The Spatial Analysis for Malaria Surveillance in Yogyakarta Special Region, Indonesia : A Cross Sectional Study

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Abstract

Background

Malaria case elimination have been seriously issue. Although the prevalence of malaria cases in Indonesia has decreased from 1.3% (2013) to 0.6% (2017), the policy of has been eliminating malaria cases remains unresolved problem. Kulon Progo is one of contributes to malaria cases in Special Region Yogyakarta. Although number of cases has been decreasing year, malaria transmission continues to be a significant.

Purpose

Strengthen the surveillance system and cluster areas of malaria cases through Q-GIS with buffering analysis and spatial analysis in Kulon Progo District in 2015–2018.

Method: Cross sectional was done. Instruments include secondary data on malaria cases occurring from 2015 to 2018 and confirmation data sheets. The questionnaire was used to collected data from 240 respondents.

Results

Malaria case trend was in the watershed area at a distance of < 250meters in Kokap Sub-district. Malaria cases were mostly found in rice fields with a distance of < 250meters in Samigaluh Sub-district. All malaria cases were in the garden areas of < 250meters in Nanggulang and the forest area of > 250meters in the Kalibawang Sub-district.

Conclusion

Probability malaria transmission are river, rice fields and gardens. It is necessary to hold training on the use of the Q-GIS application for surveillance officers.

1. Introduction

Malaria is caused by a parasite called plasmodium, which enters the human body through the bite of the *Anopheles sp* mosquito [1]–[3]. Globally, the number of malaria cases is estimated to have increased from 217 million in 2016 to 219 million in 2017. Africa has the highest number of malaria cases (92%), Southeast Asia (5%), and the Mediterranean (2%). It is estimated that 15 African countries and India account for 80% of malaria deaths. In 2017, five of them were in Nigeria (25%), the Democratic Republic of the Congo (11%), Mozambique (5%), Uganda (4%), and India (4%) [2], [3].

The majority of malaria cases in Indonesia are positive. There was a decrease in high endemic areas in 2014, from 16% in 2012 to 11% in 2014. Furthermore, the proportion of low-endemic areas went down from 68 % to 67 % in 2014. As a result, precautionary control must always be implemented because a

low-endemic area can become a high-endemic area [4]. The prevalence of malaria cases has decreased from 1.3% in 2013 to 0.6% in 2017 [5]. Kulon Progo, located in Yogyakarta Special Region (DIY), is one of the regencies in Indonesia that consistently contributes to malaria cases, with 87 cases in 2014, 122 cases in 2015, 96 cases in 2016, 84 cases in 2017, 28 cases in 2018, three cases in 2019 and two cases in 2020 [6], [7].

Malaria cases continue to rise because surveillance activities in Kulon Progo do not include an incident risk map. As a consequence, many policies and procedures focus on the administrative scope, leaving the risk area out of the spotlight. Epidemiological studies concerning the actual location must reflect where the risks are so that prevention policies developed in response to the study's findings are accurate. The Quantum Geographic Information System (QGIS) can be used to create a picture of the incidence or prevalence of health problems in a population [8], [9]. Noticing the distribution pattern of infectious disease cases can be a key health policy if surveillance activities are active down to buffer analysis or QGIS [10]–[13]. This study aims to analyze the relationship between mosquito breeding sites, the distribution of malaria cases through Q-GIS, specifically buffering, and spatial analysis in Kulon Progo Regency from 2015 to 2018.

2. Method

The objective of this study was to assess a pattern of malaria case distribution using surveillance data, with an indication of the results of malaria diagnosis in Kulon Progo District from 2015 to 2018[7], and the implementation of Q-GIS as a medium for strengthening the surveillance system and mapping of malaria case clusters in Kulon Progo District. This study applied a cross-sectional approach. Purposive sampling was used as a sampling technique [14]; and therefore, the sample size in this study was 240 cases, based on positive malaria cases diagnosed using the traditional method of thick blood and thin smear in Kulon Progo District between 2015 and 2018 [7]. Secondary data on malaria cases in Kulon Progo Health Office from 2015 to 2018 were used as the instruments, and the questionnaires served as a confirmation sheet for respondent data. GPS (Global Positioning System) was used to determine the coordinates of malaria events [15]. Direct research was carried out on the addresses of confirmed malaria cases based on secondary data from the Kulon Progo Health Office to develop the spatial map of the Kulon Progo Regency. The results of descriptive data analysis are presented in maps and tables. Maps present the endemicity of malaria cases by sub-district. Data on malaria cases are presented in a four-year time series. Area classification using QGIS software with buffer analysis [16] was utilized to determine the distribution pattern of malaria in rivers, gardens, rice fields, and forest areas that have the potential as breeding places for malaria mosquitoes [1], [17]–[20].

3. Results

3.1 Malaria Prevalence and Spatial Trends

A total of 240 respondents participated in this research. The distribution pattern based on location shows that the highest prevalence occurs in Kokap Sub-District as presented in Fig. 1. Meanwhile, the distribution pattern based on the time shows that the highest was in 2015 with 98 cases (41%), as mentioned in Table 1. In terms of the distribution of characteristics, most malaria cases were experienced by men (58.3%), aged 46–65 years (28.7%), elementary/junior high school graduated (65.4%), and working as farmers (47.5%), as presented in Table 2.

Table 1
The Distribution of Malaria Cases based on Time in
2015–2018

Time (Year)	Frequency (n)	Percentage (%)
2015	98	40.8
2016	78	33
2017	56	23
2018	8	3
Total	240	100
Data source: Kulon Progo Health Office, 2015–2018		

Table 2. The Distribution of Malaria Cases based on the Demographic Characteristics in 2015–2018; n = 240

Category	Frequency	Percentage (%)
Gender		
Man	140	58.3
Woman	100	41.7
Age (Year old)		
0–5	12	5
6–11	19	7.9
12–25	50	20.8
26–45	66	27.5
46–65	69	28.7
≥ 65	24	10
Education level		
Did not go to school	12	5
Did not complete elementary school	37	15.5
Graduated from elementary/junior high school	157	65.4
Graduated from senior high school	32	13.3
Graduated from bachelor degree/equivalent	2	0.8
Occupation		
Not labor force		
Housewife	28	11.7
Student/unemployed	45	18.8
Children	18	7.5
Labor force		
Farmer	114	47.5
Labor	13	5.4
Entrepreneur	18	7.5
Civil servant/teacher	4	1.7
Data source: Kulon Progo Health Office, 2015–2018		

3.2. Spatial Analysis

The implementation of the use of QGIS is useful, as evidenced by the clustering of the distribution of malaria cases in the Kokap and Samigaluh Sub-districts, as shown in Fig. 1. The results of spatial analysis on the distribution pattern of malaria cases show the trends of malaria cases in the watershed area of < 250 meters in the Kokap Sub-district, as shown in Fig. 2. Meanwhile, cases were discovered far from high-risk areas such as rivers and gardens. More cases, however, were noticed at < 250 meters of rice fields in the Samigaluh Sub-district, as demonstrated in Fig. 3. Figure 4 presents that cases were also discovered in the garden areas at a distance of < 250 meters after buffering was completed in Nanggulan Sub-district. Furthermore, Fig. 5 exhibits that malaria cases were identified far from river areas, gardens, and rice fields, but close to forest areas at a distance of < 250 meters in Kalibawang Sub-district.

4. Discussion

Analysis of the prevalence of malaria cases based on time shows that the overall trend has decreased, as displayed in Table 1, with the most cases found in Kokap Sub-district (Fig. 1). Figure 1 demonstrates that the results of the cluster spatial analysis have revealed that the zone with the highest cases of malaria is the Kokap Sub-district area. The spatial analysis and buffering show that the radius of distribution of case location to the place potential as risk factors [21], [22]. In this study, the buffering was performed with a radius < 250 meters to determine the approximate size limit or radius of the nearest or farthest location from the case with a potential breeding place for *Anopheles sp* mosquitoes [11], [23]. Figure 2 depicts the results of this research, which show that the spatial pattern of the highest malaria case cluster in the Kokap Sub-district from 2015 to 2018 is adjacent to the river basin area.

The results of this study indicate that the spatial trend pattern of malaria cases is in the river flow area < 250 meters. Based on river buffers, rivers can be seen to be a risk factor for malaria transmission. It has been discovered that mosquitoes can lay their eggs in rivers, puddles, and dammed water bodies. Because water is required for the oviposition and breeding stages of mosquito larvae, mosquito density is higher during the rainy season than during the dry season, resulting in seasonal malaria epidemiology [24]. *Anopheles sp* larvae breed in swamps, lagoons, ground pools, rivers, ditches, and wells, as well as habitat within a radius of 0.5 – 2 km of the homes of malaria-positive sufferers [25], [26]. The reproductive habitat of *Anopheles sp* is in seepage or flow from the river to the surrounding environment and forms puddles [12], [25]–[27]. In other mountainous and hilly areas, springs and streams with water-filled rock basins can be breeding grounds for *An. maculatus* mosquitoes [9], [23], [28].

Furthermore, rice field buffer shows that malaria cases are mostly concentrated in the radius of the buffer < 250 meters from the rice fields in Kokap Sub-district, as displayed in Fig. 2. This is compliant with the breeding habitats for *Anopheles sp* larvae, which include rivers, ponds, and rice fields [29], [30]. Rice field is a potential habitat area at high risk of malaria transmission with a buffer zone of 500 meters [31], [32].

All malaria cases were found < 250 meters from the garden area. Based on the flight distance of mosquitoes, which is 0.5 km, this means that the presence of the garden may be a risk factor for malaria transmission. During the day, the garden serves an important role as a resting place for *Anopheles sp* mosquitoes [17], [28]. This means that the presence of shrubs/gardens near the house increases the risk of malaria [33], [34]. *Anopheles maculatus* is a species of mosquito that is a vector of malaria and lives in habitats such as garden areas [10], [19]. Gardens are a high-risk area for malaria transmission, with less than 10% of the area within 1 km [35].

The results of this study also show that majority of the malaria cases occurred > 250 meters from the forest. This signifies that based on the mosquito flight distance of 0.5 km, the presence of forests is not a risk factor for malaria transmission. Which reported that forest does not have a significant effect on the incidence of malaria, with a distance of 900 to 1,250 meters [36]. However, several cases of malaria were discovered < 0.5 kilometers away from the forest area because the forest is a breeding site for *Anopheles sp*. Because of Indonesia's geographical location on the equator, it has a tropical climate, and the living environment in the forest will increase the incidence of malaria because it is classified as an endemic area. Activities such as leaving the house at night without long-sleeve clothes and repellents in mosquito breeding sites such as forests will increase the risk of transmission. According to research in Thailand, living near a mosquito breeding site increases the risk of transmission by 2.37 times, and living in a forest area with active transmission increases the risk of transmission by 7.19 times [37]. Forest and bush areas are habitats for *Anopheles balabacensis* and *Anopheles maculatus* mosquitoes[12].

Some methods of prevention and control of *Anopheles sp* vectors are spatial monitoring, analysis of time trends[21], [38], [39], and environmental management such as cleaning the environment that has the breeding potential, for example clearing shrubs in the garden area near the house [21] and closing standing water which has the potential to become a breeding ground for mosquitoes. Wearing long-sleeve clothes when going out at night, using insecticide-treated mosquito nets, using repellants, putting on mosquito repellent gauze, and giving prophylactic treatment when entering or working in endemic areas are also the ways that can prevent and control the vector [40]–[42].

The strength of this study lies in its focuses on the detection and analysis of the cluster of the distribution pattern[43] and area coverage of a geosphere phenomenon based on breeding places for malaria mosquitoes in rivers [18], [44], garden [44], rice fields [31], [34], [45], [46] and forests [44], [47], [48] by buffering [13], [49]–[52], which has not been implemented investigation thoroughly in the vulnerable areas in Kulon Progo District in 2015–2018. The findings of this study are projected to support stakeholders in making policy and providing representative management of malaria case elimination. However, this study has some limitations does not perform risk factor analysis and space-time permutation or space-time temporal analysis.

Conclusion

The malaria case distribution can be seen from the buffering of malaria locations, that rivers, rice fields, and gardens are places risky for malaria transmission, while forests are not. The GIS is very applicable in the implementation of surveillance and helps provide an overview for determining targets and policy-making strategies. It is suggested that buffering prioritize malaria areas because QGIS has not been implemented for health surveillance officers.

Declarations

Ethics approval and consent to participate

This secondary data analysis research protocol was approved by the ethics committee of Universitas Ahmad Dahlan No. 011906057.

Consent for Publication

Not applicable

Availability of data and materials

The dataset and materials used for this study can be made available only upon the approval by the Public Health Kulon Progo Department

Competing interests

The authors have no conflicts of interest to declare for this study.

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Authors' contributions

FN, HK, and SP designed the research and interpreted the results. FN, NN, SP, and VAA contributed to the research implementation and the interpretation of the results. NN, PA, RR and S participated in the data collection. FN, HK, AI, and WM handled the data analysis. The authors of this paper have read and approved the final manuscript.

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Figures

Figure 1

Figure 2

Map of Malaria Cases Distribution with River Buffers in Kulon Progo Regency in 2015 – 2018

SPATIAL DISTRIBUTION OF CLUSTERS OF MALARIA WITH RICE FIELD BUFFER, KULON PROGO, 2015-2018

Figure 3

Map of Malaria Cases Distribution with Rice Field Buffers in Kulon Progo Regency in 2015 – 2018

SPATIAL DISTRIBUTION OF CLUSTERS OF MALARIA WITH FARM FIELD BUFFER, KULON PROGO, 2015-2018

Figure 4

Map of Malaria Cases Distribution with Farm Field Buffers in Kulon Progo Regency in 2015 – 2018

SPATIAL DISTRIBUTION OF CLUSTERS OF MALARIA WITH WOODLAND BUFFER, KULON PROGO, 2015-2018

Figure 5

Map of Malaria Cases Distribution with Woodland Buffers in Kulon Progo Regency in 2015 – 2018