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Spatial Analysis of Environmental Factors Affecting Malaria in Bener Health Center, Purworejo

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Abstract
The Bener Health Center is one of the highest contributors to malaria cases in Purworejo District. In 2023, there were 134 malaria cases with an API of 2.25 per 1,000 population spread across 14 villages in the Bener Health Center working area. This study aims to determine the relationship between environmental factors and malaria incidence in the working area of Bener Health Center through a spatial approach. This study is a descriptive-analytical observational study with a case-control design. The case population in this study consisted of 134 individuals, while the control population comprised 59,457 individuals. The sample size for this study was 81 cases and 81 controls. Data were collected through interviews and observations. Data analysis included statistical analysis (univariate, bivariate, multivariate) and spatial analysis. Bivariate analysis showed a relationship between the absence of wire netting (p = 0.024; OR = 2.567), the presence of livestock shelters (p = 0.039; OR = 2.029), and the presence of breeding places (p = 0.008; OR = 3.403) with malaria incidence. Multivariate analysis showed that the absence of wire netting, the presence of livestock shelters, and the presence of breeding places simultaneously influenced malaria incidence in the working area of Bener Health Center. The distribution of malaria cases in the working area of Bener Health Center showed a clustered pattern.

INTRODUCTION

Malaria is a vector-borne disease caused by Plasmodium parasites and transmitted through the bites of infected female Anopheles mosquitoes (Ministry of Health of the Republic of Indonesia, 2023). Malaria remains a significant public health concern that requires serious attention, both globally and nationally, due to its high morbidity. In 2023, there were an estimated 263 million malaria cases reported across 83 endemic countries. Compared to 2022, the global malaria incidence in 2023 slightly increased from 58.6 to 60.4 cases per 1,000 population at risk. In 2020, global malaria deaths reached an estimated 622,000; this number gradually declined to 597,000 deaths by 2023. The malaria mortality rate exhibited a similar trend between 2000 and 2023, decreasing from 28.5 to 13.7 per 100,000 population at risk. The COVID-19 pandemic contributed to the temporary rise in both cases and deaths during this period (World Health Organization, 2024). Indonesia is classified as a malaria-endemic

country, with a total of 418,546 cases reported in 2023 (Ministry of Health of the Republic of Indonesia, 2024).

In Central Java Province, the number of malaria cases in 2023 was 1,024 cases (Central Java Provincial Health Office, 2023). However, one district in the province—Purworejo Regency—has not yet received malaria elimination certification. The number of malaria cases in Purworejo Regency showed a fluctuating trend over the 2019–2023 period: 58 cases in 2019, 25 in 2020, 5 in 2021, a sharp increase to 582 in 2022, and a slight decrease to 576 in 2023. Most malaria cases in Purworejo are indigenous, with Plasmodium falciparum as the predominant parasite species (Purworejo District Health Office, 2023). Bener Health Center has been identified as one of the major contributors to malaria cases in Purworejo Regency. In 2023, it reported 134 malaria cases, with an Annual Parasite Incidence (API) of 2.25 per 1,000 population (UPT Puskesmas Bener, 2023).

The working area of Bener Health Center is a highland region, located approximately 150 meters above sea level. Bener Health Center serves 28 villages, including Ngasinan, Nglaris, Sidomukti, Sukowuwuh, Limbangan, Guntur, Legetan, Ketosari, Kalijambe, Mayungsari, Jati, Kamijoro, Bener, Karangsari, Sendangsari, Kaliboto, Kedungloteng, Bleber, Medono, Pekacangan, Wadas, Kaliurip, Kedungpucang, Kaliwader, Cacaban Kidul, Cacaban Lor, Kalitapas, and Benowo. Although Bener Health Center covers a wide service area, it is supported by only five auxiliary health centers (Statistics Indonesia–Purworejo Regency, 2023). This condition contributes to a high service burden and may lead to delays in the detection and treatment of malaria cases, especially in villages located far from the main and auxiliary health centers.

One of the greatest challenges in reducing the malaria burden is understanding the complex interactions among the various factors that drive and shape malaria transmission dynamics (Villena, Arab, Lippi, Ryan, & Johnson, 2024). Environmental factors also have a significant impact on malaria transmission. These factors include all external conditions and elements that influence the life cycle and reproduction of organisms. Environmental factors encompass physical aspects such as temperature, humidity, rainfall, altitude, wind, sunlight exposure, water flow, housing wall conditions, the presence of wire netting on ventilation, availability of ceilings, and the placement of hanging clothes. In addition, biological environmental factors include the presence of stagnant water as mosquito breeding places, livestock shelters, and larva-eating fish. Chemical factors involve elements such as pH levels and salinity. Meanwhile, socio-cultural factors cover community habits, such as the use of bed nets, not wearing long-sleeved clothing, use of mosquito repellent, and human activities including dam construction, road building, mining, and the development of new settlements or transmigration programs (Untari, Rahardjo, & Martini, 2024). This indicates a possible correlation between environmental quality and malaria incidence in a region.

Geographically, the Bener Health Center area is located in a highland region, which is densely covered with shrubs that serve as ideal resting places for Anopheles mosquitoes. The area features varied topography, high rainfall, and diverse land use, including rice fields, forests, and residential settlements. In addition, livestock shelters—often used by Anopheles mosquitoes as resting sites—are commonly found in this area. Numerous mosquito breeding places have been identified, such as stagnant water bodies, springs, fish ponds, rice fields,

ditches, and rivers. These environmental conditions support the formation of ideal habitats for Anopheles mosquitoes to breed and facilitate malaria transmission.

In addition, a spatial approach is essential for analyzing the distribution of malaria incidence. This approach allows researchers to examine the spatial patterns of case distribution based on geographic location and to identify high-risk areas according to local environmental characteristics. Such studies can provide a spatial overview of malaria incidence and its relationship with environmental factors, serving as a foundation for more targeted malaria prevention and control programs. This provides the rationale for the present study, which investigates the association between environmental quality and malaria incidence using a spatial approach in the working area of Bener Health Center, Purworejo Regency.

METHOD

This descriptive-analytical observational study used a case-control design to examine the relationship between risk factors and malaria incidence. The study was conducted in May 2025. The dependent variable was malaria incidence in the working area of Bener Health Center. Independent variables included presence of wire netting on ventilation, wall condition, presence of a ceiling, presence of livestock shelters, presence of shrubs, and presence of mosquito breeding sites.

Cases comprised all individuals diagnosed with malaria in 2023 based on medical records for the Bener Health Center working area. Controls comprised residents who did not have malaria in 2023 and lived in the same area. Samples were selected by total sampling with a 1:1 case-to-control ratio and according to inclusion and exclusion criteria. Case inclusion criteria were: recorded as malaria-positive in 2023, resident of the working area, aged ≥18 years, and willing to participate. Case exclusion criteria were: deceased, moved out of the area, or had renovated their house since 2023. Control inclusion criteria were: no malaria in 2023, resident of the working area, aged ≥18 years, and willing to participate. Control exclusion criteria were: had renovated their house since 2023 or lived in the same household as a malaria case.

Data were collected using questionnaires and observation sheets and processed with SPSS and ArcGIS. Analyses included univariate analysis, bivariate analysis (chi-square), multivariate logistic regression, and spatial analysis.

The study received ethical approval from the Health Research Ethics Committee of the Faculty of Public Health, Diponegoro University (ethical clearance no. 161/EA/KEPK-FKM/2025). Informed consent was obtained from all participants, and confidentiality of personal data was maintained.

RESULT AND DISCUSSION

Table 1. Characteristics of Respondents in the Working Area of Bener Health Center

Characteristic	Frequency
Age Group	
17-25	11 (6.8)
26-35	25 (15.4)
36-45	37 (22.8)

46-55	41 (25.3)
56-65	37 (22.8)
>65	11 (6.8)
Sex	
Male	99 (61.1)
Female	63 (38.9)
Education Level	
No Formal Education	3 (1.9)
Did'nt Complete Primary School	11 (6.8)
Completed Primay School	84 (51.9)
Completed Junior High School	36 (22.2)
Completed Senior High School	27 (16.7)
Completed Higher Eduaction	1 (0.6)
Occupation	
Unemployed	5 (3.1)
Housewife	35 (21.6)
Farmer	68 (42.0)
Self-employed	51 (31.5)
Village Government Employee	2 (1.2)
Civil Servant	1 (0.6)
Income	
<IDR 1,000,000	118 (72.8)
IDR 1,000,000 – IDR 2,000,000	39 (24.1)
>IDR 2,000,000	5 (3.1)

Table 1 shows the sociodemographic characteristics of the study respondents. The majority of respondents were in the 46–55 age group (41 individuals or 25.3%), male (99 individuals or 61.1%), had completed primary school as their highest level of education (84 individuals or 51.9%), worked as farmers (68 individuals or 42.0%), and had a monthly income of less than IDR 1,000,000 (118 individuals or 72.8%).

Table 2. Bivariate Analysis of Environmental Factors Associated with Malaria Incidence

Variable	Malaria		p-value	OR (95% CI)
	Yes (n=81)	No (n=81)		
Wire Netting				
Inadequate	69 (85.2)	56 (69.1)	0.024*	2.567 (1.185–5.563)
Adequate	12 (14.8)	25 (30.9)		
Wall				
Inadequate	2 (2.5)	2 (2.5)	1.000	1.000 (0.137–7.276)
Adequate	79 (97.5)	79 (97.5)		
Ceiling				
Inadequate	76 (93.8)	75 (92.6)	1.000	1.216 (0.356–4.156)
Adequate	5 (6.2)	6 (7.4)		

Livestock Shelter				
Presence	43 (53.1)	29 (35.8)	0.039*	2.029 (1.081–3.809)
Absence	38 (46.9)	52 (64.2)		
Shrubs				
Presence	46 (56.8)	43 (53.1)	0.752	1.161 (0.625–2.158)
Absence	35 (43.2)	38 (46.9)		
Breeding Places				
Presence	22 (27.2)	8 (9.9)	0.008*	3.402 (1.413–8.194)
Absence	59 (72.8)	73 (90.1)		

The observational results showed that wire netting categorized as inadequate was predominantly found in the case group, with 69 respondents (85.2%), compared to 56 respondents (69.1%) in the control group. The chi-square test indicated a significant association between wire netting adequacy and malaria incidence in the working area of Bener Health Center, with a p-value of 0.024 and an odds ratio (OR) of 2.567. This means that respondents with inadequate wire netting were 2.567 times more likely to become infected with malaria compared to those with adequate wire netting.

This finding is in line with research conducted by Dalimunthe et al. in Tanjung Tiram Subdistrict in 2023, which found a significant association between the use of wire netting and malaria incidence (p = 0.004) (Dalimunthe, Meirindany, & Nauli, 2023). Wire netting installed on ventilation openings can reduce the risk of malaria transmission by preventing Anopheles mosquitoes from entering the house (Katiandagho & Donsu, 2018). Wire netting is considered effective when it is tightly installed on all ventilation openings (Engka, Rezal, & Afa, 2017). In the working area of Bener Health Center, the installation of wire netting is still rarely found. Additionally, in some households, wire netting is only installed on a portion of the ventilation openings. This condition is influenced by the community's economic situation, as not everyone can afford or prioritize the cost of purchasing wire netting.

The observational results showed that the number of respondents with inadequate wall conditions was the same in both the case and control groups, with 2 respondents (2.5%) in each group. The analysis indicated no association between wall condition and malaria incidence in the working area of Bener Health Center, with a p-value of 1.000 and an odds ratio (OR) of 1.000. This means that respondents with inadequate wall conditions had the same risk (1 time higher) of being infected with malaria compared to those with adequate wall conditions.

This finding is in line with a study conducted by Moto et al. in East Wewewa Subdistrict in 2023, which found a p-value of 0.132, indicating no significant association between wall condition and malaria incidence (Moto, Kleden, & Guntur, 2023). The condition of house walls can play a role in limiting mosquito access into the home. Adequate and solid walls are identified as protective factors against malaria (Hasyim, Dewi, et al., 2023). In the working area of Bener Health Center, most respondents had permanent walls. Permanent walls, such as those made of brick or concrete blocks, tend to be tightly sealed and do not have gaps, thus

preventing Anopheles mosquitoes from entering the house. In contrast, non-permanent walls such as wooden planks and bamboo weaving often have gaps that allow Anopheles mosquitoes to enter (Adugna, Wale, & Nibret, 2022).

The observational results showed that the presence of inadequate ceilings was predominantly found in the case group, with 76 respondents (93.8%), compared to 75 respondents (92.6%) in the control group. The analysis indicated no significant association between ceiling condition and malaria incidence in the working area of Bener Health Center, with a p-value of 1.000 and an odds ratio (OR) of 1.216. This means that respondents with inadequate ceiling conditions had a 1.216 times higher risk of being infected with malaria compared to those with adequate ceiling conditions.

This finding is in line with a study conducted by Irawati et al. in Bulukumba District in 2017, which found a p-value of 1.000 and an OR of 1.070 (95% CI = 0.521–2.197), indicating no association between ceiling presence and malaria incidence (Irawati, Ishak, & Arsin, 2017). Houses with ceilings can hinder the movement of Anopheles mosquitoes from the roof area into living spaces. In contrast, houses without ceilings provide easier access for mosquitoes to enter the house (Handayani & Lestari, 2023; Irjayanti & Pamangin, 2024). The presence of ceilings, especially those that are fully enclosed or equipped with netting, can reduce mosquito density and lower malaria transmission rates (Nankabirwa et al., 2024). Anopheles mosquitoes tend to rest in the upper parts of houses, including ceilings, so insecticide-treated ceiling nets can trap and kill mosquitoes that enter (Minakawa et al., 2022). In the working area of Bener Health Center, ceilings are still rarely found in homes. Additionally, in some houses, ceilings are installed only in certain rooms. This condition is largely influenced by the community's economic situation, as not everyone can afford or prioritize expenses for ceiling installation.

The observational results showed that respondents with livestock shelters near their homes were predominantly found in the case group, totaling 43 individuals (53.1%), compared to 29 individuals (35.8%) in the control group. The analysis indicated a significant association between the presence of livestock shelters and malaria incidence in the working area of Bener Health Center, with a p-value of 0.039 and an odds ratio (OR) of 2.029. This means that respondents with livestock shelters near their homes were 2.029 times more likely to be infected with malaria compared to those without livestock shelters nearby.

This finding is in line with studies conducted by Desimal et al. in Sekotong Subdistrict, West Lombok Regency in 2023, which found a p-value of 0.026, indicating a significant association between the presence of livestock shelters and malaria incidence (Desimal, Taufik Hidayatullah, Fauzi, & Setiawaty, 2023). Similarly, a study by Hidayati et al. in the working area of Kaligesing Health Center (2023) found a p-value of 0.002, reinforcing the link between proximity to animal shelters and malaria cases. Livestock shelters are frequently favored by mosquitoes as resting places. Anopheles mosquitoes are particularly attracted to the distinctive odor of livestock urine—such as that of cattle—which can stimulate mosquito activity around these shelters (Hidayati, Raharjo, Martini, Wahyuningsih, & Setiani, 2023; Mwalugelo et al., 2024) Moreover, mosquitoes are known to bite both humans and animals, making livestock a blood source that supports the mosquito life cycle (Hidayati et al., 2023). Livestock shelters tend to be humid and shaded environments, which are ideal resting conditions for Anopheles mosquitoes (Utami, Triwahyuni, & Julita, 2019). Poorly managed shelters—especially those

with stagnant water from livestock drinking sources—can also serve as breeding places. When livestock shelters are located close to human dwellings, mosquitoes initially attracted to animals may eventually bite nearby residents, thereby increasing the risk of malaria transmission (Desimal et al., 2023). In the working area of Bener Health Center, most of the identified livestock shelters consisted of goat pens and chicken coops.

The observational results showed that respondents with shrubs around their houses were predominantly found in the case group, totaling 46 individuals (56.8%), compared to 43 individuals (53.1%) in the control group. The analysis showed no significant association between the presence of shrubs and malaria incidence in the working area of Bener Health Center, with a p-value of 0.752 and an odds ratio (OR) of 1.161. This means that respondents with shrubs around their houses were 1.161 times more likely to be infected with malaria compared to those without shrubs around their houses.

This finding is in line with a study conducted by Trapsilowati et al. on Sebatik Island in 2016, which found a p-value of 0.068, indicating no significant association between the presence of shrubs and malaria incidence (Trapsilowati, Pujiyanti, & Negari, 2016). In the working area of the Bener Health Center, shrubs are commonly found due to the region's predominantly highland topography. Shrubs can serve as ideal resting places for Anopheles mosquitoes because of their shaded conditions. The presence of shrubs limits sunlight from reaching the ground surface, creating an environment conducive to mosquito resting (Manangsang, Ganing, Purba, Rumaseb, & Sarwadhamana, 2021; Okunlola, Oloja, Ebiwonjumi, & Oyeyemi, 2024). Stagnant water beneath shrubs can also function as breeding places for Anopheles mosquitoes, thereby increasing their population density (Manangsang et al., 2021). Furthermore, shrubs located near houses facilitate the movement of Anopheles mosquitoes into homes, increasing the likelihood of human-mosquito contact and malaria transmission.

The observational results showed that respondents with breeding places around their houses were predominantly found in the case group, totaling 22 individuals (27.2%), compared to 8 individuals (9.9%) in the control group. The analysis indicated a significant association between the presence of breeding places and malaria incidence in the working area of Bener Health Center, with a p-value of 0.008 and an odds ratio (OR) of 3.403. This means that respondents with breeding places around their houses were 3.403 times more likely to be infected with malaria compared to those without breeding places around their houses.

This finding is in line with a study conducted by Humaira et al. in Aceh Province in 2024, which found a p-value of 0.034 and an odds ratio (OR) of 1.913 (95% CI: 1.047–3.494), indicating a significant association between breeding places and malaria incidence (Humaira, Nurjazuli, & Raharjo, 2024). The presence of breeding places in a certain area increases the density of mosquitoes in that area. The closer the breeding places are to residential areas, the higher the likelihood of mosquito bites on humans (Adugna et al., 2022; Hasyim, Ihram, et al., 2023). Breeding places located within a radius of less than 50 meters from the house are among the factors that increase the risk of malaria transmission (Nababan & Umniyati, 2018). Therefore, the presence of breeding places near homes significantly raises the risk of malaria transmission. In the working area of Bener Primary Health Center, most breeding places identified include natural springs, rice fields, rivers, ponds, and drainage ditches.

Table 3. Multivariate Analysis of Environmental Factors Affecting Malaria Incidence

Variable	p-value	Exp(B)	95% CI
Wire Netting	0.014	2.739	1.227– 6.118
Livestock Shelter	0.029	2.098	1.077–4.085
Breeding Places	0.016	3.093	1.238–7.724
Nagelkerke	0,144		

Table 3 shows the influence of several independent variables on malaria incidence in the working area of Bener Health Center. Variables that were found to influence malaria incidence in the working area of Bener Health Center included the presence of wire nettng (p = 0.014), the presence of livestock shelters (p = 0.029), and the presence of mosquito breeding places (p = 0.000). Additionally, the Nagelkerke R^2 value was 0.144, indicating that these three variables collectively explained 14.4% of the variance in malaria incidence in the working area of Bener Health Center.

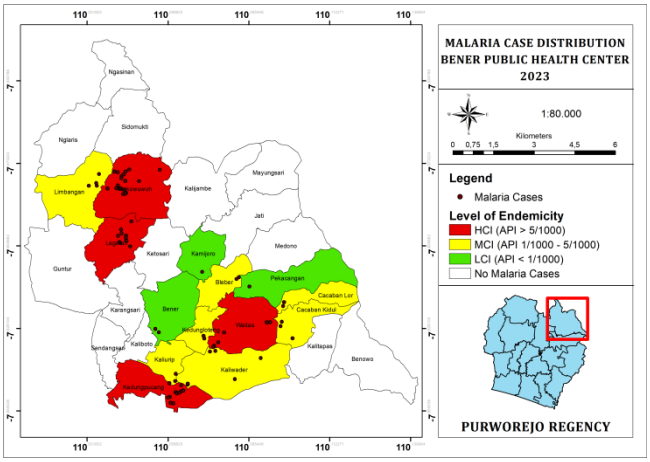

Figure 1. Spatial Distribution of Malaria Cases in the Working Area of Bener Health Center, 2023

Figure 1 shows the malaria endemicity levels in the working area of Bener Health Center. Based on the Annual Parasite Incidence (API), an area can be categorized into three levels: High Case Incidence (HCI), Middle Case Incidence (MCI), and Low Case Incidence (LCI). Areas categorized as High Case Incidence (HCI) include Kedungpucang, Legetan, Sukowuwuh, and Wadas. Areas categorized as Middle Case Incidence (MCI) include Bleber, Cacaban Kidul, Cacaban Lor, Kaliurip, Kaliwader, Kedungloteng, and Limbangan. Areas categorized as Low Case Incidence (LCI) include Bener, Kamijoro, and Pekacangan. The remaining areas are categorized as **non-case areas** (no reported malaria cases) include Benowo, Guntur, Jati, Kaliboto, Kalijambe, Kalitapas, Karangsari, Ketosari, Mayungsari, Medono, Ngasinan, Nglaris, Sendangsari, and Sidomukti.

Based on the spatial autocorrelation test, the Moran's Index was 0.254763, with a z-score of 1.803725 and a p-value of 0.071274, indicating positive spatial autocorrelation. This suggests that malaria cases tend to be spatially clustered, meaning areas with a high number of cases are likely to be located near other areas that also have a high number of cases.

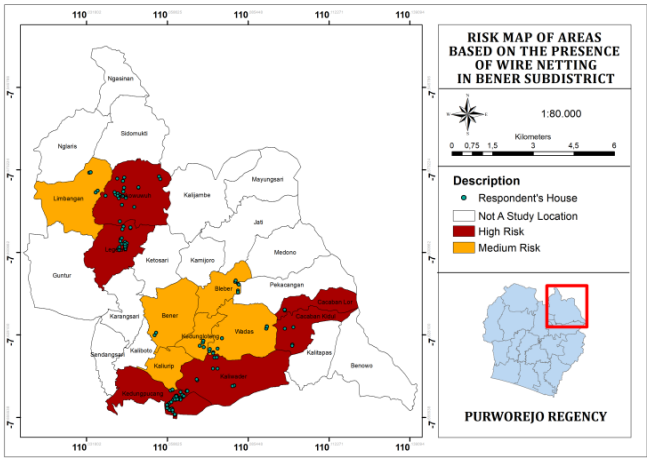

Figure 2. Risk Map Based on the Presence of Wire Netting on House Ventilation

Figure 2 shows the risk category of the area based on the presence of wire netting. Based on the presence of wire netting, the working area of Bener Health Center can be categorized into high-risk and medium-risk areas. The absence of wire netting increases the risk of malaria transmission, as wire netting has been proven effective in reducing *Anopheles* mosquito bites at night. Community perception of the disease and the benefits of physical prevention measures, such as wire netting, greatly influence protective behavior. Therefore, health promotion interventions should focus on increasing public awareness.

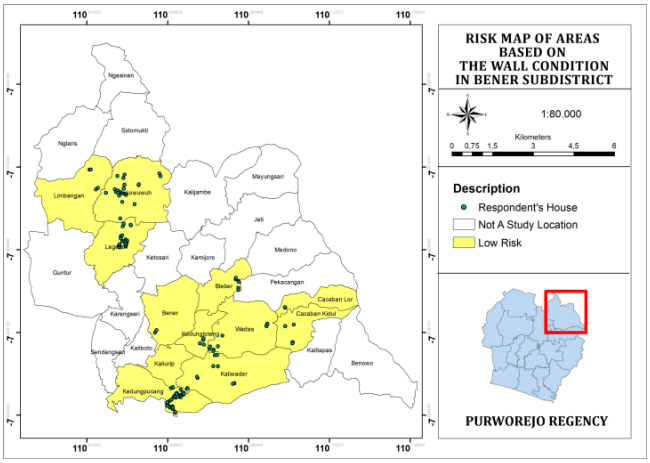

Figure 3. Risk Map Based on Wall Conditions

Figure 3 shows the risk category of the area based on the wall condition. Based on wall conditions in Bener Subdistrict, all villages included in the study area were categorized as low-risk areas. This finding indicates that most respondents' houses had permanent walls made of materials such as concrete, cement blocks, or plastered red bricks, with no cracks or holes. This type of wall is effective in preventing *Anopheles* mosquitoes from entering the house. However, several malaria cases were still found in these areas. This suggests that, although wall conditions met protective criteria against malaria, there remains a possibility of exposure to vectors due to other risk factors.

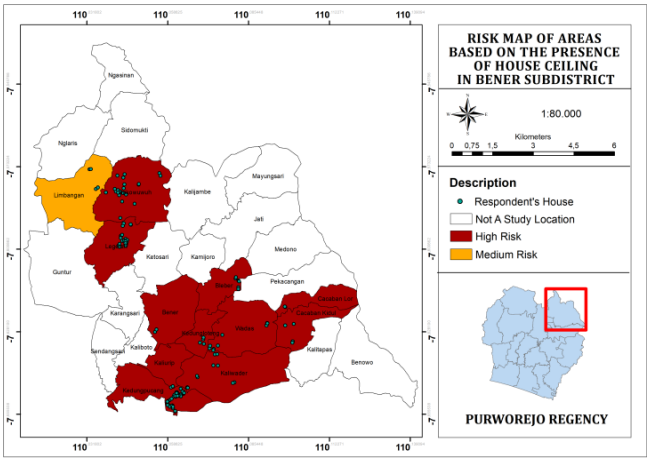

Figure 4. Risk Map Based on the Presence of Ceilings in Houses

Figure 4 shows the risk category of the area based on the presence of the house ceiling. Based on the presence of house ceilings, the working area of Bener Health Center can be categorized into high-risk and medium-risk areas. This finding indicates that improving housing quality—particularly by adding ceilings—can be an effective promotive and preventive strategy for malaria control in Bener Subdistrict. Area-based interventions, such as healthy house renovation assistance programs and community education on the importance of ceilings, are highly relevant to be implemented in high-risk villages.

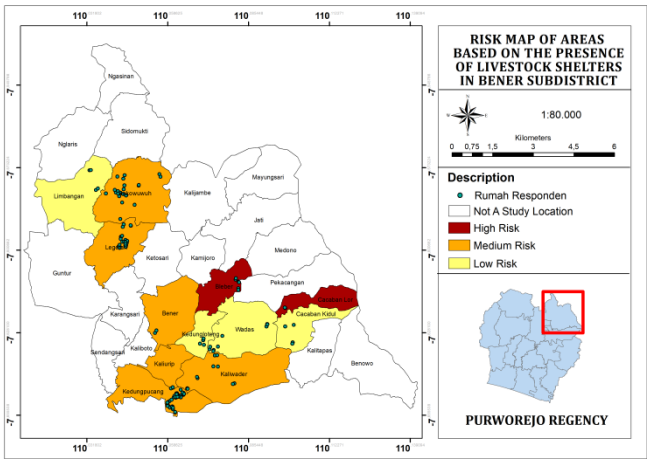

Figure 5. Risk Map Based on the Presence of Livestock Shelters

Figure 5 shows the risk category of the area based on the presence of livestock shelter. Based on the presence of livestock shelters, the working area of Bener Health Center can be categorized into high-risk, medium-risk, and low-risk areas. Areas with high shelter density and shelters located near residential houses carry a higher risk of increasing *Anopheles* mosquito populations. Therefore, the layout of livestock shelters and their proximity to homes are important factors to consider in malaria risk mitigation efforts. Relocating shelters, improving shelter sanitation, and managing the surrounding environment can be part of an environmentally based preventive approach.

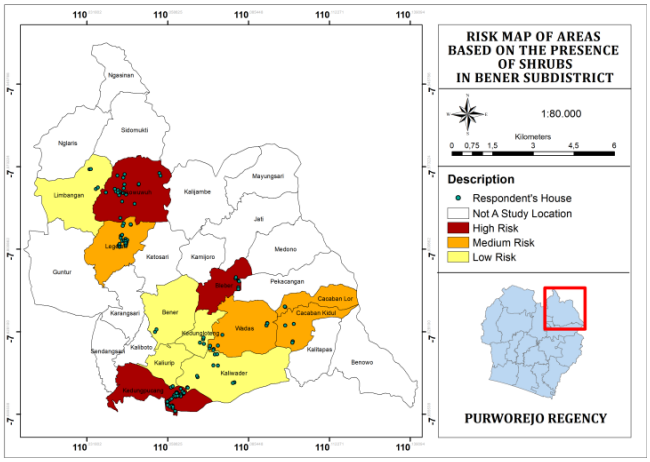

Figure 6. Risk Map Based on the Presence of Shrubs

Figure 6 shows the risk category of the area based on the presence of shrubs. Based on the presence of shrubs, the working area of Bener Health Center can be categorized into high-risk, medium-risk, and low-risk areas. Vector-borne diseases are strongly influenced by landscape structure, where land use changes—such as the presence of shrubs—can increase contact between humans and malaria vectors. Therefore, vegetation management and environmental arrangement are important strategies in area-based malaria control.

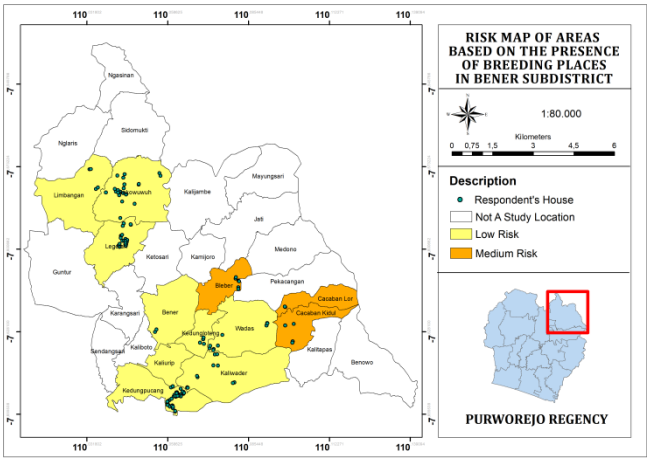

Figure 7. Risk Map Based on the Presence of Breeding Places

Figure 7 shows the risk category of the area based on the presence of breeding places. Based on the presence of breeding places, the working area of Bener Health Center can be categorized into medium-risk and low-risk areas. Areas with breeding places have an increased potential for malaria transmission. Therefore, interventions such as mosquito breeding places elimination, community education, and the use of larvicides or insecticide spraying at breeding places are necessary.

CONCLUSION

The study identified significant associations between malaria incidence and the presence of wire netting, livestock shelters, and mosquito breeding sites in the Bener Health

Center area, and spatial analysis revealed positive spatial autocorrelation indicating clustered case distribution; therefore, malaria control should prioritize environmental interventions—ensuring proper installation and maintenance of wire netting on ventilation, managing or relocating livestock shelters to reduce mosquito resting sites, and eliminating standing-water breeding habitats—combined with targeted, cluster-focused vector control and health promotion; future research should evaluate the effectiveness and cost-effectiveness of these targeted environmental interventions over time (using longitudinal or intervention trial designs) and examine socio-behavioral and climatic moderators of spatial clustering to inform adaptive, locally tailored control strategies.

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