



Spatiotemporal Vulnerability to Dengue Hemorrhagic Fever Incidence in Semarang, Indonesia

**Robertus Anna Pentekosta Kleden¹, Nur Endah Wahyuningsih²,
Sulistiyani Sulistiyani³**

*^{1,2,3}Department of Environmental Health, Faculty of Public Health, Diponegoro University,
Prof. Soedarto SH Street, Semarang, Indonesia
Email : rkleden55@gmail.com*

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Dengue hemorrhagic fever (DHF) is a disease caused by a virus carried by the *Aedes aegypti* mosquito which is a serious problem in the city of Semarang. This study aimed to analyze the vulnerability of the region to the incidence of dengue hemorrhagic fever (DHF) Semarang.

The study conducted in 2019 using secondary data from Meteorology, Climatology and Geophysics Agency (BMKG), the Central Statistics Agency, and the Semarang City Health Office. Regional vulnerability determined by the weighted overlay method. This research used descriptive analytic method with spatial approach. DHF vulnerability identified based on indicators of air temperature, air humidity, rainfall, larval free numbers, endemicity, and population density. The level of vulnerability of the area to the incidence of Dengue Hemorrhagic Fever (DHF) in Semarang City showed that 14.1% of the urban area in the city of Semarang categorized as not vulnerable, 53.1% vulnerable, and 32.8% very vulnerable.

Keywords: *vulnerability, dengue hemorrhagic fever, weighted overlay*

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Introduction

Dengue fever is a disease caused by dengue virus (DENV) and is transmitted through arthropods. The dengue virus is classified as the Arthropod-Borne Virus, the genus Flavivirus, and the Flaviviridae family (Ross, 2010). Dengue fever has evolved from sporadic disease into a major public health problem (Guzman, 2015). The Centers for Disease Control and Prevention (CDC) states that there are currently around 2.5 billion people or 40% of the world's population living in areas at risk of dengue transmission. Endemic dengue occurs in at least 100 countries in Asia, the Pacific, America, Africa and the Caribbean. The World Health Organization (WHO) estimates that 50 to 100 million infections occur each year, including 500,000 cases of DHF and there are 22,000 deaths, most of them children (Centers for Disease Control and Prevention, 2019).

Dengue Fever become serious problem in Central Java Province, it is proven that 35 districts or cities have been infected by Dengue Fever. The incidence rate (IR) of DHF in Central Java Province in 2017 was 21.68 per 100,000 population, down compared to 2016 which was 43.4 per 100,000 population. This means that the DHF IR in Central Java is lower than the national target ($<48 / 100,000$). The case fatality rate (CFR) of DHF in Central Java in 2017 was 1.24%, down from the 2016 CFR of 1.46% (Central Java Province Health Office, 2017). Data on the incidence of dengue during the last ten years (2009-2018) from the Semarang City Health Office showed a fluctuating case trend. The highest number of sufferers in 2010 (5,556 sufferers) and decreased dramatically in 2016 to 2018. The highest DHF Incidence rate (IR) occurred in 2010 (368 cases per 100,000 population) then decreased (<100 cases per 100,000 population) and increased again in 2013 (134 cases per 100,000 population), then continued to decline until IR reached 6.17 cases per 100,000 population in 2018. However, looking at the DHF CFR showed an increase since the year 2010. The highest CFR rate occurred in 2016 (5.13%), decreased in 2017 (2.68%), and 0% in 2018.

Semarang City is a dengue endemic area. Based on data from the Semarang City Health Office, it appears that in the last 3 years there was a decrease in DHF cases in Semarang from 2016 with 144 cases (IR = 25.22), then there was a decrease in 2017 with a number of cases 299 (IR = 18, 4) and in 2018 there were 103 cases (IR = 6.25). CFR in 2018 decreased from the previous year in 2017 which was 2.68 to 0.97 in 2018. However, not all of Semarang city has a high endemicity rate. There were areas that fall into the sporadic, potential, and even DHF-free categories (Semarang Health Office, 2017). It remains to be known about what are the causes of an area vulnerable to DHF.

Studies on susceptibility to dengue fever (DHF) in Indonesia are still limited. Regional vulnerability studies on DHF have not been conducted in the city of Semarang. Even though Semarang City is an area with a high population density. The population density of Semarang City increases every year. In 2012 the population density reached 4,172, in 2016 it increased to 4,289 people per km² (Semarang Central Statistics Agency, 2016). In addition, the incidence of DHF in the city of Semarang increased especially during the rainy season. Geographically, the height of the Semarang City area also varies from areas in the coastal area with a height of 0.75 meters above sea level to the area at the peak which reaches 348 meters above sea level (Semarang City Statistics, 2016). Therefore, research on studies of vulnerability to DHF in the



city of Semarang is important to do. This study aimed to analyze how the vulnerability of the City of Semarang to the incidence of dengue fever.

Methods

This research used exploratory spatial design. Secondary data were obtained from the Meteorology, Climatology and Geophysics Agency (BMKG), the Central Statistics Agency, and the Semarang City Health Office. Data collected included air temperature, humidity, rainfall, percentage of larvae free range, endemicity of the region, population density, and dengue fever cases from January to June 2019. Air temperature, humidity, and rainfall were obtained from BMKG. Percentage of larval free rates, endemicity of the area, and dengue fever cases was obtained from the Semarang City Health Office. Population density obtained from the Semarang Central Statistics Agency data. DHF vulnerability obtained by weighted overlay method. Weight of each variable based on the value of the correlation coefficient (r).

Before conducting correlation analysis, the research data were tested for normality of data used Kolmogorov Smirnov ($n = 177$). Data normality test on the variable DHF incidence rate, population density, rainfall, and PLFR showed data not normally distributed (p -value = 0.0001). Therefore, the correlation test conducted with Kendal's Tau correlation. Kendal's Tau correlation analysis results showed population density, rainfall, and endemicity associated with the incidence rate of DHF (p value <0.05) (Table 1). Air temperature and humidity were not analyzed using Kendal's Tau correlation because of the data used were the average data of Semarang city.

Table 1. Analysis of Kendal's Tau correlation between population density, rainfall, PLFR, and endemicity of DHF incidents in Semarang City in 2019

Variables (n=177)	Mean $\pm$ SD	Range	r	p
Endemicity	-	-	-0,451	0,000
Rainfall	187,69 $\pm$ 34,2	147-318	0,212	0,000
Population density	8.048,82 $\pm$ 6.536,8	278-35.765	0,115	0,030
PLFR	88,11 $\pm$ 17,2	0-99,52	0,025	0,642

Table 2. Weighting and Scoring Research Parameters

No	Raster Data Input	Category (Old Value)	Score (New Value)	Weight (%Influence)
1.	Map of average temperatures in the city of Semarang	28°C	1	5
2.	Map of the average rainfall in the city of Semarang	<100 mm and >300 mm 100 mm - 199 mm 200 mm - 300 mm	1 2 3	25
3.	Map of average air humidity in the city of Semarang	78%	1	5
4.	Map of endemicity of the area in the city of Semarang	Free Potential Sporadic Endemic	1 2 3 4	30
5.	Map of PLFR in the city of Semarang	$\geq$ 95% <95%	1 2	15



6. Map of population density in the city of Semarang	Low	1	20
	Medium	2	
	High	3	

Regional endemicity is an indicator with the highest value of r ($r = 0.451$), followed by rainfall ($r = 0.212$), population density ($r = 0.115$), and larval free rate (PLFR) ($r = 0.025$). Weight in endemicity, rainfall, population density, PLFR, air temperature, humidity respectively 30%, 25%, 20%, 15%, 5%, 5% (Table 2).

Average air temperature and humidity are 28°C and 78%, then both are given a score of 1. Rainfall categorized into 100 mm, and >300 mm; 100 mm - 199 mm; and 200 mm - 300 mm, then given a score of 1, 2, 3 (Wang, Tang, Wu, Xiao, & Cheke, 2019). Regional endemicity categorized as free, potential, sporadic, and endemic, each score 1, 2, 3, 4. PLFR categorized into $\geq 95\%$ and $< 95\%$, each given a score of 1, 2 (Ministry Indonesian Health, 2011). Categorization for population density parameters used the Natural Breaks categorization, each categorized as low, medium, high, given a score of 1, 2, 3.

The overlay results showed the value of vulnerability ranging from 1.15 to 2.15. The level of DHF vulnerability classified into 3 (three), namely not vulnerable, vulnerable, and very vulnerable. The not vulnerable category at values 1.25-1.80; vulnerable category had a value of 1.81-2.30; very vulnerable category had a value of 2.31-2.95. Furthermore, vulnerability values classified used Natural Breaks (Jenks) classification.

This study was approved by the ethics research committee of the Diponegoro University Public Health Faculty number 371 / EA / KEPK-FKM / 2019.

Results

The results showed that in the most vulnerable areas the highest number of DHF cases are 26 DHF cases. In vulnerable areas, the highest DHF cases were found in 11 cases. In areas that are not vulnerable, the highest DHF cases are 3 cases. When looking at rainfall, the rainfall in a very vulnerable area is higher than the rainfall in an area that is vulnerable and not vulnerable. The average rainfall in a very vulnerable area is 200.74 mm. vulnerable areas 181.03 mm, and non-vulnerable regions 182.48 mm. Population density in very vulnerable areas is also higher compared to vulnerable and non-vulnerable areas. The average population density in very vulnerable areas is 13,562 people / km². The average population density in vulnerable areas is 5,905 people / km², and in non-vulnerable areas is 3,317 people / km². PLFR in vulnerable areas is lower than in very vulnerable and non-vulnerable regions. The average PLFR in vulnerable areas is 90.7%, in very vulnerable regions 90.9%, and non-vulnerable regions 93.59% (Table 3).

Table 3. Median (Min-Max) Dengue Vulnerability Indicator in Semarang City

Indicator	Not vulnerable	Vulnerable	Very vulnerable
DHF cases	0 (0-3)	1 (0-11)	3 (0 - 26)
Rainfall	150 (147-318)	188 (147-238)	201 (147 - 238)
Population density	1.557 (376-15.156)	4.960 (278-24.183)	13.971 (2.565 – 35.765)
PLFR	94,3 (85 – 99,52)	92,14 (65,84-97,4)	91,995 (75,98-99,44)



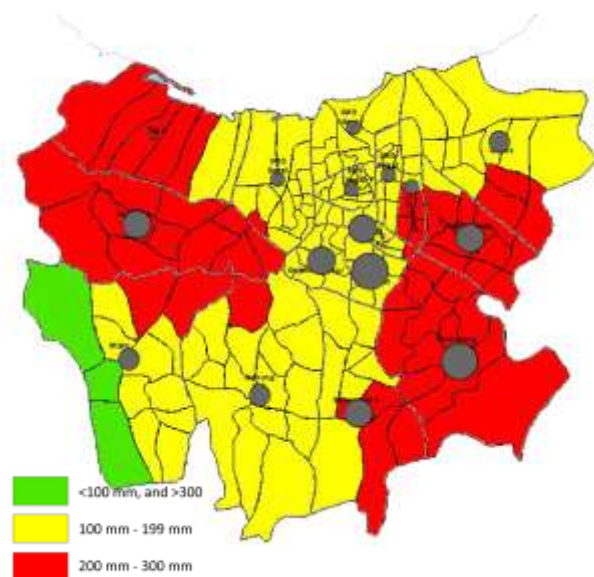
Based on the map of the distribution of dengue cases based on rainfall, the average rainfall in the city of Semarang is divided into 3 categories namely <100 mm (no potential), 100-200 mm (medium potential), and 200 - 300 mm (high potential) . There are several districts in the city of Semarang that have 200 - 300 mm of rainfall which has the potential to transmit dengue disease between them, Tembalang District, Pedurungan District, Ngaliyan District, and Tugu District. Tembalang District is the district with the highest number of DHF cases in the City, which is 115 cases. There are several villages in Tembalang sub-district that have the highest number of cases, namely Sendangmulyo with 26 cases and Sendangguwo with 20 cases. Sendangguwo sub-district and Sendangmulyo sub-district have average rainfall of 200 - 300 mm and fall into the potential category. Mijen District has a varied rainfall, Mijen District also has a small number of dengue cases which is 13 cases. There are two sub-districts in Mijen sub-district that have rainfall > 300 mm or no potential for the development of *Aedes aegypti* as a vector of dengue transmission, namely Cangkiran sub-district, Wonoplumbon sub-district, these two sub-districts have no cases of dengue in 2019 (Fig 1.a).

The area with high population density spread in Banyumanik Subdistrict, Padangsari Village. South Semarang District in Lamper Lor Village, Lamper Tengah. Gayamsari Subdistrict in Pendean Lamper Village, Siwalan, Sambirejo, Sawah Besar, Kaligawe. Pedurungan District in Gemah Village, Muktiharjo Kidul. Genuk Subdistrict in Bangetayu Kulon Village. East Semarang District in Rejosari Village, Sarirejo, Mlatiharjo. Candisari Subdistrict in Karanganyar Mountain Village, and Temple. Semarang Tengah District in Jagalan, Kranggan, Gabahan, and Lor Districts. West Semarang District in Ngemplak Simongan Village, Gisikdrono, Bongsari, Bojongsalaman, Krobokan. North Semarang District in Bulu Lor Village, Plombokan, Purwosari, Kuningan. Ngaliyan District in Bringin Village, Kalipancur (Fig 1.b).

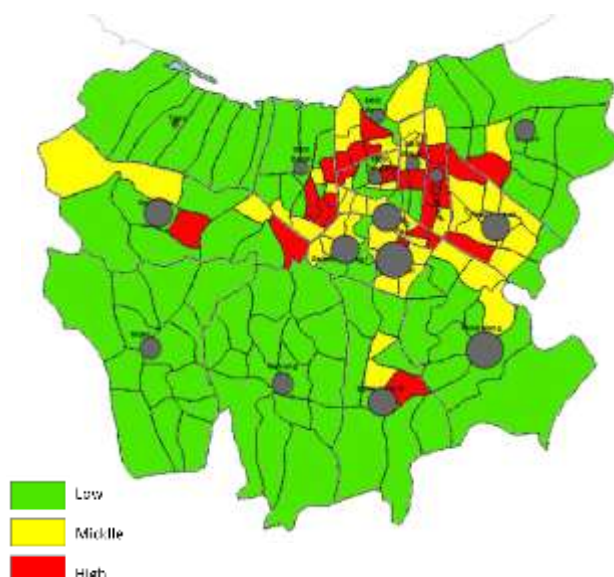
Distribution of dengue cases based on endemic areas, Banyumanik District is a district that has the most urban areas included in the category of endemic DHF. Of the 11 (eleven) villages in Banyumanik sub-district, there are 7 (seven) villages classified as endemic, 3 (three) villages classified as sporadic and 1 (one) village as potential. Tembalang Sub-district is a sub-district that has the highest DHF case in Semarang City, out of 12 (twelve) villages within the Tembalang sub-district area, there are 6 (six) villages that are categorized as endemic, while 6 (six) other villages are included in the sporadic category. The sub-district with the lowest number of DHF cases in Semarang is Tugu sub-district, which has 7 urban areas. From 7 (seven) in Tugu sub-district, there are 6 that are included in the Sporadic category and 1 (one) village as the free category (Fig 1.c). The distribution of larval free numbers (PLFR) of Semarang City shows that there are still many regions whose PLFR is <95%. The subdistricts of Genuk and Gajahmungkur have PLFR which are <95% in the entire village area. Some areas such as Tembalang and Banyumanik districts only have one village with PLFR $\geq$ 95% (Fig 1.d).



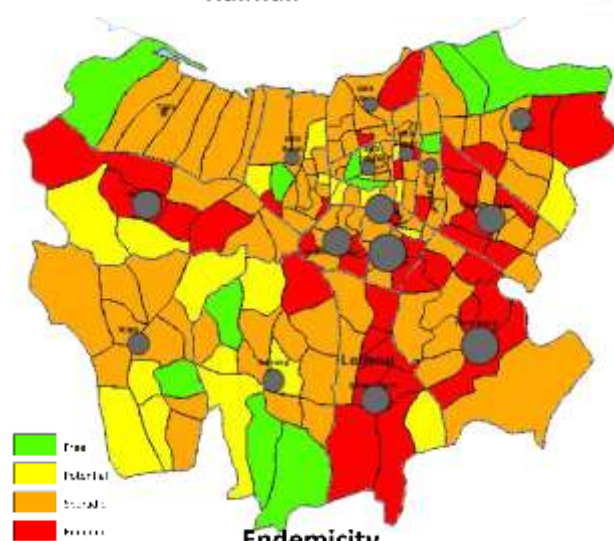
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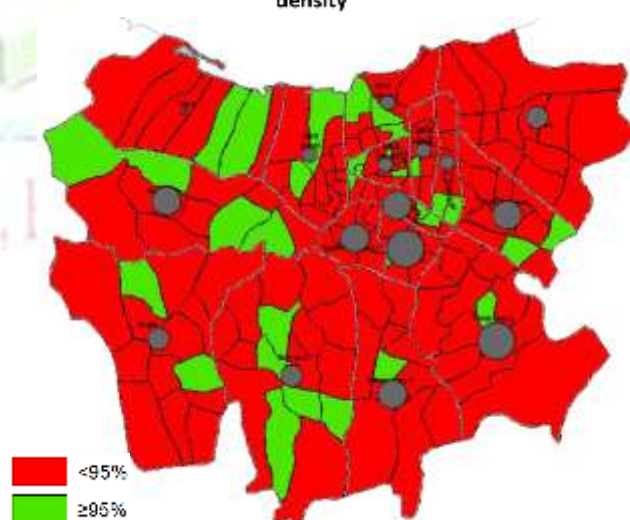
Rainfall



Population density



Endemicity



Larvae free number (LFN)

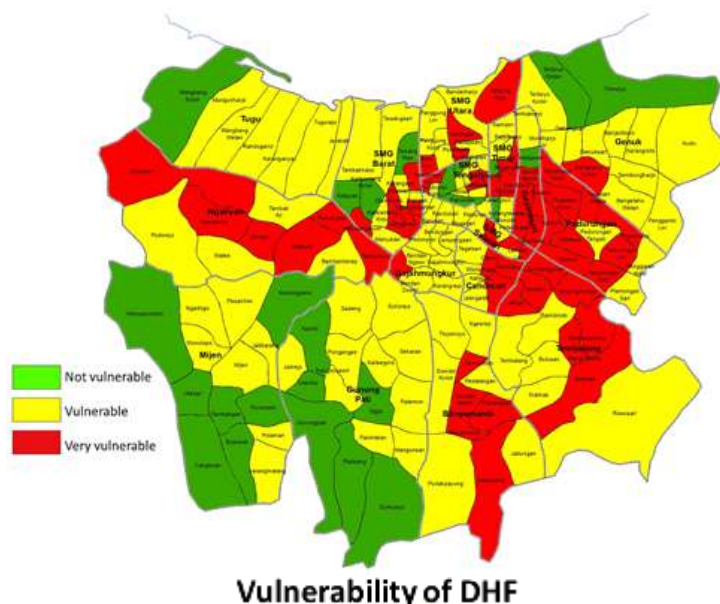


Fig 1. Distribution of DHF incidence rate based on rainfall (a), population density (b), endemicity (c), larvae free number (PLFR) (d), and vulnerability of DHF (e) in Semarang (Period January to June 2019)

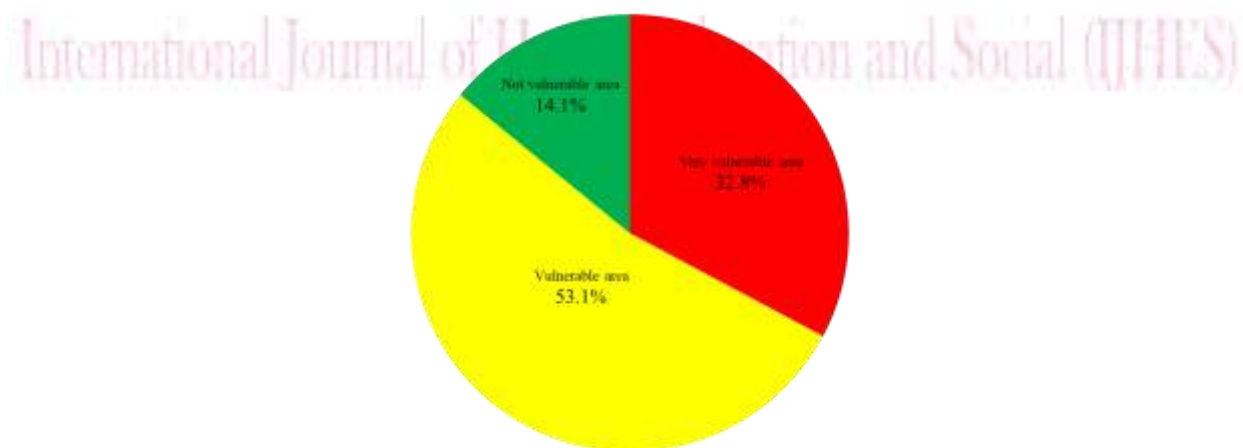


Fig.2 Semarang City DHF Vulnerability Level 2019

The results of the vulnerability analysis showed that 14.1% of the urban areas in Semarang were categorized as not vulnerable, 53.1% were vulnerable, and 32.8% were very vulnerable (Fig.2). In more detail, the distribution of Semarang City area based on the level of vulnerability has been presented in table 4.



Table 4. Regional distribution based on the level of vulnerability in Semarang City in 2019

Not vulnerable		Vulnerable		Very vulnerable	
Sub-district	Villages	Sub-district	Villages	Sub-district	Villages
Mijen	Cangkiran, Bubukan, Purwosari, Tambangan Kedungpane, Wonoplumbon Jatisari	Mijen	Karangmalang, Polaman, Wonolopo, Mijen, Jatibarang, Ngadirgo, Pesantren	Banyumanik	Gedawang, Padangsari, Banyumanik Sronol Wetan, Sumurboto
Gunungpati	Gunungpati, Plalalang, Ngijo, Cepoko, Sumurejo, Kandri	Gunungpati	Pakintelan, Mangunsari, Patemon, Pongangan, Nongkosawit, Jatirejo, Sekaran, Sadeng, Sukorejo, Kalisegoro	Gajahmungkur	Sampang
Gayamsari	Kaligawe	Banyumanik	Pudakpayung, Jabungan, Pedalangan, Sronol Kulon, Tinjomoyo, Ngesrep	Semarang Selatan	Wonodri, Lamper Lor, Lamper Tengah
Genuk	Trimulyo, Terboyo, Wetan	Gajahmungkur	Bendan Duwur, Karangrejo, Gajahmungkur, Bendan Ngisor, Petompon, Bendungan, Lemponsari	Gayamsari	Pandean Lamper, Gayamsari, Siwalan, Sambirejo, Sawah Besar
Semarang Timur	Karangturi, Kebonagung	Semarang Selatan	Randusari, Barusari, Balustalan, Mugasari, Pleburan, Peterongan, Lamper Kidul	Pedurungan	Gemah, Pedurungan Kidul, Pedurungan Lor, Tlogomulyo, Palebon, Kalicari, Tlogosari Kulon, Tlogosari Wetan, Muktiharjo Kidul,
Semarang Tengah	Sekayu, Pandansari, Pakunden	Gayamsari	Tambakrejo	Genuk	Bangetayu Kulon
Semarang Barat	Krapyak, Kalibanteng, Kulon, Tawang Mas	Pedurungan	Plamongan Sari, Penggaron Kidul, Pedurungan Tengah	Semarang Timur	Rejosari, Sarirejo, Bugangan, Mlatiharjo
Tugu	Mangkang Kulon	Genuk	SembungharjoKudu, Karangroto, Banjardowo, Gebangsari, Penggaron Lor, Muktiharjo Lor, Bangetahu Wetan, Genuksari, Terboyo Kulon	Candisari	Karanganyar, Gn Jomblang, Candi
		Semarang Timur	Karangtempel, Mlatibaru, Rejomulyo, Kamijen	Tembalang	Meteseh, Mangunharjo, Sendangmulyo, Jangli, Tandang, Kedungmundu, Sendangguwo, Jagalan,



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Not vulnerable		Vulnerable		Very vulnerable	
Sub-district	Villages	Sub-district	Villages	Sub-district	Villages
		Candisari	Jatingaleh, Kaliwaru, Wonotingal, Tegalsari	Semarang Tengah	Kranggan, Kranggan, Pendirikan Lor
		Tembalang	Rowosari, Kramas, Tembalang, Bulusan, Sambiroto	Semarang Barat	Ngemplak Simongan, Gisikdrono, Bongsari, Bojongsalaman, Krobokan , Kembangarum
		Semarang Tengah	Miroto, Brumbungan, Kembangsari, Bangunharjo, Kauman, Karangkidul, Purwodinatan, Pendirikan Kidul, Manyaran, Tambakharjo, Kalibanteng Kidul, Salamanmloyo, Cabean, Karangayu, Tawangsari, Bandarharjo, Plombokan, Dadapsari, Panggung Kidul, Panggung Lor	Semarang Utara	Bulu Lor, Purwosari, Kuningan, Tanjung Mas
		Semarang Utara	Podorejo, Wates, Bambankerep, Tambak Aji	Ngaliyan	Bringin, Ngaliyan, Kalipancur, Purwoyoso, Gondoriyo, Wonosari
		Ngaliyan	Jerakah, Tugurejo, Karanganyar, Randugarut, Mangkang Wetan, Mangunharjo		
		Tugu			

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Discussion

Previous studies conducted a vulnerability analysis using the WADI (water associated disease index) approach to dengue in Malaysia. The variables used in their research are temperature, rainfall patterns, population density, land cover, demographics, and socioeconomic. The results of this study indicate a high susceptibility to dengue in Malaysia that occurs in urban areas (Dickin, 2013). In that study, DHF was found mostly in urban areas because exposure to dengue virus was higher in high population populations. The possibility of contracting dengue virus in areas with dense population is greater than in rural areas. Other conditions that make DHF commonly found in urban areas are the number of impermanent buildings, vacant buildings, and infrastructure inadequate into breeding places for *Aedes* sp. Mosquitoes.

Another study related to regional vulnerability to DHF was conducted by Mizan, et al in 2017 in Southeast Sulawesi. The analytical method used is the analysis of the nearest neighbor and the overlapping analyst. The results of his study showed the percentage of vulnerable areas (22.91%) and very vulnerable (15.61%). The variables used by Mizan et al consisted of land use, p density, settlement patterns, population density, infectious mosquito fly network, rainfall, air temperature, and air humidity (Mizan, 2017). Mizan's research was carried out in Bau Bau City with sub-district units consisting of Batupoaro, Betoambari, Bungi, Kokalukuna, Lea-lea, Murhum, Sorawolio, and Wolio Districts. In that study, Mizan et al did not do a correlation analysis. The overlay method used only uses the score of each variable. In contrast, this study uses scores and weights to calculate regional vulnerability.

The results showed that the variable population density and rainfall are related to the DHF case in Semarang City in 2019. Rainfall is the height of rain water that falls on the ground while the condition does not evaporate, does not absorb and does not flow. Climate change causes changes in rainfall so that it has an effect on the ecosystem and affects the development of DHF vectors such as the *Aedes* sp. Mosquito. Rainfall is very influential on the survival of *Aedes* sp. rain caused an increase in humidity and increased the number of *Aedes* sp mosquito development sites outside the home (Sucipto, 2011).

The effect of rainfall on DHF events is quite important research because as a need to be a tool for estimating the variation of incidents and risks associated with climate change impacts. Population density factors affect the process of transmission or transfer of disease from one person to another. Without adequate prevention efforts, the more densely populated the more conducive the virus to multiply so as to result in an increase in cases. Dengue Hemorrhagic Fever (DHF) is an infectious disease that can be treated with regional-based disease management (Achmadi, 2012). Regional-based DHF disease management can be seen in terms of the social environment such as urbanization which can cause overcrowding. The results showed that the average population density of Semarang City reached 7,261.3 people per km². The lowest population density is in Tugu Regency, which is 1074.6 people per km² and the highest population density in Gayamsari Regency is 16,164.2 people per km². The denser the area, the



greater the potential for disease transmission. This is because areas that have high density facilitate transmission of DHF (Suyasa, 2012).

Endemic areas in Semarang City consist of free, potential, sporadic, and endemic. The highest percentage is sporadic (55.9%). Indonesia has the risk of contracting dengue fever due to the virus that causes it and its mosquitoes are widespread in all provinces, districts / cities and villages. Therefore, to control this disease, a community empowerment movement is needed by eradicating Aedes (Directorate General of Disease Control and Environmental Sanitation, 2014).

Other research on vulnerability in Indonesia shows that several factors related to climate change such as mitigation aspects, such as water scarcity, Reduction of Emissions from Deforestation and Degradation (REDD), forest conservation, disasters, land drought, floods and others. In 2013 the Research Center for Climate Change — the University of Indonesia (RCCC-UI) conducted a study on the vulnerability of dengue related to climate change, in collaboration with the Ministry of Health's Environmental Health Directorate and supported by the Indonesia Climate Change Trust Fund (ICCTF). This study involved 20 regencies / cities in 5 provinces, namely West Sumatra, Jakarta, East Java, Bali, and Central Kalimantan. Components of DHF vulnerability seen are bionomic habitat, land use (settlements, offices, businesses, schools, etc.), population density. The most dominant variable is breeding and resting places aedes sp, then followed by population density and population mobilization (Haryanto, 2018). In this study, breeding and resting places became the dominant factors because demographically the study was conducted in densely populated areas and high population mobility. The study, specifically conducted in Padang, Malang, Denpasar, Palangkaraya, on average has the characteristics of a dense population, the behavior of people who tend to ignore the existence of breeding and resting places of Aedes sp mosquitoes in their environment.

Conclusion and Recommendation

The level of regional vulnerability to the incidence of dengue fever (DHF) in Semarang City shows that 14.1% are categorized as not vulnerable, 53.1% are vulnerable, and 32.8% are very vulnerable. Future studies can use more complex variables by including socioeconomic indicators, environmental indicators in more detail at breeding places, resting places, building conditions, land use to obtain higher vulnerability sensitivity values.



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