Risk Factors And Impact To Malaria Prevalence At Endemic Forest Areas In South Kalimantan, Indonesia : A Cross Sectional Study

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Research

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Abstract

Background

Malaria is still one of the health problems in many countries including Indonesia. This is because transmission through mosquito vectors still occurs. The transmission of malaria is influenced by many factors including house and environmental conditions. South Kalimantan is one of Province in Indonesia which has endemic area, mainly in the villages at forest area. It is important to know the risk factors of malaria prevalence in an endemic forest areas in South Kalimantan, Indonesia.

Methods

This cross-sectional study was conducted on 107 adult people who lived in Batu Bulan Village and Batu Paha Village, South Kalimantan. Blood samples for malaria microscopy and Rapid Diagnostic Test is taken from cubital vein. Household factors and demographic data were obtained. Chi-square and logistic regression were performed to analyze the factors associated with malaria prevalence in South Kalimantan.

Results

The prevalence of malaria based RDT examination was 35,5% with 23.68% *Plasmodium falciparum*, 21,05% *Plasmodium vivax* and 55,27% Mix infection. Prevalence malaria based on microscopic examination was 17,75% with 47.36% % *Pl. falciparum*, 26.32% *Pl.vivax* and 26.32% *mix infection.* Demographic factors influencing the prevalence of malaria were aged below 25 years old (p = 0,01,95% Cl, OR = 2,289), villages in Batu Paha (p = 0,048,95%Cl, OR = 3,55), and occupation as a forest worker (p = 0,022,95%Cl, OR = 6,38). House factors that influence the prevalence of malaria were the condition of the walls that are open or not tight (p = 0.048 95%Cl, OR = 5,205), the roof is made of plastic (p = 0,015 95%Cl, OR = 2,831), and the presence of animal cage around the house (p = 0,015 95%Cl, OR = 6,292).

Conclusions

Malaria incidence remains occurs with high prevalence in the pupolation in remote forest areas. Intensive malaria management is needed to prevent entry and exit of people in the forest, improvement of housing conditions, expansion of the use of insecticide mosquito nets, and treatment for asymptomatic and symptomatic patients. This Intervention could have a huge impact on the success of the national malaria elimination goals.

Background

The incidence of malaria in the world has decreased significantly from 238 million to 229 million from 2010 to 2019. Case Incidence (per 1000 population) has also decreased from 80 to 58 and 57 from 2010, 2015, and 2019. So, between 2010 to 2015 there was a decrease of 22%, and between 2015 to 2019 there was a decrease of 1%. This indicates a slowdown in the decrease in the average incidence [1].

Malaria cases in Southeast Asia from 2000 to 2019 also decreased from 23 million to 6.3 million from 2010 to 2019. This 73% decline was also followed by a decrease in case incidence, from 18 to 4 cases from 2000 to 2019 [1]. This reduction in malaria cases is related to the success of various programs that have been implemented such as distribution of long-lasting insecticide treated nets (LLINs), use of indoor residual spraying (IRS), wide coverage of diagnosis using microscopes and rapid diagnostic tests, and easy access to treatment [2]. Even so, there is still a high burden in managing malaria, including the difficulty of eliminating malaria in remote areas which are the largest contributor to current cases [3].

Data from the Ministry of Health shows that The Annual Parasite Incidence (API) for South Kalimantan in 2017 was 2.09. There are 96 villages in the red category across 9 districts, one of which is Tanah Bumbu District with an API of 0.54 in 2016, 0.49 in 2017, and 0.17 in 2018. Although there has been a significant decrease in malaria cases in the last three years, still found red category villages in Kusan Hulu and Mantewe Districts. The villages with high case incidence (HCI) in Kusan Hulu and Mantewe Districts are mostly located in remote areas with secondary forest areas and on the edge of the forest [4]. Forests are one of the ecosystems that can support the formation of an environment where malaria vectors can reproduce [5, 6, 7]. Malaria in this area is the biggest contributor to malaria prevalence in South Kalimantan. Barriers to eradicating malaria in this area including difficulty road access, minimal health facilities, inadequate infrastructure, high population mobility to the forest due to socio-economic factors, and a lack of knowledge about malaria transmission.

The environment is an important factor in malaria transmission [5]. As a human and mosquito vector habitat, the influence on human behavior and the reproduction of mosquitoes is very large [7]. Anopheles mosquitoes that live in certain environments must have a habit of biting humans and have a long life cycle. This is needed by the parasite to complete its life cycle to produce an infective form (sporozoite) and transmit it to humans. Environmental temperature also affects the speed of Plasmodium development in the mosquito's body, the intensity of malaria transmission increases after the rainy season which is associated with an increase in the mosquito population. [8, 9, 10].

Other environmental factors such as the existence of breeding places for Anopheles mosquitoes (rivers, swamps, ponds, rainwater puddles) and changes in forest function affect malaria transmission significantly [2, 3, 5]. The existence of standing water can be a source of breeding for mosquitoes, especially close to residential areas [3]. Changes in forest function also affect socio-economic changes that have an impact on the incidence of malaria. For example, land clearing due to logging activities is associated with unstable conditions, including population mobility, exposure to non-immune people, and housing conditions conducive to transmission [11].

Several studies have shown an increase in the incidence of malaria in areas experiencing deforestation, especially in Africa and Latin America but decreasing in Asia. Deforestation leads to an increase in ambient temperature [12], more sunshine and puddle [13], which causes an increase in the life cycle of mosquitoes [14], the rate of growth and pupa formation is faster [15], longer survival time [16] and the high frequency of mosquito bites [17, 18].

To support the elimination program in 2030, it is necessary to carry out research related to the factors that influence the prevalence of malaria in the population in endemic areas in South Kalimantan, especially the housing and environmental conditions factors. The hypothesis that needs to be proven is the house or place residence condition that affects the malaria prevalence in forest areas. The results of this study can be used as a basis for making appropriate and effective malaria eradication program policies.

Methods

Study Area and Population

The study was conducted within Kusan Hulu District in Tanah Bumbu Region of South Kalimantan Province (20º 57' 0" LS – 30º 38' 24" LS dan 1150 24' 0" BT – 1150 49' 12" BT). The population of that district was 19.861. We did a descriptive analysis and conducted a cross-sectional study to identify environmental factors associated with malaria. Data were collected in September 2020, the early rainy season. Malaria transmission usually peaks during the rainy season, but in this district incidence of malaria is considered high throughout the year. Previous studies have documented a greater than 50% prevalence in adults. All participating respondents in this study were men and women aged 16 until 60 years and resided in two villages (Batu Bulan and Batu Paha). Sampling was done using simple random sampling of all residents who met the inclusion criteria. Villages were selected based on criteria: endemic area of malaria with annual parasite index in 2018 was more than 1%. The research was conducted in selected areas involving the health office, the malaria program manager at the local public health center, and the village authorities. Researchers and village officials will visit every house to conduct interviews, collect venous blood, and observe the surrounding environment.

Variables

We used a standardized questionnaire from kinds of literature to collect data from participants. The questionnaire was administered by trained interviewers to collect data on patient age, gender, the residence of villages, education, occupation, ethnicity, and house condition including roof condition, walls, having a house ceiling, using a mosquito wire screen, and having animal cage.

Malaria Diagnostic

The venous blood that has been taken will be dropped onto an object-glass to make thin and thick blood preparations and measured with RDT. Microscopic identification of malaria will be carried out at the Parasitology Laboratory at Faculty of Medicine Universitas Lambung Mangkurat.

Rapid Diagnostic Test Examination

Qualitative detection of *Plasmodium* spp antigens, Histidine-rich protein II (HRP2) expressed by *P. falciparum* or parasite lactate-dehydrogenase (pLDH) metabolic enzyme, expressed by all species of *Plasmodium* spp. (Pf/pan) using lateral flow immunochromatography devices containing antigen-specific monoclonal antibodies from mice. Using a capillary tube (5 μL), the whole blood sample is collected until it reaches the black line and transferred to the cassette sample well. Four drops of diluent are added vertically for testing in the well. The result is read after 15–30 min. A result is considered negative if a color band is observed in line 'C'; it is *P. falciparum*-positive if 2 colour bands are observed inline 'P.f' and C, or 3 colour bands in lines P.f, 'Pan' and C; the test is considered positive for another species of *Plasmodium* (*Plasmodium vivax*, *Plasmodium malariae*, *Plasmodium ovale*) if 2 colour bands are observed inline Pan and C. A colour band should always be observed inline C, otherwise it is considered as an invalid result and the test must be repeated.

Microscopic Diagnosis

Thick and thin blood smears were made on the same slide at the same time, air-dried for one night, and fixation with methanol. The slides were transported to the parasitology laboratory, the faculty of Medicine Banjarmasin. The slides were stained with 3% Giemsa for 10 min and screened for the presence of Plasmodium infections. The slides were read by a microscopist who was blinded to the individual RDT results. A slide was classified as negative if no *Plasmodium* asexual forms or gametocytes were found after counting 500 WBCs. Thin blood films were examined for *Plasmodium* species by counting the number of parasites per 5000 red blood cells (RBCs). For quality control purposes, a second experienced microscopist randomly selected 5% of the slides for re-examination.

Data Processing and Analysis

Data were checked for completeness and consistency and entered into an SPSS 25.0 (SPSS Inc) database. Descriptive analyses were conducted frequency with percentages for categorical variables. Both Chi-square (X2) test and multivariable Logistic Regression were performed to identify factors associated with the prevalence of malaria. An error probability (P-value) of < 0,05 was considered statistically significant. Data were presented using odds ratio (OR).

Ethical Consideration

This study was reviewed and approved by the ethical commission research at the Faculty of Medicine,

Lambung Mangkurat University Banjarmasin, Indonesia with number 292/KEPK- FK unlam/EC/IX/2020.

Figure 1. Map of Kusan Hulu District [19].

Result

Sociodemographic Characteristics

A total of 107 participants were included in this study. All of them living in Batu Bulan and Batu Paha villages. The mean age was 34,14 years old. Minimum 16 years old and maximum 60 years old with standard deviation of 11,12. In this study, we divided age into two groups (under 25 years old and upper 25 years old) and most of the participants were more than 25 years old (67,3%). Fifty-two (48,6%) of the participants has never attended school and fifty-five had attended school, but mostly only elementary school. 64,5% of the participants were male and 73,8% worked as forest workers (Table 1).

Table 1 Below presents a summary of the sociodemographic characteristics of the subject population in this study.

Variables	Frequency (N=107)
Age	
<25	35 (32,7%)
>25	72 (67,3%)
Gender	
Male	69 (64,5%)
Female	38 (35,5%)
Ethnicity	
Banjar	102 (95,3%)
Dayak	5 (4,7%)
Villages	
Batu Bulan	69 (64,5%)
Batu Paha	38 (35,5%)
Education	
No school	52 (48,6%)
School	55 (51,4%)
Occupation	
Forest workers	79 (73,8%)
Non-Forest workers	28 (26,2%)

Household characteristic factors

All houses owned by participants are not permanent with wooden walls and are not tight /open mostly (77,6%). 78.5% of the participants did not have a ceiling in their house, a small part (14%) of the roof uses plastic. Most of them also did not use mosquito netting (86.9%), a small proportion of the houses had stagnant water around the yard (35.5%). Animal cages were found in a small proportion of the participants' houses (14%) (Table 2).

Table 2 House hold characteristic factors

Variables	Frequency (N=107)
Wall	
Open	83 (77,6%)
Closed	24 (22,4%)
Have a house ceiling	
No	84 (78,5%)
Yes	23 (21,5%)
Roof	
Plastic	15 (14%)
Tin roof	92 (86%)
Mosquito wire screen	
No	93 (86,9%)
Yes	14 (13,1%)
Body water (puddles)	
Yes	38 (35,5%)
No	69 (64,5%)
Animal Cage	
Yes	15 (14%)
No	92 (86%)

Prevalence of malaria parasites in this study population

Thirty-eight (35,5%) participants in this study had Rapid Diagnostic Test confirmed malaria positivity but just only 19 participants (17,75%) had microscopically confirmed malaria parasites in their blood sample. The most of *Plasmodium* species in RDT were mixed of *P.falciparum* and *P.vivax* 21 (19,6%), followed by *P.falciparum* 9 (8,4%) and *P.vivax* 8 (7,5%). But in microscopic examination, the dominant *Plasmodium* species were *P.falciparum* 9 (47,36%), followed by *P.vivax* 5 (26,32%) and 5 (26,32%) showed mixed infections of *P.falciparum* and *P.vivax* (Table 3).

Table 3. Prevalence of malaria among the study participants

Mode of Examinations	No.of Participans	No.positive (%)	Positive for *P.f* (%)	Positive for *P.v* (%)	Positive for mixed (%)
Rapid Diagnostic Test	107	38 (35,5%)	9 (23,68%)	8 (21,05%)	21 (55,27%)
Microscopic	107	19 (17,75%)	9 (47,36%)	5 (26,32%)	5 (26,32%)

Factors associated with malaria positivity

The malaria prevalence data used to determine the relationship between risk factors and malaria incidence were based on microscopic examination. The potential risk factors associated with the incidence of malaria in this study were age, the village of residence, occupation, condition of the walls of the house, the type of roof used, and the presence or absence of an animal cage (Table 4).

Table 4. Risk factors analysis for malaria positivity detected by LM using chi-square test

Variables	Test Positivity			
	Negative	Positive	OR (95% CI)	*p* (95% CI)
Age				
< 25 years	68,58% (24/35)	31,42% (11/35)	2,289	0,010
>25 years	88,88% (64/72)	11,12% (8/72)		
Gender				
Male	81,16% (56/69)	18,84% (13/69)		0,693
Female	84,21% (32/38)	15,79% (6/38)		
Ethnicity				
Banjar	82,35% (84/102)	17,65% (18/102)		0.893
Dayak	80% (4/5)	20% (1/5)		
Villages				
Batu Bulan	76,81% (53/69)	23,19% (16/69)	3,522	0,048
Batu Paha	92,10% (35/38)	7,9% (3/38)		
Education				
No School	78,85% (41/52)	21,15% (11/52)		0,371
School	85,45% (47/55)	14,55% (8/55)		
Occupation				
Forest workers	77,2% (61/79)	22,8% (18/79)	6,380	0,022
Non Forest workers	96,4% (27/28)	3,6% (1/28)		
Wall				
Open	78,3% (65/83)	21,7% (18/83)	5,205	0,048
Closed	95,8% (23/24)	4,2 % (1/24)		

Variables	Test Positivity			
	Negative	**Positive**	**OR (95% CI)**	***p* (95% CI)**
Have a house ceiling				
No	79,8% (67/84)	20,2% (17/84)		0,199
Yes	91,3% (21/23)	8,7% (2/23)		
Roof				
Plastic	60% (9/15)	40% (6/15)	2,831	0,015
Tin roof	85,9% (79/92)	14,1% (13/92)		
Mosquito wire screen				
No	80,6% (75/93)	19,4% (18/93)		0,265
Yes	92,9% (13/14)	7,1% (1/14)		
Body water (puddles)				
Yes	76,3% (29/38)	23,7% (9/38)		0,234
No	85,5% (59/69)	14,5% (10/69)		
Animal Cage				
Yes	60% (9/15)	40% (6/15)	6,292	0,015
No	85,9% (79/92)	14,1% (13/92)		

Table 4 shows that age under 25 years is one of the risk factors in this study with a malaria prevalence of 31.42% compared to participants over 25 years of age ($p < 0.05$; OR = 2.289). Table 4 also shows that participants who live in Batu Bulan Village have a greater chance of getting malaria infection with a percentage of 23.19% ($p < 0.05$; OR = 3.522). Batu Bulan is a village in the middle of a forest inhabited by people who work as forest workers. Occupation is one of the factors that influence the incidence of malaria in this study where participants who work in the forest both as gold miners and woodcutters get malaria by 22.8% compared to participants who work not in the forest ($p < 0.05$; OR = 6.380).

Table 4 shows the condition of the participants' houses that affect the malaria incidence, in which 21.7% of participants with open house walls get malaria infection, while participants with the closed house wall are only 4.2% ($p < 0.05$; OR = 5.205). Likewise, the condition of the roof of the house made of plastic is a risk factor for the incidence of malaria, where in this study it was found that 40% of participants were infected with malaria from all participants whose roofs were made of plastic compared to roofs made of zinc ($p < 0.05$; OR = 2.831). A roof made of plastic is a roof that is not permanent, easily damaged due to sun exposure and heavy rain, so the possibility of mosquitoes getting into and biting the occupants is very large. Another factor that affects the prevalence of malaria in this study is the presence of animal sheds around the house, where in this study it was found that 40% of participants were infected with malaria compared to participants who did not have an animal pen, which was only 14.1% ($p < 0.05$; OR = 6.292.). The type of animal cage owned by residents is a chicken coop and this cage is placed between 2 and 3 meters from the house.

Sociodemographic factors that were not directly related significantly in this study were gender, race, and education. Although it was not directly related statistically ($p > 0.05$), it appears descriptively that the incidence of malaria in men was more (18.84%) compared to women (15.79%). Most of the participants were Banjarese (95.3%) who 17.65% had malaria parasites in their blood based on microscopic examination. In contrast to the Dayak tribe, only 4.7% of all participants, but 20% of them had malaria parasites in their blood ($p > 0.05$). The education category of participants in this study was almost the same between those who did not go to school (48.6%) and those who were in school (51.4%). Most of those who attend school are elementary school graduates (72.9%), while junior and senior high school graduates are still very few (18.1%, 9% respectively). As many as 21.15% of participants who did not go to school were found malaria parasites in their blood, while in school participants only 14.55% were found. Although there were differences between participants who went to school and those who did not go to school, statistically there was no significant relationship ($p > 0.05$). Several factors related to the condition of the house that were not related to the incidence of malaria in this study were the presence or absence of a ceiling in the house, installing mosquito nets, and the presence or absence of standing water around the house. As many as 78.5% of the participants did not have a ceiling in their place, 86.9% did not install mosquito netting, and only a fraction (35.5%) had standing water around their house. About 20.2% of participants with a house without a ceiling found malaria parasites in their blood, while in participants with a house with a ceiling only 8.7% had parasites found. As many as 19.4% of participants who did not install mosquito wires found parasites in the blood, while only 7.1% of participants who installed mosquito wires were positive for malaria. In the participants with standing water at home, 23.7% were found to be positive for malaria, while the participants who did not have stagnant water were only 14.5%.

Discussion

The incidence of malaria in South Kalimantan province has experienced a very significant decline in recent years. However, in several districts, including Tanah Bumbu, malaria cases were still found, especially in remote areas. Kusan Hulu sub-district is one of the districts that still have malaria-red areas. The research village is a remote area located in the Meratus mountain plain and included in a protected forest area. Therefore road infrastructure is still an obstacle to access to villages in this region. Conditions like this are one of the complications in eradicating malaria [20, 21].

The incidence of malaria usually increases at the end of the rainy season. Even so, malaria cases always occur every month in this study area. Other studies have shown that although malaria cases increased significantly in May, October to July, there are always case reports every month [22]. This research was conducted in September 2020 which is the beginning of the rainy season. The prevalence of malaria is 18.1% at the beginning of the rainy season, indicating that malaria transmission continues throughout the year in this area. The reason is that it still rains, even though it is in the dry season. High sun exposure causes a high intensity of evaporation so that there are always active clouds. The average length of exposure ranges from 1.2 hours to 7 hours in September 2020. The average rainfall intensity ranges from 0.9–16 mm, with the number of rainy days ranging from 5–28 days/month. The average minimum temperature during the dry season is 22.7^{o}C – 24.7^{o}C and the average maximum temperature is 30.5^{o}C – 32.9^{o}C [23]. This condition is a good condition for the breeding of Anopheles sp [24].

Research in Guangdong, China showed that the temperature threshold associated with malaria transmission is unclear [25], yet, Kim et al. showed that malaria transmission changes slightly above 24°C in Korea. This may be due to the relatively shorter temperature range in sub-tropical [26]. In contrast to Indonesia, which has a tropical climate with 2 seasons, where the average temperature is relatively hot. It is known that the optimal development of the malaria parasite at temperatures between 25–30^{o}C. Research also shows that at hotter temperatures, *P. falciparum* reproduction is more optimal than *P.vivax*. *P.falciparum* undergoes the entire life cycle in a shorter time at temperatures of 28–30°C. Heat favors the development of *P. falciparum* and may have a significant effect on mosquito infection rates and parasite density. *Plasmodium vivax* completes growth and development in a wider range from 15 to 30°C and may therefore be less sensitive to temperatures [25].

The relationship between malaria transmission and temperature is still widely debated. Several studies using the Martens 3, Bayoh-Mordecai, and Bayoh-Lunde models show that malaria transmission is more efficient at 25^{o}C, but based on the Martens 2 and Bayoh Ermert model, malaria cases were more prevalent in areas with temperatures approaching 27^{o}C. The Martens 1 model has a peak temperature of 20.4^{o}C and Bayoh-Parham at 26.3^{o}C [27]. This explains why in high mountain areas with temperatures below 18^{o}C, malaria transmission is rare and almost doesn't exist. However, if the temperature increases, there will be an increase in transmission. Liu et al. showed that an increase in temperature of 5^{o}C – 10^{o}C would result in a 22% increase in malaria cases within 4 weeks [28].

The number of rainy days in the rainy season in South Kalimantan ranges from 20 to 30 days/month within light (50 mm) to heavy (100 mm) and very heavy (> 150 mm) rainfall. The average humidity in this area is between 80–90% [23]. Rain can form new puddles that can become breeding places for Anopheles mosquitoes, this will increase the density of vector mosquitoes. This has led to an increase in malaria cases during the rainy season and beyond. However, very heavy and extreme rainfall do not always cause an increase in the breeding place for Anopheles mosquitoes. Research shows that in areas with very heavy or extreme rainfall, mosquito eggs and larvae are washed away and wasted, disrupting the development cycle [29].

Plasmodium falciparum was the most common species in this study, with about 47.37% of all malaria-positive, followed by *P. vivax* and mixed infections. This study has similarities with the research of Nath and Mwchahary in India which showed that the prevalence of *P. falciparum* was still high in forest and non-forest areas [8]. The high of *P. falciparum* infection indicates a risk of serious complications. However, falciparum malaria can be treated quickly using an artemisinin regimen. In contrast to *P. vivax* infection, which is usually more difficult to treat because it has a hypnozoite stage in the liver [30]. To kill this hypnozoite stage, treatment with Primakuin is required for a longer oral administration time and potentially causes low drug adherence rates. *P.vivax* also can transmit malaria despite the low parasite density in the blood. Mixed infections (*P. vivax* and *P. falciparum*) that are persistent and usually asymptomatic are common in areas within low malaria transmission. Infections with low-density parasitemia can progress to high-density infections at other times, and this tends to maintain the level of endemicity [31, 32, 33].

Most of the participants with positive malaria parasites in this study were asymptomatic. It is probably a consequence of acquired immunity due to the high transmission intensity in this area. People with asymptomatic malaria have the potential to spread and sustain transmission if they are not detected and given treatment. This research was conducted at the beginning of the rainy season, which theoretically is not the peak of malaria transmission. It is possible to find more cases during the peak season of transmission at the end of the rainy season. Therefore, it is necessary to carry out regular surveillance to detect and monitor asymptomatic malaria to prevent wider transmission [31, 32].

Batu Bulan and Batu Paha Villages are the remote villages in Tanah Bumbu Regency. These two villages are on the border with Banjar Regency. Most of the people who live in this village are Banjarese. Another tribe that also exists is the Dayak tribe, although the numbers are small. They have lived side by side for a long time, making physical ethnic separation extremely difficult. Ethnically, there is no significant difference in the incidence of malaria between the two tribes. Apart from being mixed, the factor of the same occupation as forest workers was the reason there was no significant difference in the prevalence of malaria based on ethnicity. The study by Achidi et al. in Cameroon shows that there are differences in the number of parasitemia in 3 different tribes even though they live in the same area. This difference is due to a genetic variation in the immune response to a pathogen [34]. Some tribes have a certain susceptibility to malaria, while others may be more resistant to infection. However, the research also shows that this difference is due more to pathogenic factors than to immune factors [35].

Activities in the forest are one of the risk factors for malaria transmission in The Kusan Hulu District. Forest workers were 4,332 times more likely to be infected with malaria through the bite of *Anopheles sp*. The types of work they do are gold miners and woodcutters. Gold mining in these forest areas starts in the morning around 04.00. This is the reason why gold miners are more frequently infected with malaria. Similarly, Sanford et al. showed that working in the forest is a risk factor for malaria transmission in Cambodia 2 to 3 times. This research also shows that living in a village that is in the forest has a high probability of contracting malaria (aOR 12.47) [2]. In Asia-Pacific, forest activities such as agriculture, logging, and gold mining at high risk for exposure to malaria. Workers in these forest areas tend to show patterns of mobility between endemic and non-endemic areas which can contribute to sustaining transmission and even lead to new cases of malaria that have previously been eliminated [36].

The forest ecosystem provides a suitable habitat for the development of the malaria mosquito vector. Environmental factors including climate, vegetation, and the availability of breeding places are important factors in malaria transmission. The mosquito species that is often found in the forest is *Anopheles balabacencis*. This species is the main vector of *P.knowlesi* transmission in Malaysian Borneo [37]. Malaria vectors found in South Kalimantan based on research by Harbach et al. in 1987 are *An. balabacencis* and *An. leucosphyrus* [38]. Research by Indriyati et al., In Siayuh village, Kotabaru district, which is adjacent to the Tanah Bumbu district, shows that the most common species of Anopheles are *An. Tessellatus*, *An.vagus*, *An. Kochi* and *An. hyrcanus* gr. *Anopheles tesselatus* and *An.vagus* are mosquitoes that are potential vectors of vivax malaria, which are commonly found near livestock sheds. Meanwhile, in the gold mining area, there are many species of *An. maculatus* and *An. leucosphyrus* [39]. This is also similar to the research of Edward et al., which shows that *An. maculatus* is the most dominant vector in the gold mining area on the border of Thailand and Myanmar [40].

Vector species and their biting behavior are important factors in malaria transmission in some areas with high insecticide-treated bed nets coverage [40]. Some areas show that vector biting behavior in the early evening or at dawn affects the incidence of malaria despite the very high use of bed nets. The main vector with its characteristics and behavior in an area must be known so that prevention can be carried out appropriately and effectively. The habit of biting vectors such as indoors or outdoors, the time of biting, and their preference for animal or human blood will affect the transmission of malaria in an area [41, 42, 43].

The structure of the house has been proven to be one of the factors that facilitate the transmission of malaria [41, 42, 43]. The results of this study indicate that almost all residents own houses with wooden walls and tin roofs. Only a small proportion of the population has a plastic roof. The population who experienced malaria infection in this study had a partially open house. The malaria vector biting outdoors will freely enter this open house and obscure the indoor/outdoor bite difference. People are more easily exposed to mosquito bites if they live in a shack or temporary house where the walls are mostly open and the roof is not permanent [40]. A study in Vietnam showed that wooden or bamboo houses had a higher risk than permanent houses in the same village (odds ratio 4.18 Cl 1.45–12.10) [6]. It is easier for mosquitoes to enter houses with wooden or bamboo walls through open gaps. Arranging bamboo or wood in an overlapping or layered manner can reduce the possibility of mosquitoes entering the house. The use of insecticide-treated mosquito nets in the house that is not tight can reduce the bite of malaria vector [44]. Similar observations in Gambia and Ethiopia show that houses equipped with ceilings and mosquito nets can reduce the density of mosquitoes inside the house [45, 46, 47].

The existence of cattle sheds around the house or inside the house is one of the risk factors for malaria transmission [48]. In this study, residents who had cattle sheds around their houses were more likely to be exposed to malaria (OR = 6.292) compared to residents who did not have cattle sheds. The livestock that kept in this village is chickens and goats with a cage distance from the house ranging from 2 to 3 meters. Having cattle sheds can lead to an increase in vector density around the house. This risk will increase if the cage is inside the house [49]. It shows that livestock can attract Anopheles, especially those that are zoophilic. The presence of livestock can also reduce Anopheles mosquito bites in the home, but not all studies support this result. The impact of livestock on malaria and vector density is complex. Some studies show that livestock provides zooprophilic protection while other studies show that livestock increases the risk of [50.51].

The research of Hasyim et al. shows that there is a positive relationship between keeping animals in the house and the prevalence of malaria (AOR = 2.809). The explanation for this result is that the presence of livestock attracts the population of mosquitoes that are vectors of Plasmodium into the house, thereby increasing exposure to humans through zoopotentiation. Zoopotentiation can also occur if physical disturbance caused by animals (e.g., standing water, hoof prints, watering sites) increases the potential for larval habitat and therefore increases vector density near houses [48]. Increased abundance of goats or sheep has been shown to increase Anopheles mosquito abundances. within a 20 m radius around Kenyan households. Each additional goat or sheep increases local malaria vector abundance [52].

Limitation of Research

The weakness of this study is that data collection was only carried out once in September 2020, ifthere is a prolongation time this time is extended it may be possible to obtain a more larger number of participants. Besides, access to the research area is tremendously difficult, accompanied by grossly inadequate infrastructure, making the process of storing blood sampling difficult. This study also did not measure temperature and rainfall in real-time, only taking data from the Meteorology and Geophysics Agency. Entomological measurements were also not carried out, due to the limitations of the researchers. However, this study can be a preliminary study to see the relationship of malaria with density, behavior, and habits, as well as the presence or absence of Plasmodium in the mosquito vector body.

Recommendations

The results of this study indicate the large potential for malaria transmission in remote forest areas with people working in the forest as the main occupation. People who live in villages in the middle of the forest with houses that are structurally open and uninhabitable leave them unprotected from mosquito bites. The existence of livestock sheds increases the risk of malaria infection because animals can act as vector attractants. All of these factors contribute to maintaining transmission through undetected infection. Surveillance in this remote area is tremendously difficult to carry out due to difficult road access, lack of lighting with electricity, and long distances from public health centers. By knowing the risk factors and their barriers, a more precise and effective malaria management program can be planned for this area. Intervention efforts such as reducing the reservoir or breeding place of *Anopheles sp.* in gold mine excavations, routine screening, and mass drug administration based on the screening results can help reduce malaria transmission. Expanding the usage of insecticide-treated mosquito nets to the population and replacing them regularly can be done, especially for houses that are not tight and whose roofs that made of plastic. Spraying houses with tight walls, especially at resting places for mosquitoes in the house, avoiding keeping animals in the house, and keeping livestock away from the house can help reduce the likelihood of mosquito bites in humans. The formation of malaria volunteers who are tasked with conducting counseling and screening in remote villages can also be an alternative in the management of malaria eradication planning so that the goal of malaria-free Indonesia by 2030 can be achieved.

Conclusions

This study provides evidence on factors that influence the high prevalence of malaria in remote forest areas in South Kalimantan. The factors that influence malaria are age, village, occupation, and the structure of the house. The influential factors of the house are the walls that are not tight/open, the roof made of plastic, and the presence of animal cages around the house. Intensive malaria management is needed to improve housing conditions, expansion of the use of insecticide mosquito nets, and treatment for asymptomatic and symptomatic patients. This intervention could have an enormous impact on the success of the national malaria elimination goals.

Abbreviations

AOR = adjusted odds ratio

API = Annual parasite incidence

OR = Odds ratio

RDTs = Rapid diagnostic tests

IRS = Indoor residual spraying reduction

Declarations

Ethics Declarations

We further confirm that any aspect of the work covered in this manuscript that has involved population has been conducted with the ethical approval and that such approvals are acknowledged within the manuscript. This study was reviewed and approved by the ethical commission research at the Faculty of Medicine, Lambung Mangkurat University Banjarmasin, Indonesia with number 292/KEPK- FK unlam/EC/IX/2020. All participants gave written concent.

Concent for Publication

Not applicable

Competing Interest

The authors declare that they have no competing interests

Availability of data and materials

All data is available on reasonable request

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Contributions

II conceived the study, designed the study tools, conducted the interviews, data analysis and wrote the draft of manuscript. UH has provided direction related to the research concept and research flow, data analysis and improvement of the draft manuscript. YPD has provided guidance to strengthen research concepts and conduct research, analyse data and improve manuscript drafts. HA has assisted in the development of the research flow, examination methods, reading the results of data analysis, improving manuscripts and final reports.

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Figures

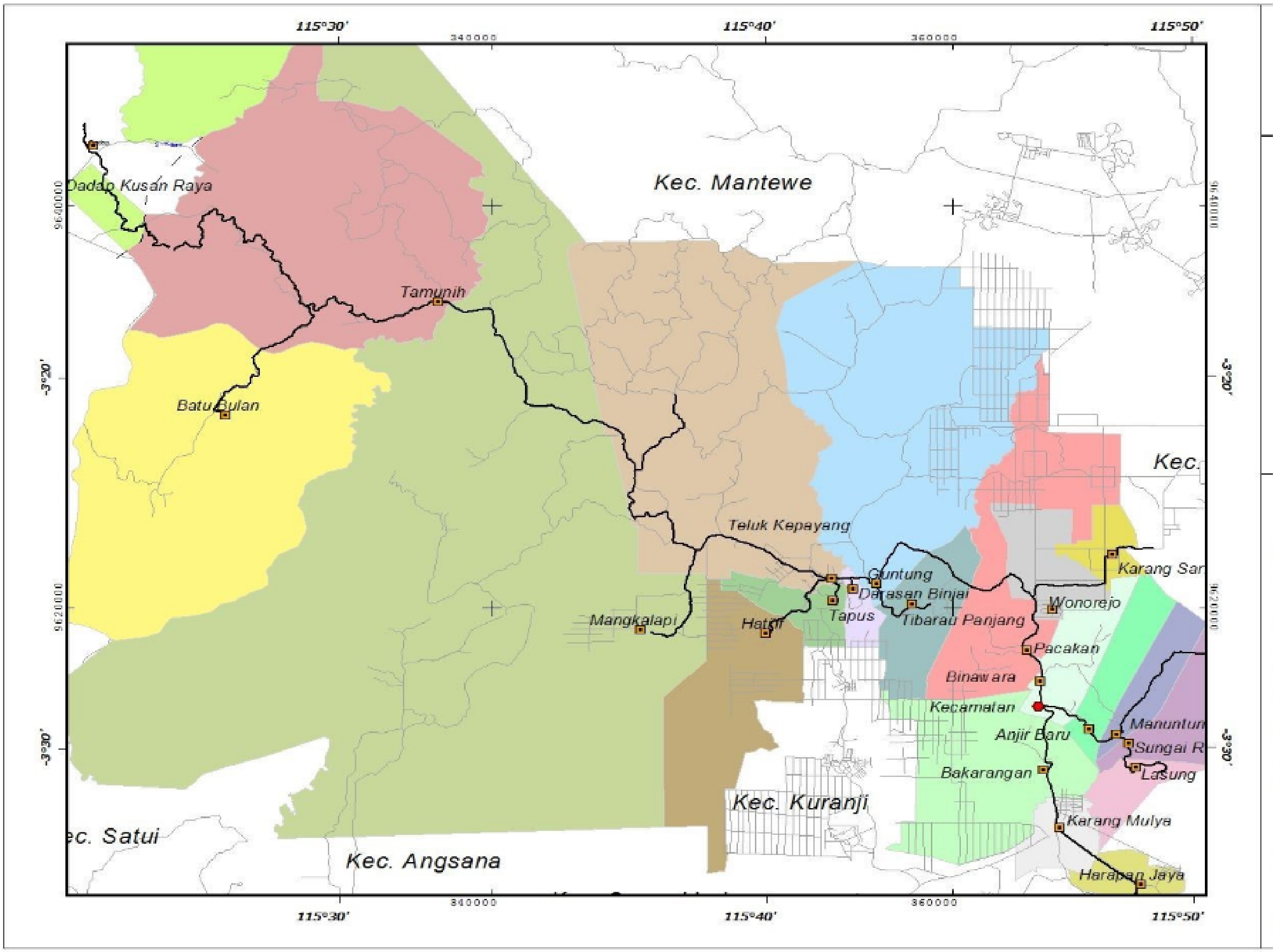

Figure 1

Map of Kusan Hulu District [19].