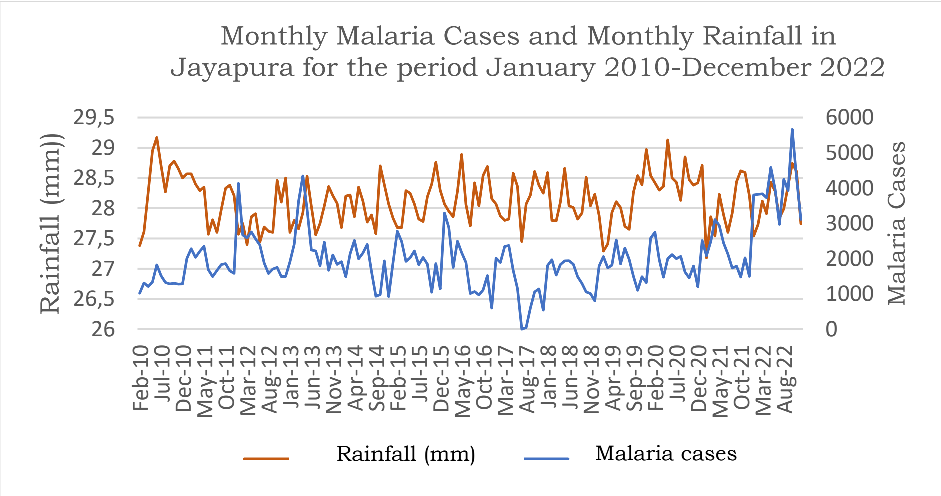

Figure 1. Monthly malaria and monthly rainfall in Jayapura period January 2010- December 2022.

Based on the results of the correlation test between rainfall and annual malaria showed that in lag 2 in 2010, there was a significant relationship (t = 0.70, p = 0.02). The strength relationship was categorized as strong strength (r = 0.50-0.75). The relationship was positive, which means if an increase in one variable was followed by an increase in increase in another variable or if an increase in rainfall was followed by an increase in malaria incidence.

Table 2. The relationship between rainfall and the incidence of malaria in Jayapura in 2010-2022.

Year	**Lag 1**		**Lag 2**		**API**
	r	p-value	r	p-value	
2010**	-0.03	0.91	0.70	0.02	60.8
2011*	-0.03	0.33	-0.03	0.92	86.3
2012*	0.15	0.62	0.00	0.99	100.6
2013**	0.42	0.16	0.38	0.21	110.2
2014*	0.03	0.99	0.30	0.32	76.2
2015*	0.40	0.19	0.48	0.10	89.8
2016*	0.44	0.14	-0.04	0.88	73.2
2017**	0.05	0.97	0.20	0.51	51.3
2018*	0.01	0.96	0.54	0.06	63.0
2019*	0.37	0.22	0.42	0.16	71.5
2020*	-0.35	0.25	-0.10	0.74	76.7
2021*	0.18	0.57	0.36	0.24	72.2
2022*	-0.09	0.97	-0.15	0.64	118.9

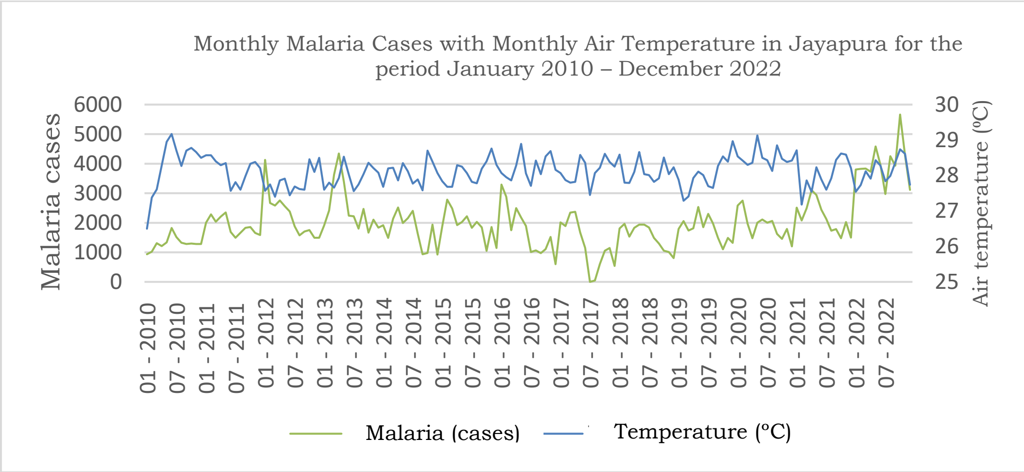

Figure 2. Monthly malaria and monthly air temperature in Jayapura period January 2010- December 2022.

The results of the Spearman correlation test between air temperature and malaria cases in lag 1 showed that as much as 2 years in the city of Jayapura showed a significant relationship with a very strong relationship value in 2010 (r = -0.618; p = 0.032) and was positive, and in 2011 shows a strong and positive relationship (r=0.52; p=0.03) (Table 3).

Table 3. The relationship between air temperature and the incidence of malaria in Jayapura in 2010-2022.

Year	**Lag 1**		**Lag 2**		**API**
	r	p-value	r	p-value	
2010*	0.86	0.02	0.18	0,66	60.8
2011*	0.52	0.03	0.45	0.13	86.3
2012*	0.06	0.85	0.35	0.26	100.6
2013*	-0.41	0.17	-0.45	0.13	110.2
2014*	0.38	0.21	-0.06	0.83	76.2
2015*	-0.57	0.04	-0.08	0.78	89.8
2016*	-0.11	0,71	0.09	0.76	73.2
2017*	-0.30	0.33	-0.22	0.49	51.3
2018*	0.37	0.42	0.03	0.92	63
2019*	-0.38	0.21	-0.22	0.51	71.5
2020*	-0.35	0.25	0.36	0.24	76.7
2021**	-0.42	0.17	0.46	0.13	72.2
2022*	-0.09	0.97	-0.31	0.32	118.9

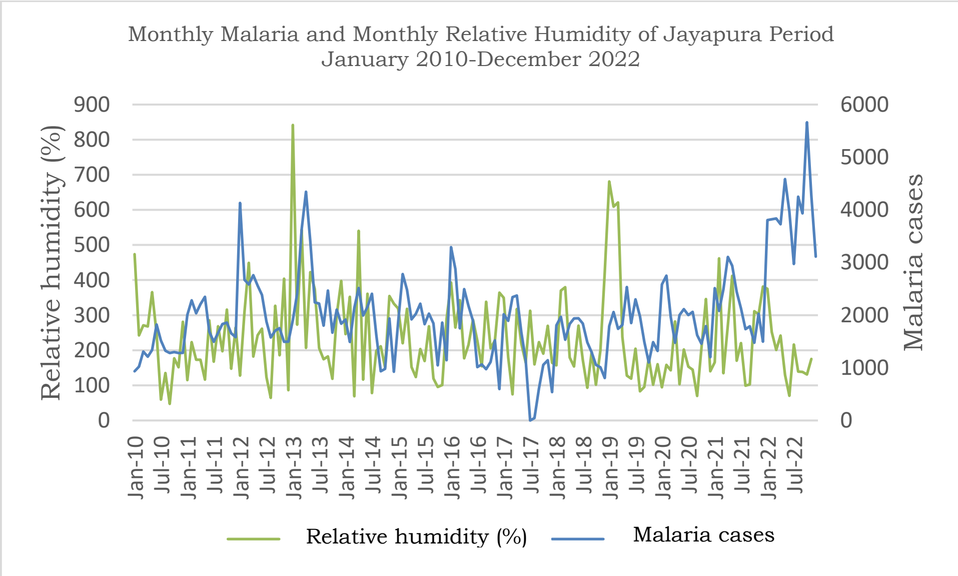

Figure 3. Monthly malaria and monthly relative humidity of Jayapura period January 2010- December 2022.

The results of the Spearman correlation test between Relative Humidity and malaria cases at lag 1 show that as many as 3 years in the city of Jayapura, there is a significant relationship with a strong relationship value in 2013 (r=-0.61; p= 0.03) and 2019 (r=0.53 ; p = 0.04) and the relationship is positive. And in 2011, there was a strong relationship (r= -0.67, p= 0.01), and the relationship was negative. Based on results, Spearman's correlation test between humidity and malaria incidence in lag 2 shows that 4 years in the city of Jayapura, there is a significant relationship with the value of a strong relationship in year 2, namely in 2013 (r= 0.58, p= 0.04) and 2019 (r= 0.72, p = 0.007) and the relationship is positive, while the other 2 years, namely in 2011 there was a strong relationship – in 2016 (r = -0.69, p = 0.03) and 2015 (r = -0.55, p = 0.02) and the relationship was negative (Table 4). It means if there is an increase in other variables, it will be followed by a decrease in other variables. This means if there is an increase in relative humidity, then followed by a decrease in the incidence of malaria.

Table 4. The relationship between humidity and the incidence of malaria in Jayapura in 2010-2022.

Year	Lag 1		Lag 2		API
	r	p-value	r	p-value	
2010*	0.26	0.43	0.37	0.28	60.8
2011*	-0.67	0.01	-0.60	0.03	86.3
2012*	0.04	0.88	-0.21	0.49	100.6
2013*	0.61	0.03	0.58	0.04	110.2
2014*	0.10	0.73	0.40	0.18	76.2
2015*	-0.24	0.45	-0.55	0.02	89.8
2016*	0.52	0.07	0.16	0.60	73.2
2017*	-0.49	0.10	-0.23	0.40	51.3
2018*	0.03	0.92	0.53	0.07	63
2019*	0.53	0.04	0.72	0.007	71.5
2020*	-0.50	0.09	-0.27	0.38	76.7
2021*	0.44	0.14	0.38	0.21	72.2
2022*	0.05	0.85	0.01	0.96	118.9

Referring to the bionomics of mosquitoes *Anopheles spp*, and the results of the correlation test lag 1 and lag 2 between annual parasite incidence malaria with rainfall, air temperature, and relative humidity found that lag 2 has a strong correlation value so that the ecological study of this research uses the basic reference analysis data.

4. Discussion

This study found that the highest monthly cases of Malaria in Jayapura during January 2010 – December 2022 occurred in January, April, and May for 7 years out of a total 12-year period, while the highest monthly rainfall occurred in the January period, 3 months or 4 months before The highest occurrence of malaria cases is 7 years out of a total period of 12 years. This study found that rainfall and the incidence of malaria in Jayapura in 2010-2022 had a significant and positive relationship at a 2-month lag with the strength of the fat relationship. These results are in line with research conducted by Rezeki et al. in Purworejo, which found a significant relationship between rainfall and malaria cases at a lag of 3 months.[14] However, this is not in line with the research conducted by Dabaro et al. in an Ethiopian city, who found that monthly rainfall significantly correlated with the number of cases of malaria with delay or lag 0 and lag 2 months.[15]

Rainfall plays a major role in the transmission of malaria, although it has no direct effect on the parasite. Rainwater creates ponds which can become breeding grounds for mosquitoes *Anopheles spp.* High rainfall can increase humidity and extend the life of adult mosquitoes.[16] However, excessive rainfall or high intensity can also wash away the breeding grounds and remove larvae and pupae, thereby reducing the abundance of adult mosquitoes.[18] The relationship between rainfall and the fluctuating number of malaria cases from 2010 to 2022 does not show a linear pattern. Caused because rainfall with low and moderate intensity can create vector breeding sites or breeding places for mosquito *Anopheles spp.*[19] Meanwhile, high-intensity rainfall can have an impact on reducing malaria cases height Rainfall can destroy vector breeding places because they are carried away by flood currents.[20] The size of the influence of rainfall on malaria depends on the type of rain, the intensity of the rain, the number of rainy days, and the type of vector and vector breeding places. Rain interspersed with heat will increase the chances of breeding *Anopheles spp.*[21]

This study found that the highest monthly cases of Malaria in Jayapura during January 2010 - December 2022 occurred in January, April, and May for 7 years out of a total period of 12 years, while the lowest monthly temperatures mostly occurred in March and July periods, namely 6 years out of a total period of 12 years. This study also found that air temperature and the incidence of malaria in Jayapura City in 2010-2022 had a significant and positive relationship at a lag of 1 month (2010 and 2011) with very strong and very strong relationships. This is in line with Resiany's research (2017) conducted in Central Java which found a significant relationship between air temperature and malaria cases at a lag of 1 month. This research is not in line with malaria studies in the same month or lag 0. conducted by Nilasari in Yogyakarta that found a significant relationship between air temperature and the distribution of malaria cases in the same month or lag 0.[22] The optimal air temperature for mosquitoes is 23-27°C. Temperature tolerance for each mosquito species is not the same. However, almost all mosquito species cannot survive in extreme environmental temperatures with changes between 5°-6°C which affect the adaptation process. Air temperature affects the cycle slow-moving or extrinsic incubation period. Higher air temperatures will shorten cycle time slow-moving with an average daily temperature of 27°C.[23] Air temperature affects the cycle of sporogony or extrinsic incubation. The higher the temperature, the shorter the extrinsic incubation period. Conversely, the lower the temperature, the longer the extrinsic incubation. The environmental temperature that is considered conducive ranges from 25–30°C. Mosquito growth will stop if the temperature is below 10°C or more than 40°C.[24]

This study found that the highest monthly Malaria cases in Jayapura City during January 2010 – December 2022 mostly occurred in January, April, and May for 7 years out of a total period of 12 years, while the highest monthly relative humidity mostly occurred in January and December periods 7 years out of a total period of 12 years. This study found that rainfall and the incidence of malaria in Jayapura City in 2010-2022 had a significant and positive relationship at lag 1 in 2013 and 2019 with a strong and positive relationship and in 2013 with a strong and positive relationship. Negative. Then it had a significant relationship at lag 2 in 2013 and 2014 with a strong and positive relationship value, and in 2011 and 2015, it had a strong and negative relationship. This is in line with research conducted by Apriliana in Lampung, which found a significant relationship between relative humidity and malaria cases (r= 0.533; p= 0.017).[20] Humidity affects the mosquito life cycle, human biting habits, and mosquito density. Low relative humidity shortens the life of mosquitoes, while high relative humidity extends their life. Higher humidity increases the frequency of mosquito bites and the density of mosquitoes.[25] Physical factors, humidity, and Air can affect mosquito breeding, blood-sucking habits, rest, and others. Humidity low can shorten the life of mosquitoes. Humidity of less than 60% will cause evaporation of water from the mosquito's body which can lead to dehydration of the mosquito's body. Humidity air above 60% will increase the activity of *Anopheles spp* to suck blood.[26,27]

5. Conclusion

This study found that rainfall and the incidence of malaria in the city of Jayapura in 2010-2022 had a significant relationship and had a positive relationship at lag 2 in 2010. Other results found that air temperature and malaria in the city of Jayapura from 2010-2022 had a significant relationship. Significant and has a positive relationship at lag 2 in 2010 and 2011. This study also found that humidity relative and the incidence of malaria in Jayapura in 2010-2022 had a significant relationship and a negative relationship at a 2-month lag in 2011 and 2015, while in 2013 and 2014, it had a strong and positive relationship.

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