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The Implementation of Spatial Weighted Regression on Detecting the Risk Factors of Malaria Incidences In Kulonprogo District

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Abstract

Malaria is still a public health problem caused by Plasmodium parasites. This disease is naturally transmitted through the bite of female Anopheles mosquitoes. Kulonprogo Regency is one of the malaria endemic areas that needs to be developed to combat malaria. This research aims to describe the distribution of malaria cases to determine vulnerable areas in Kulonprogo Regency. This research was an observational analytic with cross sectional design conducted in April - October 2018. This research used the total sampling of 62 malaria cases. Data analysis was performed by using a Geographic Information System approach with overlay, buffer, cluster techniques, and spatial weighted regression. Based on the results of the partial analysis, it was found that 62 cases of malaria spread in 6 sub-districts namely: Kokap, Pengasih, Samigaluh, Kalibawang, Wates and Sentolo. The distribution of malaria cases clustered in Kokap Sub District, namely in Kalirejo Village (29 cases) and Hargorejo Village (9 cases). The overlay and buffer techniques found that the distribution of cases spread in Menoreh hills which have forest vegetation. Malaria-prone areas in Kulonprogo Regency were found in Kalirejo Village and Hargorejo Village through the results of spatial analysis using a Geographic Information System approach. Thus, malaria control efforts were focused on these vulnerable areas.

Keywords: Kulonprogo Regency, Malaria, Geographic Information System

1. Introduction

According to World Health Organization (WHO), morbidity and mortality due to malaria tended to decline in the period of 2005-2015. But there are still approximately 3.2 billion people or almost half of the world's population are at risk of malaria. In 2015, WHO estimated that there were around 214 million new cases of malaria with the death of around 438 thousand people worldwide and about one third or 306 thousand occured in children under five.

In Indonesia it is still a big problem that threatens people, especially for those living in malaria endemic areas and remote areas far from health services (Solikhah, 2012).

Malaria is still a public health problem at the global level, as well as in Indonesia. But now, the problem of Malaria in Indonesia tends to decrease. In 2010, in Indonesia there were 465,764 positive cases of malaria and this number decreased in 2015 to 209.413 cases (Kemenkes, 2017). The incidence of malaria in Indonesia is up to 18.6 million cases per year. Kulonprogo Regency is one of the malaria endemic areas not only in Yogyakarta Special Region but also in Java Island. According to the DIY Health Office (2012), there are 241 malaria cases in Yogyakarta, and 95% of them (237 cases) occurred in Kulonprogo Regency.

Geographical Information System (GIS) is defined as an information system that is used to enter, store, recall, process, analyze and produce geo-referenced data or geospatial data to support decision making in the planning and management of land use, natural resources, transportation environment, city facilities, and other public services. GIS is designed to collect, store and analyze an object where geographical location as an important characteristic, and it requires critical analysis. Geographical Information System is a system of computer software, hardware and data as well as humans to manipulate, analyze and present information which is tied to the spatial location (Budiyanto, 2004).

Malaria control has to be carried out in areas that have great potential in transmission. It will make the better implementation of malaria prevention (Puspaningrum *et al*. 2016). Information on the vulnerability of an area to the risk of transmission of malaria can be identified through mapping using a Geographic Information System approach. Knowing the vulnerability of a region to malaria make it easier to determine more effective and efficient disease prevention and control measures. Therefore, it is necessary to examine further the use of Geographic Information Systems to map the vulnerability of malaria incidence areas and identify risk factors for malaria events in Kulonprogo Regency. Thus, it can be used for appropriate intervention of decision making and breaking the chain of malaria transmission especially in Kulonprogo Regency.

2. Lierature Review

2.1. Malaria

Malaria is an infectious disease caused by the Plasmodium parasite that lives and multiplies in human blood cells. This disease is naturally transmitted through the bite of a female Anopheles mosquito. Plasmodium species in humans are namely Plasmodium falciparum, P. vivax, P. ovale, and P. malariae. (Dirjen PP dan PL, 2008).

Infection of malaria parasites can cause a variety of symptoms, ranging from symptoms that are absent or very mild to severe illness and even death. Malaria can be categorized as uncomplicated or severe (complicated). In general, malaria is a curable disease if diagnosed and treated immediately and correctly. All clinical symptoms associated with malaria are caused by erythrocytic or blood stage asexual parasites. When the parasite develops in erythrocyte, many known and unknown waste substances such as hemozoin pigments and other toxic factors accumulate in infected red blood cells. It is discharged into the bloodstream when infected cells lyse and release invasive merozoites. Hemozoin and other toxic factors such as glucose phosphate isomerase (GPI) stimulate macrophages and other cells to produce cytokines and other soluble factors that act to produce fever and hardness and may affect other severe pathophysiology associated with malaria (World Health Organization, 2016).

Erythrocytes infected with Plasmodium falciparum, especially those with mature trophozoites, attach to the vascular endothelium of the venular blood vessel wall and are not free to circulate in the blood. When infected erythrocyte sequestration occurs in the brain vessels, it is believed to be a contributing factor to the severe disease syndrome known as cerebral malaria, which is associated with high mortality (World Health Organization, 2016)

2.2. Geographic Information System

Geographical Information System (GIS) is an information system that is used to enter, store, recall, process, analyze and produce geo-referenced data or geospatial data, to support decision making in the planning and management of land use, natural resources, transportation environment, city facilities, and other public services. GIS is designed to collect, store and analyze an object where geographical location is an important characteristicand requires critical analysis (Budiyanto, 2004).

Geographic Information System is a system of computer software, hardware and data, and personnel to help manipulate, analyze and present information that is tied to a spatial location (ESRI, 2011).

Based on some of the above understanding it can be concluded that GIS is a system consisting of hardware, software and computer data as well as personnels who help manipulate, analyze and issue geographic (geospatial) information to support decision making.

3. Method

3.1. Area Study and Population

This is an observational analytic research with data collection retrospectively. This research was conducted in Kulonprogo Regency which is malaria endemic area in the province of Yogyakarta Special Region. The population used in this study is the number of malaria cases in Kulonprogo Regency consisting of 12 sub-districts in 2017.

3.2. Outcome Definition

Analysis of the spatial relationship between malaria incidence and each risk factor was carried out in the population who had been diagnosed with malaria in 2017. The sampling technique used was a total sampling of 62 malaria cases. The dependent variable is malaria incidences in Kulonprogo Regency in 2017 according to District (Y). Independent variables are risk factor of malaria incidence in Kulonprogo Regency which consists of: the number of cases with house condition risk factors (X1), number of cases with environmental risk factors (X2), number of cases with risk factors for population density (X3), number of cases with knowledge risk factors (X4), number of cases with attitude risk factors (X5) and number of cases with risk factors behavior (X6).

3.3. Data Collection

This study used secondary data obtained from malaria case reported by district health office and primary health centre at Kulonprogo Regency. Primary data were taken using by questionnaire. The coordinate data at the household level were collected by determining the point of longitude and latitude.

3.4. Data Management and Cleaning

Data collection was done by entering data directly into the ODK collect application database. Furthermore, data checking was done to detect data errors or inconsistencies. Data analysis was carried out after checking the entire data collection. The data analysis was carried out by using Geoda for spatial weighted regression software, epi info 7 and quantum GIS for layout. The geographic location of all households were recorded by using a mobile GPS on a smartphone. Then, the geographic location data were imported in epi info 7 and quantum GIS software and checked on the map polygon boundary.

Geoda software for spatial weighted regression was used to explore the spatial diversity by forming different regression models at each observation location.

3.5. Statistical Analysis and Modelling Spatial Relationship

Data analysis was carried out by using a Geographic Information System approach using overlay, buffer, cluster, and weighted regression techniques. Geographically Weighted Regression (GWR) method is a linear regression method equipped by location weight. This technique is used to map spatial patterns, examine relationships, and check redundancy between independent variables and geo-visualization. The model framework is shown in Figure 1 which explains the dependent variable for this model (malaria cases confirmed in 2017 at the sub-district level). Statistical values entered into GIS vectors are prepared on polygon maps as non-spatial data. Spatial distribution of data was visualized with a chloropleth map to show malaria prevalence at the population density (Ndiath, *et al*, 2015)

The equations produced in this study are (Nadya, *et al.*, 2014; Aprianti and Widodo, 2017):

1. GWR Equation Model

$$\boxed{y_i = \beta_0(u_i,v_i) + \beta_1(u_i,v_i)x_{1i} + \ldots + \beta_p(u_i,v_i)x_{pi} + \varepsilon_i, i = 1,2,\ldots,n}$$

yi = Response variable at location i

(ui, vi) = Coordinate geographical location (longitude, latitude) at the i location

Xpi = Variable p-predictor at location i

βp (ui, vi) = Parameters at the i location which correspond to the independent variable to p, xpi

βp (ui, vi) = GWR constant

εi = Error at the point of the assumed I-independent location, identic and normally distributed with mean values and variances σ2

2. Breusch Pagan

Breusch Pagan tests are used to find the value of spatial heteroscedasticity. The formula used in the pagan breeding test is:

$$\boxed{BP = \frac{1}{2} f^T z(z^T z)^{-1} z^T f \sim x^2_{(z-1)}}$$

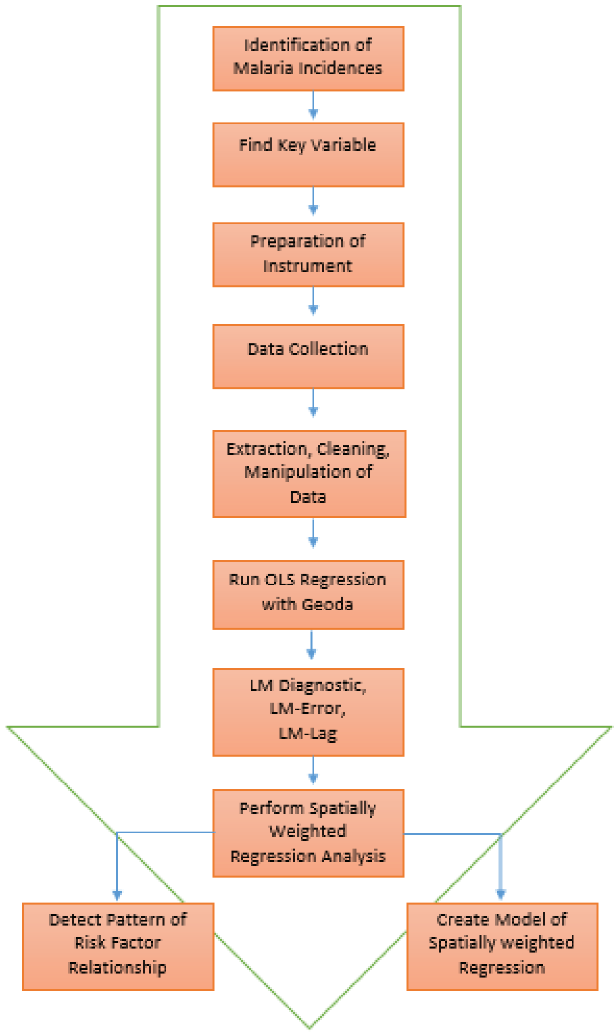

Figure 1: Methodological Framework.

z = Matrix measuring n x (p + 1) which contains a vector of x that has already normalized for each observation.

f = Vector size (n x 1).

n = Number of observation areas

p = Number of explanatory variables.

3. Moran Index

Moran index is used to find the value of spatial autocorrelation, for that the formula used to find the value of the moran index is:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

i = Moran Index

n = Number of locations

xi = Value at location i

xj = Value at location to j.

x = Average of the number of variables or values

wij = Element in standardized weighting between regions i and j.

4. Result and Discussion

4.1. Clinical and Demographic Profile of Malaria Patient

By using univariate analysis it can be shown that most of malaria cases in Kulonprogo regency are male (68%), mostly have lower educational background and 45% working as farmer. Based on table 2, most of cases are not risky status for house condition (54.84%); not risky environment (51.61%); not risky population density (85.48%); not risky knowledge (54.84%); not risky attitude (66.13%) and not risky practice for malaria control (59.68).

4.2. Risk Factor Malaria Hotspots

The spread of malaria cases in Kulonprogo District is clustered in two locations, Kalirejo Village (29 cases) with an average altitude 264 above sea level and in Hargorejo Village (9 cases) with an average altitude 200 above sea level. All cases are found in radius of 2 km from the clustered center. This is consistent with several studies which found the fact that some species of Anopheles mosquitoes have flight ability up to 2 km from their breeding place (Munif, 2009). For more details, see fig. 2.

The highest malaria cases were found in areas with low population density. This is also an evidence by the results of spatial weighted regression that there is no significant

Table 1: Distribution of Demographical Profile.

Variables	**Frequency (n=62)**	
	Count	**%**
Sex		
Male	42	67.74
Female	20	32.26
Education		
Never get format education	3	4.84
Not graduated primarily school	7	11.29
Graduated primarily school	23	37.1
Graduated junior high school	12	19.35
Graduated senior high school	17	27.42
Occupational		
Not working	3	4.84
Student/college	12	19.35
Housewife	4	6.45
Soldier/police	1	1.61
Private sector employee	1	1.61
Entrepreneur	4	6.45
Farmer	28	45.16
Labor	6	9.68
Other	3	4.84

Table 2: Distribution of Variables.

Variables	**Frequency (n=62)**			
	Not Risky	**%**	**Risky**	**%**
House Condition	34	54.84	28	45.16
Environment	32	51.61	30	48.39
Population	53	85.48	9	14.52
Knowledge	34	54.84	28	45.16
Attitude	41	66.13	21	33.87
Practice	37	59.68	25	40.32

relationship between population density and the incidence of malaria in Kulonprogo District. Based on map, Kalirejo and Hargorejo are included into low density population area. For more details, see Figure 3.

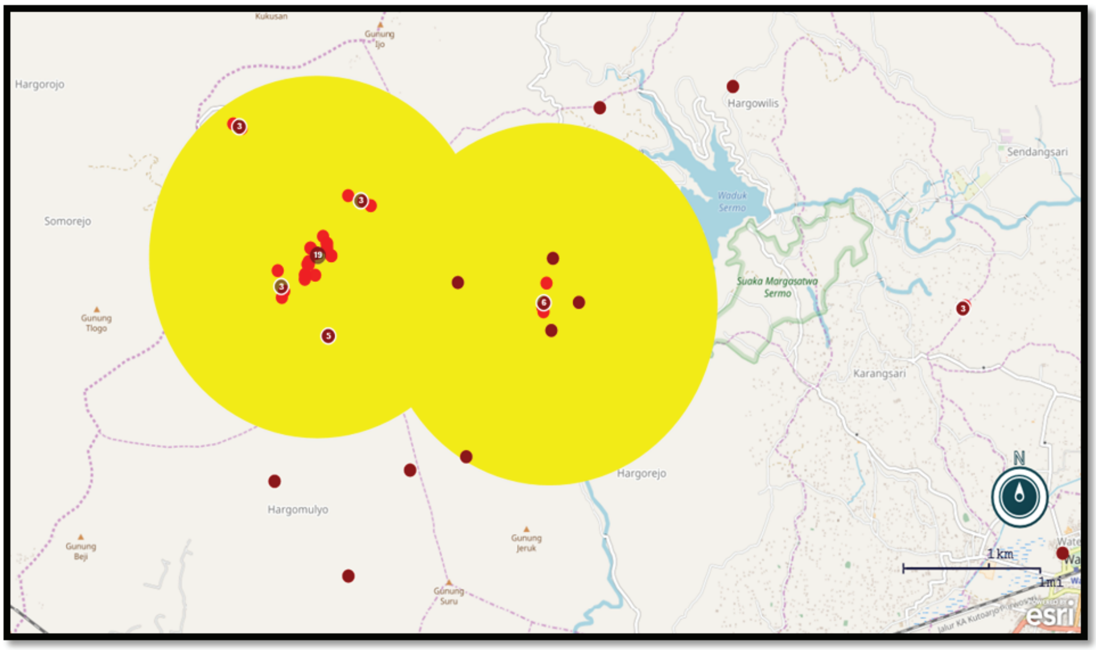

Figure 2: Spreading of Malaria Incidences in Kulonprogo Regency.

Table 3: Spatial Weighted Regression Statistic.

Variable	Coefficient	Std. Error	Z-Value	Probability
House Condition	0.66077	0.072088	9.166161	0.0000
Environment	0.13739	0.066771	2.05769	0.03962
Population Density	0.00386	0.004316	0.89484	0.37087
Knowledge	1.02382	0.07856	13.03079	0.0000
Attitude	-0.51472	0.16840	-3.05650	0.0022
Practice	0.54267	0.107112	5.06633	0.0000

4.3. Spatial Weighted Regression

Based on the results of spatial weighted regression analysis, factors that influence the incidence of malaria in Kulonprogo Regency are the condition of the house, environment, knowledge, attitude, and behavior. This can be seen from the p-value which is less than 0.05. From the results of the analysis, it is also known that population factors did not affect the incidence of malaria in Kulonprogo Regency (p-value> 0.05).

In epidemiological triangle theory, malaria transmission can be viewed from three aspects, namely Host (human), Agent (Plasmodium), and Environment (Environment and vector). In the Host aspect, characteristics that exist in humans such as age, sex, and work will affect a person to be exposed to malaria. Besides that, aspects of knowledge, attitudes and behavior can influence the spread of malaria in various places. In the agent aspect, the characteristics of the plasmodium parasite can also influence the spread of

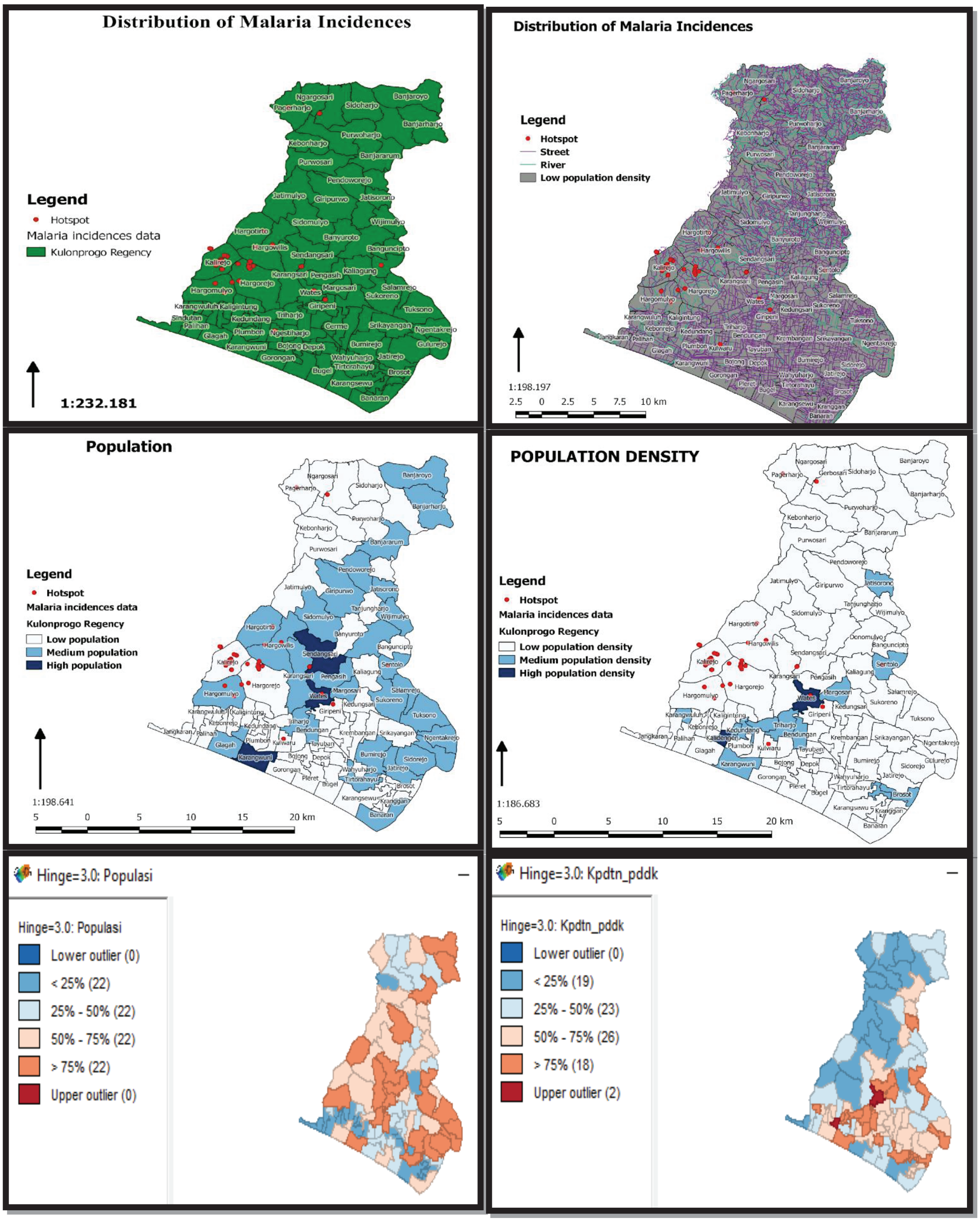

Figure 3: Risk Factor Hotspot.

malaria in various regions. For environmental aspects, climatic factors, environmental conditions around the place of residence, also the presence and type of mosquitoes that spread malaria can be determining factors for malaria distribution in an area (WHO, 2013).

The house condition turns out to have an important influence in malaria transmission in this study. At night, there are mosquitoes that enter the house just to suck blood then go out also before and after sitting on the wall to rest first, so that the condition of a house with many holes is one of the risk factors for malaria (Kemenkes, 2013).

According to Bambang (2005), one of the factors contributing to the high incidence of malaria in an area is the environmental factor that can become a place for vector breeding such as waterlogged excavation holes, rice fields that are always flooded, and untreated fish ponds/ ponds. Environmental conditions affect the incidence of malaria. The existence of lakes, brackish water, and puddles in forests, rice fields, swamps, and fish farms, forest clearing and mining in an area will increase the likelihood of malaria occurrence because the place is a breeding place for malaria mosquitoes. Based on Dahuna's research (2015), anopheles mosquito larvae are often found in open and closed waters, exposed to sunlight directly or indirectly, and gathered in places sheltered by floating water plants (water grass, algae, water hyacinth, etc.). Habitat of anopheles larvae is associated with various kinds of aquatic plants. This plant is used for larvae to tether themselves and the place for the development of microflora and fauna which is a source of food for larvae.

Based on the results of the study it was found that cases that have high and low knowledge related to the level of danger of malaria, vector transmission, symptoms, prevention and treatment of malaria were not much different, namely 55% for high knowledge and 45% for low knowledge. As with knowledge, in terms of attitude and behavior, only 34% of cases have a low attitude towards what is done when they have malaria symptoms, the perception and behavior of malaria-transmitting mosquitoes, and the attitude of preventing malaria and 40% of cases with bad behavior related to health seeking behavior, prevention behavior of mosquito bites, and environmental cleanliness. The large number of respondents with low knowledge, attitudes and behavior is one of the determinants of the high incidence of malaria in Kulonprogo. This result is not much different from the research conducted by Kebede *et al*. (2017) in Ethiopia which stated that 49% of their research subjects had low knowledge of malaria, 45% with a low attitude, and 32% with bad behavior. This study also mentions that a person's knowledge of malaria will affect his attitude regarding malaria control, and a good attitude will influence a person to behave well related to malaria prevention. Another consequence of the lack of knowledge of malaria is the lack of one's knowledge about malaria, especially in the aspects of parasites, vectors, human ecology, and the environment is an obstacle in overcoming malaria. (Harijanto, 2000).

Based on table 4, it can be seen that the risk factors for home conditions, environment, knowledge, attitudes and practice significantly (p-value <0.05) entered the spatial weighted regression model so that it can be said that these risk factors affect the

Table 4: Spatial Weighted Regression Model of Malaria Incidences in Kulonprogo Regency.

Variable	Coefficient	Std. Error	Z-Value	Probability
Constant	-0.02599	0.05271	-0.49316	0.62190
House Condition	0.66077	0.072088	9.166161	0.0000
Environment	0.13739	0.066771	2.05769	0.03962
Population Density	0.00386	0.004316	0.89484	0.37087
Knowledge	1.02382	0.07856	13.03079	0.0000
Attitude	-0.51472	0.16840	-3.05650	0.0022
Practice	0.54267	0.107112	5.06633	0.0000

incidence of malaria in Kulon Progo Regency, where knowledge variables have the greatest value in influencing the incidence of malaria (coefficient value = 1.02382). Spatial weighted regression model equations for malaria cases in Kulon Progo Regency are:

$$y_i = \beta_0(u_i, v_i) + \beta_1(u_i, v_i)\, x_{1i} + \ldots + \beta_p(u_i, v_i)\, x_{pi} + \varepsilon_i,\ i = 1,2,\ldots,n$$

$$y = -0.02599 + 0.66077\,(x_1) + 0.13739\,(x_2) + 1.02382\,(x_4) - 0.51472\,(x_5) + 0.54267\,(x_6)$$

Where y = Number of Malaria Cases, x_1 = House Condition, x_2 = Environment, x_4 = Knowledge, x_5 = Attitude, x_6 = Practice

Then the interpretation of the model obtained is:

1. The number of malaria cases (y) will increase by 0.66077 if the number of cases with home condition risk factors (x_1) increases by 1 unit with the condition that other predictor variables are constant.

2. The number of malaria cases (y) will increase by 0.13739 if the number of cases with environmental risk factors (x_2) increases by 1 unit provided that other predictor variables are constant.

3. The number of malaria cases (y) will increase by 1.02382 if the number of cases with knowledge risk factors (x_4) increases by 1 unit provided that other predictor variables are constant.

4. The number of malaria cases (y) will increase by -0.51472 if the number of cases with attitude risk factors (x_5) increases by 1 unit provided that other predictor variables are constant.

5. The number of malaria cases (y) will increase by 0.54267 if the number of cases with risk factors for action (x_6) increases by 1 unit provided that other predictor variables are constant.

Table 5: GWR Model Fitness.

Model	R Squared	S. E of Regression	Log Likelihood	AIC	SC
GWR	0.996	0.237	1.903	12.193	32.012

Based on table 5, it can be seen that the regression model produces R^2 of 99.6% with a standard error of 0.237 and an AIC value of 12.193 which means that the regression model obtained is able to explain the level of diversity of malaria cases in Kulonprogo Regency at 99.6%, the remaining 0.4% explained by variables other than the model.

This result is similar with the research of Ndiath, *et al* (2015) which found there is 99 percent confidence that malaria occurrence in the study area positively influenced by explanatories variables. This result is not unexpected because the factors can encourage the growth of Anopheles populations and facilitate the malaria transmission. A modelling based on GWR and OLS regression showed important risks factors of malaria hotspots. The outputs of such models can be a useful tool to understand occurrence of malaria hotspots in Senegal.

5. Conclusion

Malaria-prone areas in Kulonprogo Regency were found in Kalirejo Village and Hargorejo Village through the results of spatial analysis using a Geographic Information System approach. Thus malaria control efforts are focused on these vulnerable areas.

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