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Regional Case Study

The Distribution of Dengue Fever Case Based on Environmental Factors using Spatial Analysis

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Abstract

Dengue hemorrhagic fever (DHF) cases in the working area of Margorejo Health Center increased significantly from seven (2021) to 66 (September 2022). One of the efforts to anticipate the disease is acknowledging the distribution pattern of DHF using GIS. This study proposes to reveal the spatial pattern of case distribution, mapping of the vulnerable area, and overlay of LFP (larvae-free rate) related to DHF in the determined working area of Margorejo Health Center. This study was descriptive. The population was patients of DHF. The selected samples were 66. Data were analyzed utilizing univariate and spatial analyses, based on the Average Nearest Neighbor statistical analyses, p-value = 0.001, Z-score = -7.078, and NNI = 0.54<1. These results indicate a clustered spatial pattern, primarily in densely populated areas. The distribution is seen in the buffer area of 250 meters, 750 meters, and 800 meters. The dengue case intensity, population density, and buffer area determine vulnerable areas. Based on the elaborated maps, further, follow-ups related to countermeasures and prevention of DHF are expected to be carried out in the determined area.

Keywords: Dengue fever; environmental factors, GIS, spatial analysis

1. Introduction

Dengue hemorrhagic fever (DHF) is an environmental-based infectious disease caused by the dengue virus through a mosquito called *Aedes aegypti*. This disease has been acknowledged as a global health issue, primarily in tropical and subtropical places. The excessive number of DHF capses in almost all provinces led to the WHO's (World Health Organization) decision to make Indonesia a DHF hyperendemic country in 2009. WHO estimates that 100 million symptomatic cases and 300 million asymptomatic cases appear yearly (Harapan et al., 2021). Based on Indonesia Health Profile data for 2021, DHF cases were at 73,518, with an incidence rate of 27 per 100,000 population. This condition resulted in the death of 705 cases (Ministry of Health of the Republic of Indonesia, 2022). According to data from the Director General of Prevention and Control of the Ministry of Health, DHF cases reached 87,501, with 816 deaths in the 36th week of 2022.

DHF cases in Central Java (2021) reached 4,674, with an incidence rate of 12.8 per 100,000 population, which was also the highest CFR (Case Fatality Rate) in Indonesia by 2.71% (Ministry of Health of the Republic of Indonesia, 2022). The total number of DHF cases in Pati Regency in the same year was 159. DHF infection is significantly related to several factors, such as transfer from the outer region, population density, and air and climate conditions—covering temperature, humidity, and rainfall. In addition, the field monitoring of DHF reveals a strong correlation between the disease and social, economic, and environmental factors such as population density, level of sanitation, and ventilation (Yue et al., 2018).

DHF is also a top health issue in Margorejo Health Center. Based on data from Statistics Indonesia, the population of the Margorejo Sub-district is 63,411. It ranges to 6,181 ha with a population density of 10.26 people/km^2 (Statistics Indonesia of Pati Regency, 2022). Referring to DHF data (2021) from the Health Office of Pati Regency, the Margorejo Health Center found seven cases. It was unfortunate that in 2022, there was a significant increase. By 12 September 2022, the Margorejo Health Center have found 66 DHF cases.

Effective control of DHF cases can be executed by mapping field cases using spatial analysis. This analysis can provide an overview of the actual location and pattern of distribution of DHF cases through an image of the earth's surface. Geographic information system (GIS) is a new technique for mapping and monitoring the global health distribution of infectious diseases in domain and time. It can be used mainly in activities such as identification of spread, prevention and control, allocation of resources, and detection of social emotions. Geographic information can be essential for tracking a pandemic. GIS can track diseases' current and historical prevalence along with several other factors that describe geography, population, and environment (Gangwar & Ray, 2021). The resulting maps allow the integration of prevention and control strategies and public health policies for DHF control (Zambrano et al., 2019).

A better thorough understanding of DHF outbreaks, especially the spatial pattern, will assist in allocating resources for its prevention and control (Yue et al., 2018). Both can be held with several alternatives. The first thing is community-based control that focuses on eradicating the DHF vector. The second is biological control, namely genetic engineering on male mosquitoes to hamper or stop their reproduction. The third is chemical control with insecticides from chemicals or vegetables (Wang et al., 2020).

Several studies related to spatial analysis and mapping of DHF cases based on GIS have been carried out in some regions in Indonesia. Sandukh et al. (2021) concluded that the distribution of dengue cases in groups was found in the working area of the Sikumana Health Center, Kupang City. The study also managed to find a link between dengue cases and a very high population density. Another research by Ayuningtyas (2023) also succeeded in concluding that there is a significant relationship between population density and dengue incidence. Simiraly, research by Pomey et al. (2019) suggest that dengue cases was found in high-density areas.

Studies related to DHF mapping by Yasir et al. (2021) show the same pattern. The distribution of clustered DHF with HI (House Index), CI (Container Index), and BI (Breteau Index), which are on the moderate level, is close to number 5 with the buffering on zone < 50 m and < 600 m. According to a study by Handini and Haidah (2021), eleven DHF cases were distributed in seven areas. Some activities are categorized as environmental factors, namely the absence of water drains and container cover. Meanwhile, the social factors are the lack of socialization in the communities. Studies related to the distribution of dengue cases using spatial analysis mainly based on GIS have never been carried out before in the working area of the Margorejo Pati Health Center. There has been no mapping of vulnerable areas, so dengue control and prevention measures have not been optimal.

This study aims to reveal 1) the spatial pattern of distribution, 2) the mapping of vulnerable areas, 3) the overlay of Larvae-Free Percentage (LFP) in the working area of Margorejo Health Center to stand as guidance for stakeholders to pay more attention to the field and organized programs.

2. Methods

2.1 Data Collection

This study was a descriptive analysis. It applied Geographic Information System (GIS) to display the spatial pattern of DHF case distribution towards the population density. This research was done from September to October 2022 in the working area of Margorejo Health Center, Pati Regency. The population of this study was all DHF patients. The sample was selected using total sampling—by looking at the total of DHF cases by 12 September 2022, resulting in 66 people. The research instruments included patient data sheets, location maps, Microsoft Excel 2016, and QGIS 3.22.7. The administrative map of the Margorejo Sub-district was obtained through a filtering process for the administrative map of Central Java Province from the Ina Geospatial Portal. Secondary data sources were obtained from the Division of Disease Prevention and Control of the Margorejo Pati Health Center. The data contained DHF cases, LFP, and things related to village administration, population, and area.

2.2 Data Analysis

Data analyses were univariate and spatial. The univariate analysis contained case distribution, village, and the month of registration, age, and gender of DHF patients. Meanwhile, spatial analysis was carried out using a GIS-based approach to visualize distribution patterns, vulnerable areas, and overlay of DHF cases using three methods: average nearest neighbor, buffering, and dan overlay.

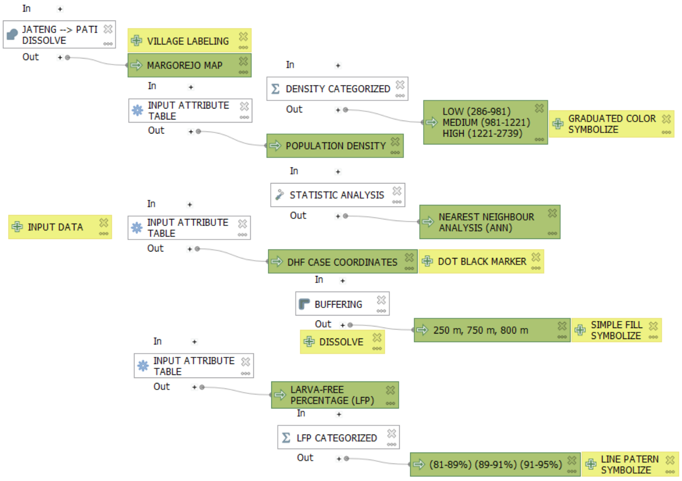

Figure 1. Step by step of data analysis using GIS

Data on confirmed DHF patients in the input in the Excel application is then grouped according to the village of residence and stored in CSV format (comma delimited). Data analysis with GIS starts with the input of the map of Pati Regency and filters of Margorejo sub-district with dissolve, namely 18 villages consisting of: Badegan, Pegandan, Wangunrejo, Bumirejo, Dadirejo, Margorejo, Langenharjo, Muktiharjo, Sukoharjo, Sokokulon, Sukobubuk, Banyuurip, Ngawen, Langse, Penambuhan, Jimbaran, Metaraman, and Jambean Kidul.

After the map of Margorejo District appears, the attribute table data is entered with the categories of village, number of population, area, population density, and dengue cases according to the secondary data. The distribution of dengue cases can be known by overlaying colors according to the number of cases; the darker the color of the overlay, the higher the number of dengue cases in the village.

The coordinates of the dengue case are entered in the delimited test using selected secondary DHF data from Excel in CSV format. After the dengue case was marked with a black dot, buffering was carried out to close the vulnerable area based on the flight distance of the *Aedes aegypti* mosquito, which is 250-750 meters, and buffering 800 meters at the boundary of Margorejo District. Finally, overlaying the pattern of the LFP was carried out on the spatial analysis layer of dengue cases with population density and buffering layers.

3. Result and Discussion

3.1 Case Distribution

Univariate data analysis was used to describe the distribution and frequency of dengue cases based on age and gender, village population and population density, monthly cases, and Larva-Free Percentage (LFP).

Table 1. Frequency of patient distribution based on age and gender

No	Characteristic	Frequency	%
1	Age		
	0-14	49	74.2%
	15-49	16	24.3%
	≥ 50	1	1.5%
2	Gender		
	Male	37	56.1%
	Female	29	43.9%

Source: Margorejo Health Center, 2022

DHF case is distributed to all age groups. Most cases are found in a group of 0-14 years old (49 individuals or 74.2%), followed by a group of 15-49% years old (16 individuals or 24.3%), and a group of ≥ 50 years old (1 individual or 1.5%). Males dominate as the DHF patients by 56.1% (37 persons), while females are 43.9% (29 persons). According to the preceding table, most cases are experienced by kids. This condition might be caused by the kids' tendency to play in a vulnerable room with mosquitos, such as a house or school (Idris & Zulaikha et al., 2021). No significant difference can be observed in terms of gender. This result aligns with a study that states that gender is not a risk factor for DHF because of insignificant differences in the case (Rahmawati et al., 2019).

Table 2. Distribution of population density

No.	Village	Population	Area Width (Km²)	Population Density (People/Km²)	Total of DHF Case
1	Badegan	1,481	2.68	553	0
2	Pegandan	3,120	5.89	530	0
3	Wangunrejo	2,634	3.19	827	4
4	Bumirejo	4,759	3.21	1,483	7
5	Dadirejo	3,336	2.27	1,470	2
6	Margorejo	5,131	4.91	1,047	4
7	Langenharjo	2,969	2.49	1,191	1
8	**Muktiharjo**	**9,011**	**3.29**	**2,739**	**25**
9	Sukoharjo	6,570	3.77	1,743	9
10	Sokokulon	2,604	2.68	972	0
11	Sukobubuk	3,147	3.19	986	8
12	Banyuurip	2,042	3.95	517	1
13	Ngawen	2,699	2.33	1,158	0
14	Langse	2,060	1.48	1,390	0
15	Penambuhan	2,780	2.17	1,281	2
16	Jimbaran	2,109	1.99	1,062	0
17	Metaraman	1,077	3.77	286	1
18	Jambean Kidul	5,422	5.22	1,039	2

Source: Margorejo Health Center, 2022

Population density measures the population in each unit area (km² or hectare). The most populated Margorejo Sub-district is Muktiharjo Village, which is 2,739 people/km². Sukoharjo follows it with 1,743 people/km² and Bumirejo with 1,483 people/km². These three villages possess the most DHF cases in the working area of the Margorejo Health Center. This research aligns with a study that explains that areas with a high density of ≥401 people can potentially have more DHF cases than those with a low population density (Paruntu, 2018).

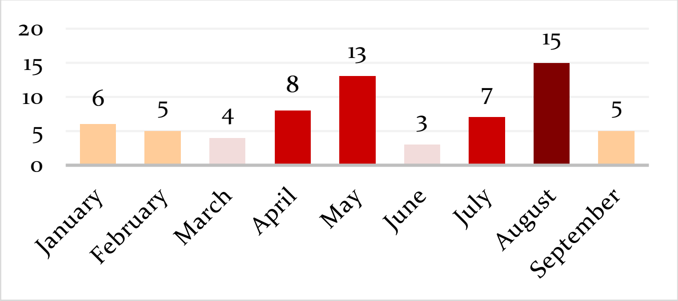

Figure 2. Distribution of monthly DHF case

The total of DHF cases in the working area of Margorejo Health Center by 12 September 2022 is 66. Most cases occurred in Muktiharjo by 25. Most were found in August by 15 and May by 13. The distribution might be caused by climate factors such as rainfall and temperature (Irma et al., 2021).

Tabel 3. DHF case distribution based on larva-free percentage (LFP)

Village	% Larva-Free Percentage	Total DHF Cases
Badegan	95%	0
Pegandan	95%	0
Wangunrejo	95%	4
Bumirejo	95%	7
Dadirejo	95%	2
Margorejo	95%	4
Langenharjo	95%	1
Muktiharjo	81%	25
Sukoharjo	95%	9
Sokokulon	95%	0
Sukobubuk	90%	8
Banyuurip	95%	1
Ngawen	95%	0
Langse	95%	0
Penambuhan	95%	2
Jimbaran	95%	0
Metaraman	95%	1
Jambean Kidul	95%	2

Source: Margorejo Health Center, 2022

Univariate analysis on the DHF case buffer area with population density state that: DHF cases spread in the 250-meter area by 56 and in the 750-meter area by 10. 45 DHF cases (69.7%) occurred in areas with high density, 14 cases (21.21%) in medium one, and seven cases (10.6%) in the low-populated area. LPF univariate analysis with DHF cases shows that 34 cases occurred in areas where LPF was less than 95%, and 32 cases occurred in areas with LPF > 95%.

Spatial analysis was done using Excel and QGIS. Data of confirmed DHF patients were inputted in Excel and then classified according to address coordinate. All was then saved in CSV format.

3.2 Distribution Map

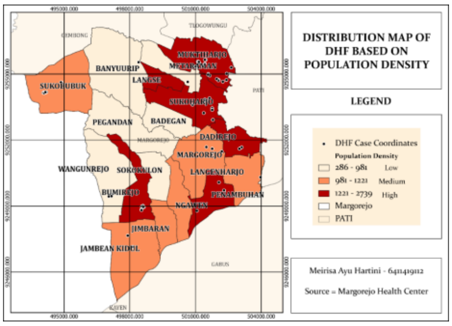

Figure 3. Distribution map of DHF based on population density

The distribution map of DHF cases based on population density can be seen in Figure 1. On the map, all the population densities are red, with the low category (286 – 924 people/km^2) in an opacity level of 30%, the medium (924 – 1221 people/km^2) in the opacity level of 60%, and the high (1221 – 2739 people/km^2) in the opacity level of 90%. DHF cases are marked with a black dot on each coordinate. Based on the spatial analysis results, DHF cases tend to occur more frequently, especially in medium and high-populated areas. In the low populated area, not many DHF cases are found. Analysis with Average Nearest Neighbor was also conducted to prove it with visualization and statistics.

Table 4. Average nearest neighbor analysis

Average Nearest Neighbor Summary	
Observed MD	219.460476
Expected MD	565.279743
NN Index	0.388233
Z-score	-9.507987
Point Count	66
p-value	0.000001

The analysis was conducted using the Average Nearest Neighbor feature in the GIS application. The analysis is the ratio of the results of the division between the observed and expected average distance (based on a random distribution with the same number and covering the same total area). The significance of these results is measured from the Z-score and p-value as a determinant of whether the null hypothesis is accepted or rejected. (Yusrina et al., 2018)

The results of the Average Nearest Neighbor spatial analysis in the GIS application show the *p-value = 0.001* which means that there is a very significant relation between population density and dengue cases and the Z-score = -9.507 <-2, which means there is a spatial pattern of DHF cases in the working area of the Margorejo Health Center. The Nearest Neighbor Index shows the value of NN Index = 0.38 < 1, which makes the distribution pattern of DHF cases in the working area of the Margorejo Health Center clustered. Most cases of clustered DHF (25 cases) were in areas with the highest population density, namely Muktiharjo Village, with 2,739 people/km^2, and villages with low population density, namely Metaraman Village, with 286 people/km^2, with only 1 case of DHF. This study supports research that the distribution of dengue cases in groups was found in the working area of the Sikumana Health Center, Kupang City (Sandukh et al., 2021). The study also managed to find a link between dengue cases and a very high population density. Another research also succeeded in concluding that there is a significant relationship between population density and dengue incidence (Ayuningtyas, 2023). Simiraly, research by Paomey et al. (2019) suggest that dengue cases was found in high-density areas (Paomey et al, 2019). In addition, population density also affects the transmission or spread of disease from one person to another; the denser the population, the more vulnerable it is to DHF spreading (Paruntu et al., 2018).

Chandra et al.'s research in Jambi City strengthens the theory that population density influences DHF cases; the denser the population, the higher the DHF cases (Chandra, 2019). Research by Masrizal also proposed that high population density causes easier transmission due to short distances from homes (Masrizal & Sari, 2016). Moreover, other studies support the theory that population density increases the risk of DHF spreading faster because of the distance the Aedes aegypti mosquito flies (Kusumawati & Sukendra, 2020). Kirana and Pawira's research in Genuk Sub-District also showed that the distribution of clustered DHF cases was found in several places (Kirana & Pawenang, 2017). Research by Mala and Jat (2019) also suggested that the incidence of Dengue Fever in the study area of Delhi clustered geographically (Mala & Jat, 2019). Research in Guangzhou City, China, DHF cases also clustered in certain monthsfigure and densely populated districts (Yue et al., 2018).

A layer is added to the DHF case coordinates in the buffering analysis. In the vector menu, select buffering tools, then enter the buffer area distance, which is 250 meters, 750 meters from the coordinates of the DHF case, and the buffer line is combined with the dissolve. Buffering was also carried out on the Margorejo map, drawn on the outer boundary line for 800 meters to find out how far the cases reach outside the administrative area.

3.3 Vulnerable Area Map

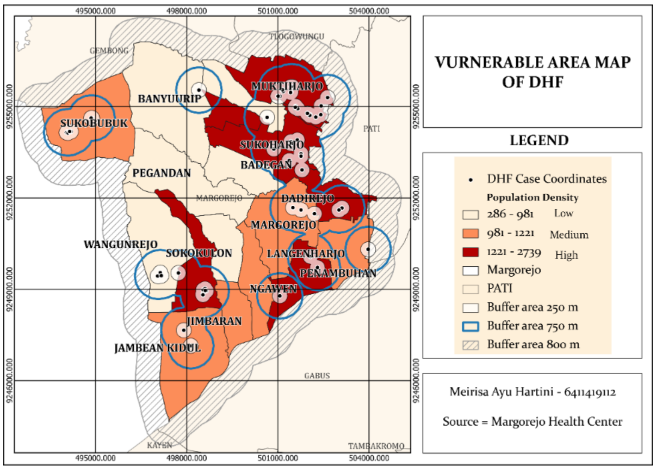

Figure 4. Vulnerable area map of DHF

The map of dengue-prone areas can be seen in **Figure 3**. The 250-meter buffer area is marked with a white circular zone with 50% opacity. The 750-meter buffer area is depicted as a gray circular line that dissolves so that it continues to one another. Meanwhile, the 800-meter buffer area is given a gray shaded symbol and drawn from the sub-district border line to show the length the buffer area extends outside Margorejo.

Based on the buffering of the DHF cases, most case distribution occurs at a distance of 250 meters in village areas with relatively high population density. While buffering is at the maximum flying distance of mosquitoes, most of the DHF transmission occurs within the range of 750 meters. The manifestation of the mosquito's flight distance is 250 to 750 meters since mosquitoes do not have the energy to fly further than that distance (Sulistyo, 2019). Buffer analysis uses mosquito flight distance to find out how far DHF cases are spread from the point of occurrence (Kusumawati & Sukendra, 2020).

The map shows that high-risk DHF cases spread from the northeast to the south of the Margorejo Sub-District area. The vulnerable area is characterized by many DHF case points with medium-high density and is included in the buffer area. Villages that fall into this category are Muktiharjo, Sukoharjo, Dadirejo, Margorejo, Langenharjo, Penambuhan, Ngawen, Jimbaran Kidul, Bumirejo, and Sukobubuk. At several points in the case, the risk of transmission at a radius of 250 and 750 meters even reached areas outside Margorejo up to 800 meters from the regional administrative boundaries. Based on the 800-meter buffer area, outside the sub-districts that are at risk are Pati and Gabus sub-districts.

Research related to DHF mapping by Yasir (2021) shows the same pattern. The distribution of clustered with HI, CI, and BI at moderate levels is close to number 5, with buffering carried out in zones <50 m and <600 m (Yasir et al., 2021). Mapping of DHF by Handini and Haidah (2021) shows DHF cases are spread in 7 regions with 11 cases. Physical environmental factors are mapped based on the undrained and uncovered containers. The biological factor is based on the cheerful houses and LFP. The social factor is based on the unsocialized people and those with the habits of hanging clothes (Handini & Haidah, 2021).

The layer was added from secondary data for LFP overlay analysis with DHF cases. The data was entered in the attribute table layer of LFP and classified into 3, namely coverage of LFP (81-89%) LFP (89-91%), and LFP (91-95%) with different symbols and colors for each category. The classification was conducted using graduated tools and divided into three classify. Then in the symbol tool, symbols were selected to represent the 3 LFP classifications.

3.4 Overlay Map

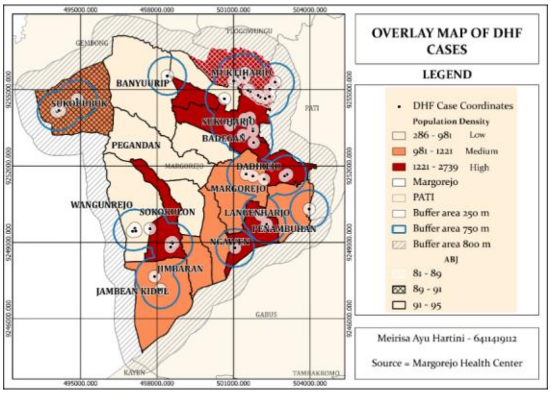

Figure 5. Overlay map of DHF cases

The larvae-free rate (LFP) is a parameter for a PSN. It is deemed successful if LFP has reached the national target (95%). The initial prevention stage is used as an indicator to determine if the house does not contain Aedes aegypti larvae. As long as there are breeding places, mosquitoes can quickly breed and produce new individuals. New mosquitoes contaminated with the Dengue virus will again transmit DHF (Alfianti & Siwiendrayanti, 2021).

LFP overlay analysis with DHF cases can be seen in **Figure 4**. Based on LFP data from the Margorejo Health Center, most areas have reached 95%. They are marked with a black outline symbol. Meanwhile, only Muktiharjo and Sukobubuk Village areas are in 81% (white cross line) and 90% (black cross). The relation between LFP and the distribution of DHF cases is less visible on the map because DHF cases are still found in areas with 95% LFP. This can be affected by limitations on updating PSN data. PSN data for 2022 is unavailable because PSN 3M Plus activities were not implemented due to the pandemic. This is supported by Sukesi's research (2022) that *jumantik* cadres were inactive during the pandemic even though public awareness regarding DHF control was good (Sukesi et al., 2022). Setiyoningrum (2020) states that PSN behavior is related to the larva-free rate (LFP) (Setyoningrum et al., 2020).

The map from the Geographic Information System (GIS) analysis described in the previous explanation should guide stakeholders in determining control measures and prevention policies, especially in areas with high prevalence and areas prone to DHF. The Margorejo Health Center has carried out countermeasures such as administering Epidemiology Investigation, larvicides, and fogging, but these are only effective if preventive measures support them. It is hoped that the local government will develop *jumantik* cadres to follow up on efforts to continue the 3M Plus PSN program.

Communities, especially in vulnerable areas, should always be vigilant against DHF transmission. It is also hoped that there will be community support to prevent and eradicate DHF by implementing the PSN 3M Plus program. 3M can be done by: a) draining water containers/reservoirs (tubs, buckets, refrigerators, dispensers); b) Closing the container/water reservoir (tank, drum, jug); c) Reusing used items that have the potential to become stagnant water where mosquitoes lay their eggs (cans, tires, bottles) while "Plus" is an effort to avoid mosquito bites with activities such as; 1) sowing larvicides, 2) using mosquito repellents, 3) using mosquito nets, 4) rearing larvae-eating fish, 5) planting plants that mosquitoes do not like, 6) regulating ventilation and light in the house, 7) getting used not to hang clothes, and 8) using of shower/running water for bathing (Yuningsih, 2018).

In the case of dengue hemorrhagic fever (DHF), GIS mapping has been used to offer improved surveillance and community-based intervention programs for controlling dengue and aids in measuring the successful prevention rate (Wang et al., 2020). Spatial analysis using GIS has also visualized the dynamic development of the aggregation of disease incidence (hotspots) for dengue (Faridah et al., 2021). In addition, GIS has been used to predict dengue outbreaks based on disease surveillance, meteorological, and socio-economic data (Jain et al., 2019). Disease mapping using GIS can help identify risk areas and potential epidemic initiators, aiding decision-makers in determining which regions should be treated intensively to reduce mosquito breeding and the prevalence of DHF (Sahdev et al., 2020). Overall, GIS can be an effective tool in reducing DHF cases by identifying risk areas and implementing targeted interventions to control the spread of the disease.

Suggestions for further research are to pay attention to the time of data collection so that the number of samples can be sufficient, to use a more stable computer programming for ArcGIS, and to add more environmental factor variables that may be related to the DHF mosquito breeding areas such as the distribution of SPAL and dug wells in the study area.

4. Conclusion

The spatial pattern of the DHF cases distribution in the working area of the Margorejo Health Center is clustered, especially in medium to a high populated areas. DHF-prone areas are mapped in Muktiharjo, Sukoharjo, Dadirejo, Margorejo, Langenharjo, Penambuhan, Ngawen, Jimbaran Kidul, Bumirejo, and Sukobubuk. On the overlay map, DHF cases are still found in areas with high LFP. Based on the results maps that have been described, it is hoped that there will be follow-up actions related to the focus on DHF prevention and control, especially in the areas that have been mapped.

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