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MALARIA INCIDENCE TRENDS AND THEIR ASSOCIATION WITH CLIMATIC VARIABLES IN EAST KALIMANTAN, INDONESIA, 2014–2020

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Abstract

Introduction: *Malaria is still a worldwide health problem, which includes Indonesia. Vector-borne diseases are climate-sensitive and this has raised extended concern over the implications of global climate change on future disease risk. This study aims to analyze the relationship between climate factors and malaria cases in East Kalimantan Province as an illustration to assist the malaria elimination program.* ***Methods:*** *Laboratory confirmation of malaria cases 2014-2020 was analyzed for trends derived from the E-Sismal data. Decomposition analysis was performed to assess seasonality. Climatic data (humidity, temperature, and rainfall) were analyzed with the incidence of malaria using Spearman rank correlation and model analysis with Poisson regression.* ***Results and Discussion:*** *The API value did not decrease significantly, which was only 0.07% from 2014 to 2020, but there was a change in the number based on the type of parasite from Plasmodium falciparum to vivax, which means that program intervention efforts have occurred, while Plasmodium vivax can relapse. There was a seasonal trend decomposition of monthly Plasmodium falciparum and Plasmodium vivax from December to March. Relative humidity shows a positive correlation while monthly temperature shows a negative correlation with P. vivax malaria cases each month.* ***Conclusion:*** *The outputs from this study are going to be useful at numerous levels of decision-making, for example, in fitting associate early warning and property methods for temperature change and climate change adaptation for malaria infection management programs in East Kalimantan.*

INTRODUCTION

Malaria is still a worldwide health problem, specifically for tropical and subtropical international locations (1). Globally, the occurrence of malaria could be very wide, particularly within the vicinity between longitude 60° in the north and 40° in the south, overlaying more than a hundred international locations with tropical and sub-tropical climates (2). The populace liable to malaria is around 2.3 billion or 41% of the world's populace. Every year the wide variety of malaria instances is 300-500 million and causes 1.5 to 2.7 million deaths, specifically in sub-Saharan Africa. South and Southeast Asia and Central America. Areas which are now freed from malaria are Europe, North America, most of the Middle East, most of the Caribbean, and elements of South America. Australia and China (3).

Malaria manipulation endorsed through the WHO consists of diagnosis, chemotherapy, incorporated vector control in-domestic programs along with Indoor Residual Spraying (IRS) or distribution of insecticide-handled mosquito nets/Long Lasting Insecticide Net (LLIN) to lessen transmission and risk infectious diseases (4). This manipulation has additionally been applied in Indonesia; however, till now malaria has persisted creating a public fitness problem which is classified as a concern by the Ministry of Health of Indonesia.

There are five kinds of parasites that purpose malaria in humans, *Plasmodium falciparum, Plasmodium vivax, Plasmodium ovale, Plasmodium malariae,* and the newest one is *Plasmodium knowlesi*. Mixed contamination may also arise in endemic regions with a couple of Plasmodium species (1). According to the World Malaria Report WHO, there were 216 million instances of malaria in 2016 with a death toll of approximately 445,000 instances and 211 million instances in 2015 with a death toll of approximately 446,000 (5).

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Annual Parasite Incidence (API) is an indicator of malaria morbidity rate described in per 1,000 population. The API in Indonesia in 2019 increased compared to 2018, from 0.84 to 0.93 per 1,000 population. Based on data from the East Kalimantan Provincial Health Office, data on malaria cases based on the API indicator decreased from 2010 to 2017, respectively, in 2010 2.25‰; 2.1‰; 1.12‰; 0.75‰; 0.68; 0.45‰; 0.35‰; until 2017 to 0.34‰. Based on the district, North Penajam Paser District (PPU) is the highest number of malaria cases with an API score of 5.2‰ (6).

Naturally, malaria transmission occurs because of the interaction between the agent (Plasmodium spp), the definitive host (*Anopheles* spp) and the intermediate host (human). Therefore, malaria transmission is influenced by the presence and fluctuation of vector populations (transmitters are Anopheles spp mosquitoes), one of which is influenced by rainfall intensity, as well as the source of the parasite *Plasmodium* spp. or sufferers in addition to the presence of a susceptible host (7). Anopheles species can become malaria vectors if they have a long life, high contact with humans, and are the dominant species in that location (8). In Indonesia, there are more than 90 species of *Anopheles* spp. and that have been known to be vectors are as many as 18 species with the best known being *An. sundaicus, An. barbirostris, An. maculatus* and *An. Aconitus* (9).

Analysis by forecasting is one method of predicting disease situations, one of which is influenced by climate, such as malaria and dengue. An analysis that has been carried out in Kotabaru, Indonesia, shows that an approach using decomposition analysis can develop a spatial decision support system to assist the local health office in controlling malaria locally so that the control carried out is effective in achieving the goal of malaria elimination (10).

Several studies show Malaria is associated with climatic factors. Recently, a study conducted in Nigeria showed that rainfall and temperature had an effect on the incidence of malaria with a correlation coefficient of $R2 \geq 70.0$ in the ecological zones of Rainforest, Freshwater, and Mangroves (11). Research using climate data has also been carried out in all districts in South Sumatra, Indonesia, which shows that the rainfall variable affects the incidence of malaria using geographically weighted regression (GWR) analysis (12). Another study in Purworejo, Indonesia, also showed the same results with three statistical approach models, namely 0.05, 0.01 and 0.001 significance levels. Research using climate data is also widely used to predict disease incidence with monthly and annual climate patterns (13). This study aims to determine the trend of malaria incidence by forecasting and to find out the relationship between climate factors and malaria cases in East Kalimantan Province as an illustration to help the malaria elimination program. Trend analysis with forecasting can be used to determine seasonal patterns of malaria incidence so that intervention patterns can be determined before the transmission season.

METHODS

Research Area

East Kalimantan is the second biggest province after Papua in Indonesia and one of the five provinces on Borneo Island. East Kalimantan, as the brandnew capital city, has 127.267 km land region. Meanwhile, the region of marine control is 25,656 rectangular km. East Kalimantan is positioned between 113º44' and 119º00' East Longitude and between 2º33' North Latitude and 2º25' South Latitude (14).

East Kalimantan has an undulating topography from mild to steep slopes, with elevations starting from 0-1500 meters above sea degree (masl) with a slope of 0-60%. The lowland regions of this province are commonly observed at more than 1,000 meters above sea degree with a slope of 300%. The plateau is placed within the northwest, immediately adjoining to the Malaysia region. Broadly speaking, the topography of East Kalimantan is 43.35% of the land location protected within the slope above 40%. Meanwhile, 43.22% is situated at an altitude of 100-1,000 meters above sea degree. East Kalimantan includes seven regencies and three cities. East Kalimantan is bordered by North Kalimantan at the north, the Makassar Strait, and the Celebes Sea at the east, South Kalimantan at the south and Central Kalimantan, West Kalimantan, and in addition to the Sarawak Part of East Malaysia at the west (14).

Several malaria managements, including vector management, distribution of mattress nets to danger agencies and pregnant women, indoor residual spraying (IRS), and antimalarial treatment, were applied on the examined site. Based on the Statistic Center Agency, there are one hundred eighty fitness facilities and 689 sub-fitness facilities to operationalize public fitness packages, along with malaria management packages in East Kalimantan.

Collecting Data

Data collection was carried out at the Provincial Health Office through recapitulated data from the district level in East Kalimantan. The month-to-month laboratory records showed malaria instances through 2014–2020 received from the East Kalimantan Provincial Health Office. All malaria times ought to be stated with the resource of the use of the Community Health Center through e-SISmal, a specific country-wide reporting system and application for malaria. E-SISmal statistics consisted of age, gender, diagnosis (*P. falciparum, P. vivax, P. ovale, P. malariae, P. knowlesi,* and mixed) confirmed with the resource of the use of microscopic examination or fast diagnostic test (RDT) and geolocation (village information or PHC). The manipulate programmer at Community Health Center prepares and sends a monthly report form to the provincial degree for validation in advance than sends it to the National Ministry of Health. Population records for villages are accumulated from the files of the neighborhood Statistics Central Agency (14), and climate records such as rainfall, temperature, and humidity are received from the Meteorological, Climatological, and Geophysical Agency (15).

Data Analysis

Descriptive evaluation accomplished to summarize the wide variety of instances via way of means of age institution (< 5, 5–9, 10-14, 15-54, and > 55 years), sex, and form of malaria contamination. Pearson correlation was used to decide the affiliation of Plasmodium contamination with age institution and sex. Trend evaluation was accomplished to look at developments within a wide variety of malaria instances via means of age, sex, and form of contamination over the years. In the usage of the two tailed approach for developments. p-value < 0.05 is considered statistically significant. Statistical assessment was achieved through the use of SPSS 21 version (IBM, Armonk, NY, USA). A multiplicative seasonal decomposition assessment using SPSS 21 version decomposed the monthly occurrence of P. falciparum and P. vivax (Yt) into a composite trend (Tt), a seasonal component (St), and mistakes or residual component (Et) (16). The relationship between phrase decomposition and malaria prevalence was defined in the formulation.

$$Y_t = T_t + S_t + E_t$$

Analysis of graphs and climate data (humidity, temperature, and rainfall) and their effect on the incidence of malaria was performed with Spearman's rank correlations. Statistical evaluation used SPSS 21 version (IBM, Armonk, NY, USA).

Ethics Statement

Ethical approval for this research was obtained from the Ethics Committee of the Health Research and Development, Indonesia with the number: LB.02.01/2/ KE.156/2021.

RESULTS

Descriptive statistics

Malaria cases were reported as many as 11, 902 during 2014-2020. Malaria cases were significantly higher in men (88.5%) and individuals > 15 years old (91.3%) and the least in those > 64 years (1.3%) (Table 1). Based on the API score, the malaria trend in East Kalimantan had the opportunity to decrease with a decrease of the API score from 2014, 2015, and 2016, but then it increased again in 2017 to 2020. By sex, malaria instances were drastically better in adult males than females over time (p = 0.044). Based on age, malaria instances were stated large within the population ≥ 15 years (p < 0.06). All forms of infections had proven a downward fashion in 2016; however, they extended once more till 2020 (p < 0.001). Types of contamination *P. malariae, P. ovale*, and *P. knowlesi* are few in range and no longer arise each year. In the recapitulation of facts, there's a distinction between the full range of every species and overall malaria instances each year from 0 – 77%. The greatest distinction was in 2016 whilst there was no distinction in 2020.

Table 1. Annual Malaria Cases and the Proportion by Sex, Age and Type of Infection, East Kalimantan, Indonesia (2014-2020)

Variable	n (%)	No. of Case (%)							
		2014	2015	2016	2017	2018	2019	2020	p-value
Sex									
Male	11547 (88.5)	1667 (80.4)	1281 (79.2)	1120 (90.5)	1458 (92.4)	2073 (89.6)	1913 (92.6)	2035 (94.2)	0.044
Female	1499 (11.5)	407 (19.6)	336 (20.8)	118 (9.5)	120 (7.6)	241 (10.4)	152 (7.4)	125 (5.8)	
Age(years)									
<5	258 (2.0)	82 (4.0)	114 (7.1)	10 (0.8)	12 (0.8)	24 (1.0)	7 (0.3)	9 (0.4)	0.06
5-14	700 (5.4)	169 (8.1)	204 (12.6)	50 (4.0)	66 (4.2)	86 (3.7)	61 (3.0)	64 (3.0)	
15-64	11917 (91.3)	1796 (86.6)	1279 (79.1)	1170 (94.5)	1487 (94.2)	2181 (94.3)	1970 (95.4)	2034 (94.2)	
>64	171 (1.3)	27 (1.3)	20 (1.2)	8 (0.6)	13 (0.8)	23 (1.0)	27 (1.3)	53 (2.5)	
Total	13046(100)	2074(100)	1617(100)	1238(100)	1578(100)	2314(100)	2056(100)	2160(100)	

Variable	n (%)	No. of Case (%)							p-value
		2014	2015	2016	2017	2018	2019	2020	
Type of infection									
P. falcifarum	5198 (43.7)	1097 (54.0)	905 (56.4)	82 (29)	690 (45.7)	848 (37.7)	709 (34.3)	867 (40.1)	
P. vivax	4803 (40.4)	637 (31.4)	543 (33.8)	160 (57)	570 (37.7)	910 (40.5)	1028 (49.8)	955 (44.2)	
P. malariae	43 (0.4)	2 (0.1)	2 (0.1)	0 (0.0)	1 (0.1)	18 (0.8)	11 (0.5)	9 (0.4)	<0.001
P. ovale	2 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.1)	0 (0.0)	0 (0.0)	
P. knowlesi	6 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.1)	3 (0.1)	1 (0.0)	
mixed	1850 (15.5)	294 (14.5)	155 (9.7)	40 (14)	250 (16.5)	468 (20.8)	315 (15.2)	328 (15.2)	
Data difference	1144 (9)	44 (2)	12 (1)	956 (77)	67 (4)	66 (3)	-1 (0)	0 (0)	
Total	11902 (100)	2030 (100)	1605 (100)	282 (100)	1511 (100)	2248 (100)	2066 (100)	2160 (100)	
Overall API per 1000 people		0.69	0.47	0.39	0.48	0.67	0.63	0.62	

Decomposition analysis

The month-to-month sample of *P. falciparum* and *P. vivax* infections in East Kalimantan at some point of 2014 – 2016 is given in Figure 1.

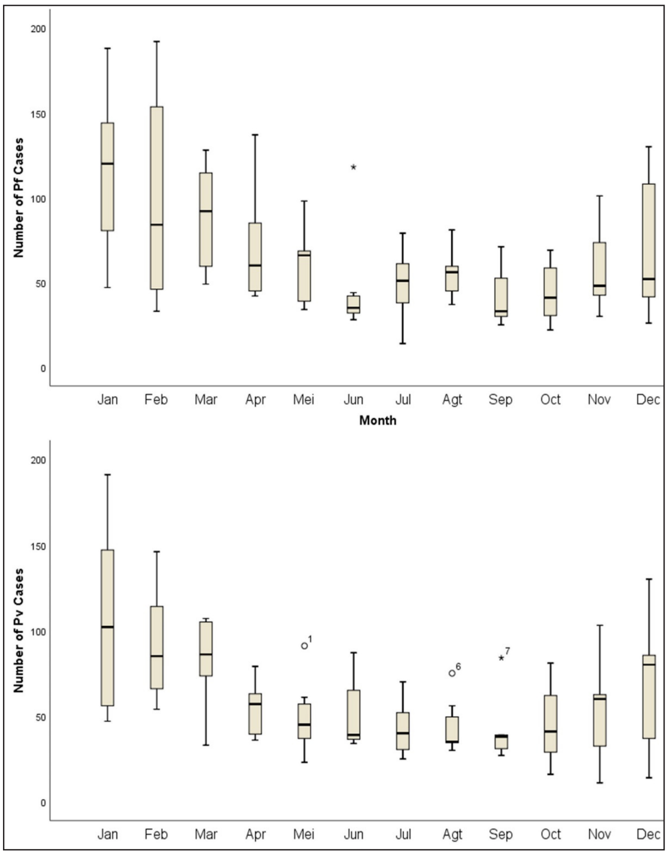

Figure 1. Monthly Distribution of Malaria in East Kalimantan, Indonesia during 2014-2020

The maximum common variety of *P. falciparum* instances was in February, while the common variety of *P. vivax* instances improved in December–February. This implies the variety of *P. falciparum* and *P. vivax* instances decreased greatly from June to September. The effects of the decomposition assessment showed a big reducing manner for the times of *P. falciparum* and *P. vivax* (Figure 2). In addition, decomposition assessment showed a smooth seasonal pattern for every infection. For *P. falciparum* infection, a single pinnacle was found every February each year, but a bimodal seasonal pattern was found for P. vivax infection (February and June).

Weather Correlation Analysis with Malaria

The climate data increased, followed by an increase in cases, of both *falciparum* malaria and *vivax* malaria. Temperature pattern increased in December-April where humidity and rainfall are low (Figure 3). Spearman's rank correlation was used to research the connection among malaria cases (*P. falciparum* and *P. vivax*) in the course of the observed duration and climate predictors at monthly intervals. In East Kalimantan, relative humidity confirmed a high correlation with *P. vivax* at a 1-month c program language period on the 95% self-assurance level (Table 2). While month-to-month temperature confirmed a poor correlation with P. vivax in every month on the 99% self-assurance level (Table 2) Meanwhile, the rainfall factor showed to be uncorrelated to the *P. vivax* case as well as all climatic factors (humidity, temperature, and rainfall) were uncorrelated to the *P. falciparum* case in East Kalimantan.

Table 2. Spearman's Rank Correlation Between Weather Variables and Malaria Cases (*P. Falciparum* and *P. Vivax*) in East Kalimantan

Spearman Test	Temperature (⁰C)	Humidity (%)	Rainfall (mm)
Pf Case	-0.194	0.127	0.003
Pv Case	-.242*	.405**	0.181

***. Correlation is significant at the 0.01 level (2-tailed),*
**. Correlation is significant at the 0.05 level (2-tailed).*

Table 3. Poisson Regression Coefficients of Weather Data with Malaria Cases (*P. Falciparum*) from January 2014 to December 2020 in East Kalimantan, Indonesia

Variable	β	S.E.	*p-Value*
Temperature	-24,80346	9.336792	0.008
Humidity	0.9932632	1.653624	0.548
Rainfall	-0.0636202	0.0390182	0.103
QICu		**-422.9083326**	

AIC: Akaike's information criterion, β: coefficients, S.E: standard error.
AIC: 853.8167, BIC: 863.5399

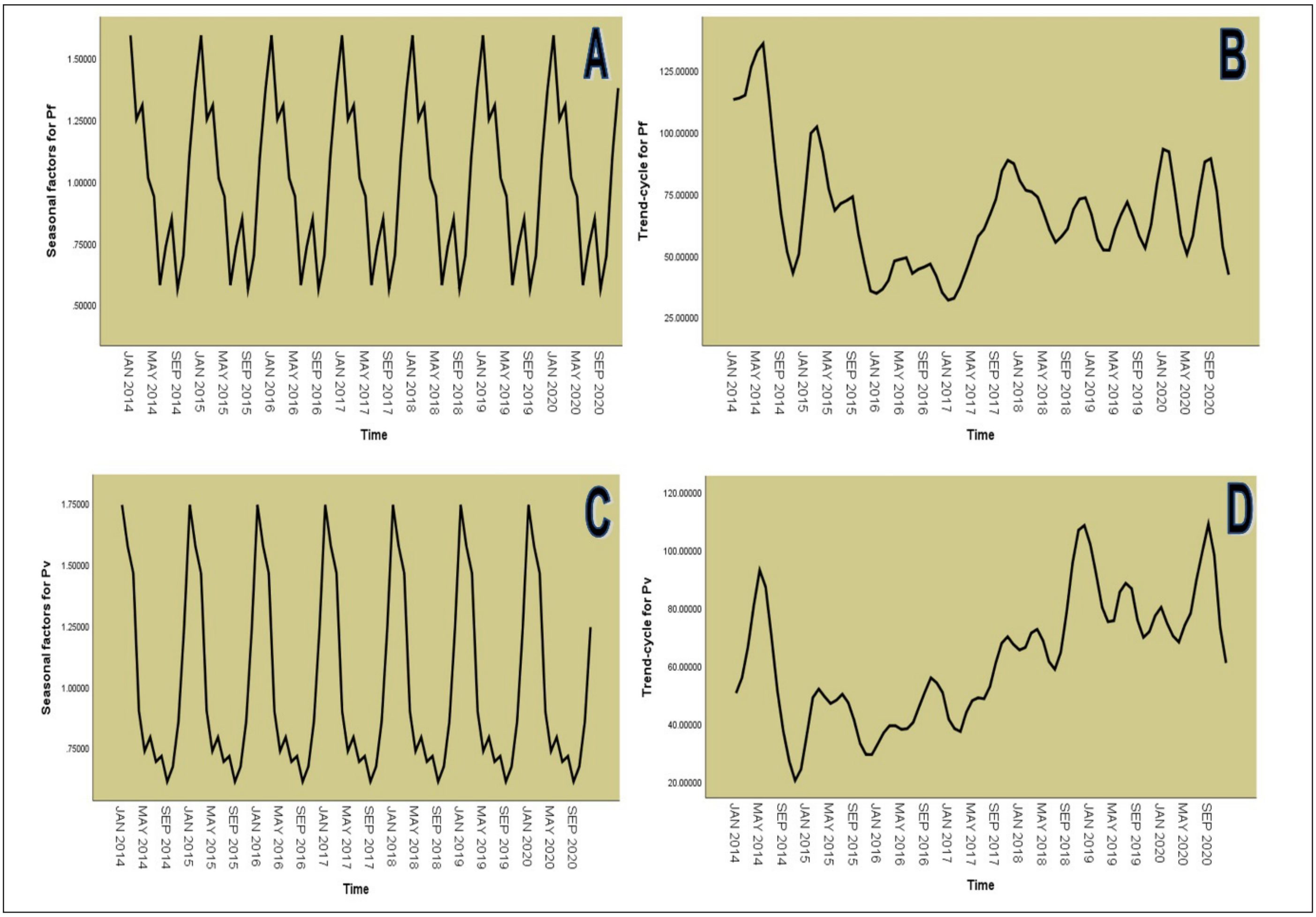

Figure 2. Trends Seasonal Decomposition of Monthly A. Seasonal Factors and B. Trend Cycle for *P. falcifarum* case, C. Seasonal Factors and D. Trend Cycle for *P. vivax* case (2014-2020), East Kalimantan, Indonesia

The Poisson regression model for Plasmodium Falciparum was

$$\ln(Y) = 677.9468 - 24{,}80346_{Xtemperature} + 0.9932632_{Xhumidity} - 0.0636202_{Xrainfall}$$

The amount of humidity positively affected the number of malaria cases in East Kalimantan (Poisson regression model: humidity table X). The temperature and rainfall had a negative effect on the number of malaria cases (Poisson regression model: temperature and rainfall, Table X) (Table 3). The Poisson regression model for Plasmodium Falciparum was

$$\ln(Y) = -\,9.822697 - 10.17071_{Xtemperature} + 4.238997_{Xhumidity} - 0.0501545_{Xrainfall}$$

Table 4. Poisson Regression Coefficients of Weather Data with Malaria Cases (*P. Vivax*) from January 2014 to December 2020 in East Kalimantan, Indonesia

Variable	β	S.E.	*p-Value*
Temperature	-10.17071	7.980327	0.202
Humidity	4.238997	1.413382	0.003
Rainfall	-.0501545	0.0333496	0.133
QICu		**-409.721736**	

AIC: Akaike's information criterion, β: coefficients, S.E: standard error.
AIC: 827.4435, BIC: 837.1667

Table 5. Time-Series Poisson Regression of the Monthly Malaria (*P. Vivax*) Cases (2014-2020) on the Weather Factors in East Kalimantan, Indonesia

Variable	Model I			Model II		
	β	S.E.	*p-Value*	β	S.E.	*p-Value*
Temperature	-2,480,346	9.336792	0.008	-15.68792	8.139636	0.054
Rainfall	-0.06362	0.039018	0.103	-.0001757	0.0302799	0.995
Humidity	0.9932632	1.653624	0.548			
QICu	**-422.9083326**			**-414.1970404**		

Table 6. Time-Series Poisson Regression of the Monthly Malaria (*P. Falciparum*) Cases (2014-2020) on the Weather Factors in East Kalimantan, Indonesia

Variable	Model I			Model II		
	β	S.E.	*p-Value*	β	S.E.	*p-Value*
Temperature	-2,480,346	9.336792	0.008	-26.09623	9.049425	0.004
Rainfall	-0.06362	0.039018	0.103	-0.051909	0.033664	0.123
Humidity	0.9932632	1.653624	0.548			
QICu	**-422.9083326**			**-423.097322**		

The amount of humidity positively affected the number of malaria cases in East Kalimantan (Poisson regression model: humidity table X). The temperature and rainfall had a negative effect on the number of malaria cases (Poisson regression model: temperature and rainfall, Table X) (Table 4).

Humidity is definitely related to malaria occurrence within the subtropical town of East Kalimantan, Indonesia. Temperature and rainfall pace is inversely related to the malaria occurrence of each month.

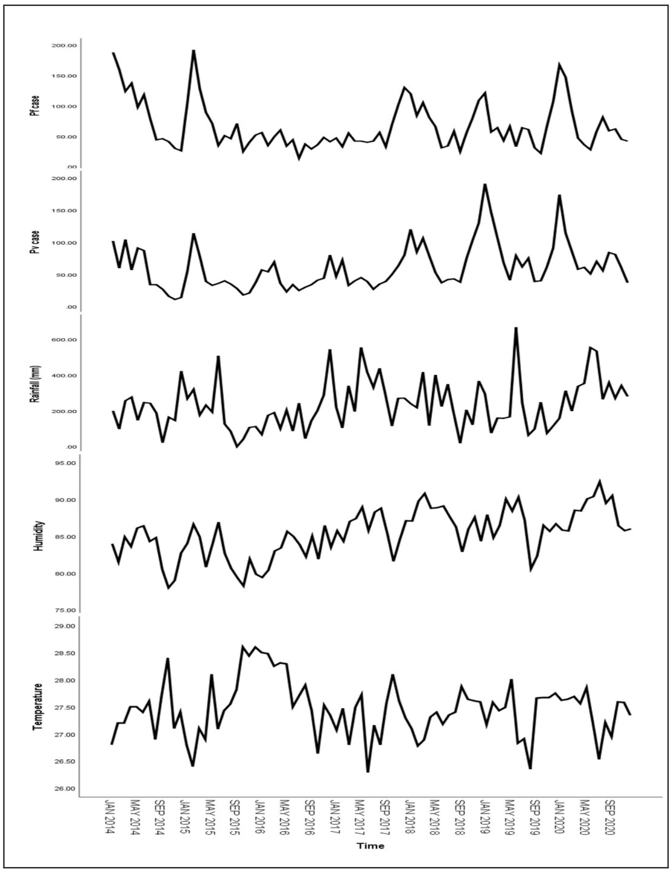

Figure 3. Malaria Case (*P. falciparum* and *P. vivax*). The Weather Data (Rainfall, Humidity, and Temperature) from 2014 to 2020 in the East Kalimantan Provinces of Indonesia.

DISCUSSION

In Indonesia, *P.falciparum* and *P.vivax* are the dominant species compared to *P.malariae, P.ovale,* and *P.knowlesi*. Likewise, on the Borneo island, including East Kalimantan, malaria infection is more dominated by *P. falciparum* and *P. vivax* (17). It is indicated by the very low number of *P. malariae* and *P. ovale* infection cases and does not occur every year in East Kalimantan. The same phenomenon also occurred in South Kalimantan and Central Kalimantan where *P. malariae* and *P. ovale* cases were very rare and almost non-existent throughout the year, while the prevalence of *P. falciparum* infections was 79.2% and *P. vivax* 20.8 % for Central Kalimantan, and 45.7% for the prevalence of *P. falciparum* and *P. vivax* cases in South Kalimantan (18). It is known that *P. malariae* and *P. ovale* are more commonly found in Eastern Indonesia, especially Papua (19). So that the cases of *P.malariae* and *P.ovale* infections in East Kalimantan are suspected to be imported malaria cases brought by immigrants from these endemic areas of Eastern Indonesia.

P.knowlesi is malaria in macaques *Macaca fascicularis* and *M. nemestrina* as reservoir hosts which is transmitted to humans through the bite of *Anopheles Leucosphyrus* spp and *An.latents* mosquitoes (20). *P.knowlesi* is found on the Borneo islands, especially Sarawak, Malaysia, South Kalimantan, Central Kalimantan and East Kalimantan, Indonesia (21). The low number of *P.knowlesi* cases could be due to the relatively rare location of *P.knowlesi* transmission from apes to humans, which generally occurs in the forest. In addition, the process of transmitting *P. knowlesi* between monkeys is also much higher when compared to infection from monkeys to humans (22). In addition, the low number of *P.knowlesi* cases in East Kalimantan may also lead to difficulties, limitation and microscopic identification errors because they are morphologically similar to *P.falciparum* and *P.malariae*, so it is recommended to examine *P.knowlesi* samples using nested PCR (23).

The pattern of malaria cases in East Kalimantan is almost the same as other regions in Indonesia where the highest percentage of malaria cases occurs in men rather than women with an age range of > 15-64 years, namely in the productive age (24). This phenomenon is caused by the fact that men of productive age are more active for activities or work outside, especially working in places and times that have higher potential risk for malaria transmission, such as forests or being outside at night (25). Other factors are related to immunity and the socioeconomic role of men to work outside even at night, thereby lowering the body's immunity and so making it more susceptible to infection with diseases, including malaria (26).

The peak pattern of malaria transmission and cases in East Kalimantan occurred in February for *P. falciparum* and December to February for *P. vivax* and was associated with seasonal patterns in Indonesia. December to February is categorized as the wet months, which is included in the range of the rainy season in Indonesia where high enough rainfall can trigger a risk to appear water puddles on the ground which have the potential to increase the quantity of *Anopheles sp* breeding habitat as a malaria vector (27). The average number of *P. falciparum* and *P. vivax* cases was much lower from June to September, this was also influenced by the dry months with minimal rainfall in that period where the East Kalimantan region is classified as a monsoon region and generally characterized by sparse or unequal with rains from May to September (27) thus causing the dryness of the breeding habitat of the *Anopheles sp,* which also has an impact on decreasing the transmission rate of malaria cases in the area. Likewise, a significant decrease in malaria cases occurred in 2016 associated with a strong El Nino event that occurred from May 2015 to February 2016 (28). El Nino is a natural phenomenon where there is a significant decrease in rainfall and an extension of the dry season so that it can dry up puddles which are the breeding habitat of *Anopheles sp* and have an impact on the decline in the *Anopheles sp* population so that the transmission and number of malaria cases also decreases.

In Bangladesh, the rainfall and humidity were the most significant variables influencing *Anopheles sp* density but temperature were not found as a significant variable on malaria incidence and the abundance of *Anopheles sp* (29). The phenomenon was exactly the same with this study. Other research found that the water temperature was also not significantly correlated with the abundance of *Anopheles* immatures (30). But research in Lampung Province, Indonesia contradicts with the phenomenon and found that water temperature also affects the density of *Anopheles sp,* especially *An.sundaicus* (31).

In terms of malaria control in East Kalimantan Province, in addition to understanding the relationship between climate and malaria incidence, information on species and bionomics of malaria vectors is needed to implement effective control efforts. For example, in Thailand, four species of malaria vectors were found, namely *An. minimus*, *An. maculatus, An. annularis* and *An. barbirostris.* The four vector species have different behavior and tendencies. *An. minimus* has a trend collected throughout the year, with the peak abundance before and after the rainy season. *An. maculatus* shows the main peak during the rainy season while *An. annularis* and *An. barbirostris* showed the peak abundance during the transition from the rainy season to the dry season. In terms of the location of the capture, *An. minimus* is more commonly found indoors, while *An. annularis* and *An. barbirostris* was more abundant in outdoor collections with each species indicating their potential role in indoor or outdoor malaria transmission (32). In Pakistan, temperature changes caused a temporal shift in the presence of the malaria vector *An. subpictus* which predominates in the warm season. This is attributed to the incapacity of *An. subpictus* to tolerate low temperatures in addition to its capacity to resist better conductivity, turbidity, pH and natural pollutants with ammonia from drying conditions throughout the nice and warm season. Larvae and adult mosquitoes of An. subpictus disappear absolutely from January to June and reappear at the start of the monsoon every year (33).

In Meghalaya, India, the distribution of *Anopheles sp* as malaria vectors varies significantly between seasons and regions. The mean density of *Anopheles sp* was significantly higher in urban areas in all seasons, but higher in agricultural and pasture lands area only in the rainy and post-rainy seasons. This shows that there is a significant relationship between land use and land cover modification with the presence of vectors and malaria cases in an area (34). Therefore, the implementation of land use and land cover modification should ideally predict the potential future impacts of deforestation on vector density using information on the type of planned agricultural development adapted to the ecology of the local *Anopheles sp* (35).

A research claimed that *An. nigerrimus* is the one of the malaria vectors in East Kalimantan (36), but the other several species of Anopheles scattered in the Borneo islands also have the potential risk as malaria vectors and include *An. balabacencis, An. barbirostris, An. leucosphyrus, An. maculatus, An. minimus, An. nigerrimus, An. subpictus,* and *An. sundaicus* (37). Most of the Borneo islands are dominated by *An. balabacensis,* but specifically *An. barbirostris* and *An. leucospyrus* is an infectious vector in some areas in the interior, while *An. sundaicus* are dominant species at the coastal areas (38). *An. niggerimus* as a malaria vector in East Kalimantan has the specific characteristic of biting humans outdoors at dusk and at night and is rarely found indoors or in cattle pens. The breeding habitat is in ponds and lakes that are clear and grassy, shady rice fields, or on the banks of rivers with lots of vegetation and sometimes also found in brackish water (39). It is necessary to update information for various types of malaria vector species and their bionomics in East Kalimantan Province, especially for species that have potential as vectors.

In the malaria control program activities in East Kalimantan, it was found that the case recording process was not good where there was a difference in the number of malaria cases between the number of cases per sex and age and the number of cases per species of malaria. A poor case recording system can hinder the achievement of malaria elimination targets in East Kalimantan. Learning from the experience of successful malaria elimination in several other provinces in Indonesia, monitoring and evaluation is one of the activities that support the achievement of elimination. Several things need to be implemented in order to achieve malaria elimination, including mapping of endemic areas, identification of focus areas of transmission, early case finding with collaboration between the community and health workers, preparation of strategic control plans, full support across relevant sectors and local governments, implementation of planned effective control programs, as well as monitoring and evaluation of strategy and control developments (40).

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CONCLUSION

Our investigation confirmed that the connection among malaria instances and climatic elements is multifaceted. Vector bionomics at and perform non-stop tracking of malaria transmission and documenting device developments are wanted in surveillance and manage applications in recognized high-danger regions to be successful for removal purpose in 2030.

REFERENCES

1. Mace KE, Arguin PM, Tan KR. Malaria Surveillance - United States, 2015. *MMWR Surveill Summ*. 2018;67(7):1-28. https://doi.org/10.15585/mmwr.ss6707a1
2. Ferrao JL, Niquisse S, Mendes JM, Painho M. Mapping and Modelling Malaria Risk Areas Using Climate, Socio-Demographic and Clinical Variables in Chimoio, Mozambique. *Int J Environ Res Public Health*. 2018;15(4):795. https://doi.org/10.3390/ijerph15040795
3. World Health Organization. World Malaria Report 2020: 20 Years of Global Progress and Challenges. Geneva: World Health Organization; 2020. https://apps.who.int/iris/bitstream/handle/10665/337660/9789240015791-eng.pdf
4. Chaccour CJ, Alonso S, Zulliger R, Wagman J, Saifodine A, Candrinho B, et al. Combination of Indoor Residual Spraying with Long-Lasting Insecticide-Treated Nets for Malaria Control in Zambezia, Mozambique: A Cluster Randomised Trial And Cost-Effectiveness Study Protocol. *BMJ Glob Heal.* 2018;3(1):e000610. http://dx.doi.org/10.1136/bmjgh-2017-000610
5. Marlinae L, Arifin S, Ulfah N, Sudarmawan S, Warsono SAP. Analysis of Impact of Use of Incident Thickness in Pregnant Woman in Area of Malaria (Gunung Raja Mentawe Village Districts of Tanah Bumbu South Borneo). *Indian J Public Heal Res Dev*. 2018;9(7):90–93. http://eprints.ulm.ac.id/id/eprint/5891
6. Province Health Office of East Kalimantan. Laporan Kasus Malaria Kalimantan Timur. Samarinda: Province Health Office of East Kalimantan; 2017.
7. Beck-Johnson LM, Nelson WA, Paajimas KP, Read AF, Thomas MB, Bjornstad ON. The Importance of Temperature Fluctuations in Understanding Mosquito Population Dynamics and Malaria Risk. *R Soc Open Sci*. 2017;4(160969):1-11. https://doi.org/10.1098/rsos.160969
8. Tyrrell MB, Verdonck K, Muela SH, Gryseels C. Defining Micro - Epidemiology for Malaria Elimination : Systematic Review and Meta-Analysis. *Malar J*. 2017;16(1):1–20. https://doi.org/10.1186/s12936-017-1792-1
9. Akpan GE, Adepoju KA, Oladosu OR. Potential Distribution of Dominant Malaria Vector Species in Tropical Region Under Climate Change Scenarios. *PLoS One*. 2019;14(6):e0218523. https://doi.org/10.1371/journal.pone.0218523
10. Juhairiyah J, Andiarsa D, Indriyati L, Ridha MR, Prasodjo RS, Dhewantara PW. Spatial Analysis of Malaria in Kotabaru, South Kalimantan, Indonesia: an Evaluation to Guide Elimination Strategies. *Trans R Soc Trop Med Hyg*. 2021;155(5):500-511. https://doi.org/10.1093/trstmh/traa125
11. Pradhan S, Hore S, Maji SK, Manna S, Maity A, Kundu PK, et al. Study of Epidemiological Behaviour of Malaria and its Control in the Purulia District of West Bengal, India (2016--2020). *Sci Rep*. 2022;12(1):1–11. https://doi.org/10.1038/s41598-021-04399-x
12. Hasyim H, Nursafingi A, Haque U, Montag D, Groneberg DA, Dhimal M, et al. Spatial Modelling of Malaria Cases Associated with Environmental Factors in South Sumatra, Indonesia. *Malar J*. 2018;17(630):1–15. https://doi.org/10.1186/s12936-018-2230-8
13. Rejeki DSS, Nurhayati N, Budi AJI, 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. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5996329/
14. Central Statistic Agency of East Kalimantan Province. East Kalimantan in Figures. Samarinda: Central Statistic Agency of East Kalimantan Province; 2018.
15. Indonesian Agency for Meteorological, Climatological and Geophysics. Climate Data. Balikpapan: Indonesian Agency for Meteorological, Climatological and Geophysics; 2021. http://www.bmkgbalikpapan.id/
16. Cleveland WP, Tiao GC. Decomposition of Seasonal Time Series: A Model for the Census X-11 program. *J Am Stat Assoc*. 1976;71(355):581–587. https://doi.org/10.2307/2285586
17. Sitohang V, Sariwati E, Fajariyani SB, Hwang D, Kurnia B, Hapsari RK, et al. Comment Malaria Elimination in Indonesia : Halfway There. *Lancet Glob Heal*. 2018;6(6):e604–e606. https://doi.org/10.1016/S2214-109X(18)30198-0
18. Ridha MR, Fakhrizal D, Hidayat S, Liani E. An Overview of Malaria Elimination Efforts in South Kalimantan from 2010 to 2018. *Int J Public Health*. 2021;10(1):97–102. https://doi.org/10.11591/ijphs.v10i1.20617
19. Dini S, Douglas NM, Poespoprodjo JR, Kenangalem E, Sugiarto P, Plumb ID, et al. The Risk of Morbidity

and Mortality Following Recurrent Malaria in Papua, Indonesia: A Retrospective Cohort Study. *BMC Med*. 2020;18(28):1–12. https://doi.org/10.1186/s12916-020-1497-0

20. De Ang JX, Yaman K, Kadir KA, Matusop A, Singh B. New Vectors that are Early Feeders for *Plasmodium knowlesi* and Other Simian Malaria Parasites in Sarawak, Malaysian Borneo. *Sci Rep*. 2021;11(7739):1–12. https://doi.org/10.1038/s41598-021-86107-3
21. Divis PCS, Hu TH, Kadir KA, Mohammad DSA, Hii KC, Daneshvar C, et al. Efficient Surveillance of Plasmodium Knowlesi Genetic Subpopulations, Malaysian Borneo, 2000--2018. *Emerg Infect Dis*. 2020;26(7):1392-1398. https://doi.org/10.3201/eid2607.190924
22. Naik DG. *Plasmodium knowlesi*-mediated Zoonotic Malaria: A Challenge for Elimination. *Trop Parasitol*. 2020;10(1):3-6. https://doi.org/10.4103/tp.tp_17_18
23. Miguel-Oteo M, Jiram AI, Ta-Tang TH, Lanza M, Hisam S, Rubio JM. Nested Multiplex PCR for Identification and Detection of Human Plasmodium Species Including *Plasmodium knowlesi. Asian Pac J Trop Med*. 2017;10(3):299–304. https://doi.org/10.1016/j.apjtm.2017.03.014
24. Umma IA, Robinson WD, Jamilu FA, Gwarzo GD, others. Prevalence of Malaria Parasitaemia among Febrile Nigerian Children with Severe Malnutrition in Northwestern Nigeria. *Niger J Basic Clin Sci*. 2017;14(2):113-116. https://www.njbcs.net/article.asp?issn=0331-8540;year=2017;volume=14;issue=2;spage=113;epage=116;aulast=Umma;type=0
25. Grigg MJ, Cox J, William T, Jelip J, Fornace KM, Brock PM, et al. Individual-Level Factors Associated with the Risk of Acquiring Human Plasmodium Knowlesi Malaria in Malaysia: A Case-Control Study. *Lancet Planet Heal*. 2017;1(3):e97--e104. https://doi.org/10.1016/S2542-5196(17)30031-1
26. Ferring D, Hausermann H. The Political Ecology of Landscape Change, Malaria, and Cumulative Vulnerability in Central Ghanas Gold Mining Country. *Ann Am Assoc Geogr*. 2019;109(4):1074–1091. https://doi.org/10.1080/24694452.2018.1535885
27. Lestari RP, Rachmawati E, Budiwati T, Indrawati A, Nasution RI. Status Deposisi Basah di Beberapa Wilayah Pemantauan di Indonesia Periode 2008-2015. *Ecolab*. 2018;12(2):71–82. https://doi.org/10.20886/jklh.2018.12.2.71-82
28. Anyamba A, Chretien J-P, Britch SC, Soebiyanto RP, Small JL, Jepsen R, et al. Global Disease Outbreaks Associated with the 2015--2016 El Niño event. *Sci Rep*. 2019;9(1930):1–14. https://doi.org/10.1038/s41598-018-38034-z
29. Sharower MG, Latif MA, Uddin SM. Temporal Distribution and Abundance of Mosquito Vectors in Dhaka City. *J Asiat Soc Bangladesh, Sci*. 2020;46(1):27–35. https://doi.org/10.3329/jasbs.v46i1.54226
30. Getachew D, Balkew M, Tekie H. Anopheles Larval Species Composition and Characterization of Breeding Habitats in Two Localities in the Ghibe River Basin, Southwestern Ethiopia. *Malar J*. 2020;19(65):1–13. https://doi.org/10.1186/s12936-020-3145-8
31. Davidson JR, Sukowati S, Asih PBS, Syafruddin D, Baskin RN, St Laurent B, et al. Using Barrier Screens to Characterize Mosquito Composition, Flight Activity, and Abdominal Status in South Lampung, Indonesia. *Parasit Vectors*. 2018;11(440):1–11. https://doi.org/10.1186/s13071-018-3031-1
32. Edwards HM, Sriwichai P, Kirabittir K, Prachumsri J, Chavez IF, Hii J. Transmission Risk Beyond the Village: Entomological and Human Factors Contributing to Residual Malaria Transmission in an Area Approaching Malaria Elimination on the Thailand--Myanmar Border. *Malar J*. 2019;18(221):1–20. https://doi.org/10.1186/s12936-019-2852-5
33. Ananthakrishnan. Insect Functional Dynamics in the Unique Xeric Ecosystem of the Thar Desert, Northwestern Rajasthan (India): Before and After the Advent of Indira Gandhi Nahar Pariyojana. New Pali Road: Tanay Sharma; 2017. https://www.scientificpubonline.com/bookdetail/Insect-Biodiversity-Functional-Dynamics-and-Ecological-Perspectives/9788172336417/85
34. Chen D, Shevade V, Baer A, He J, Hoffman-Hall A, Ying Q, et al. A Disease Control-Oriented Land Cover Land Use Map for Myanmar. *Data*. 2021;6(63):1-15. https://doi.org/10.3390/data6060063
35. Fornace KM, Diaz A V, Lines J, Drakeley CJ. Achieving Global Malaria Eradication in Changing Landscapes. *Malar J*. 2021;20(69):1–14. https://doi.org/10.1186/s12936-021-03599-0
36. Setiyaningsih R, Yanti OA, Lasmiati L, Mujiyono M, Prihatin MT, Widiarti W, et al. Keanekaragaman Anopheles dalam Ekosistem Hutan dan Resiko Terjadinya Penularan Malaria di Beberapa Provinsi di Indonesia. *Media Litbangkes*. 2019;29(3):243–254. https://doi.org/10.22435/mpk.v29i3.1460
37. Heriyanto B, Boe DT, Widiarti, Boesri H, Widyastuti U, Ch.P B, et al. Atlas Vektor Penyakit di Indonesia Seri 1. Jakarta: Ministry of Health of Republic Indonesia; 2011. http://perpustakaan.bppsdmk.kemkes.go.id//index.php?p=show_detail&id=1697
38. Indriyati L, Andiarsa D, Hairani B. Vektor Malaria Baru di Kabupaten Kotabaru, Provinsi Kalimantan Selatan, Indonesia. *Vektora J Vektor dan Reserv Penyakit*. 2017;9(1):1–8. https://doi.org/10.22435/vk.v9i1.4522.1-8
39. Gunathilaka N, Hapugoda M, Wickremasinghe R, Abeyewickreme W. A Comprehensive Analysis on Abundance, Distribution, and Bionomics of Potential Malaria Vectors in Mannar District of Sri Lanka. *Malar Res Treat.* 2019;2019(1650180):1–13. https://doi.org/10.1155/2019/1650180
40. Noviyanti R, Miotto O, Barry A, Marfurt J, Siegel S, Thuy-Nhien N, et al. Implementing Parasite Genotyping into National Surveillance Frameworks: Feedback from Control Programmes and Researchers in the Asia--Pacific Region. *Malaria J*. 2020;19(271):1-20. https://doi.org/10.1186/s12936-020-03330-5