Time-Series Analysis of Climate Change Effect on Increasing of Dengue Hemorrhagic Fever (DHF) Case with Geographic Information System Approach in Yogyakarta, Indonesia

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ABSTRACT

Dengue Hemorrhagic Fever (DHF) is an infectious disease which is still a national health problem. The cases tend to increase every year and spread wider along with human activities and mobilization. The phenomenon of global warming and climate change is expected to increase the number of dengue cases. Dengue cases in Yogyakarta still fluctuate every year. This study aims to apply time-series analysis to identify the effect of climate change on the increasing cases of DHF with Geographic Information System approach. This study was an observational analytic study which used an ecological study design. This research was conducted in April-November 2019 in Yogyakarta by using time-series analysis techniques and Geographic Information System overlay techniques. The result of study shown climate factors (rainfall, air temperature, and humidity) simultaneously influence the incidence of DHF (p-value = 0.000). All villages in Yogyakarta were an endemic area in 2013-2019. Therefore, the community should take precautions to prevent dengue infection and increase early vigilance when rainfall season, temperature and humidity increase. Recommendation for District Health Office to use weather data in the planning of prevention and control programs DHF.

Keywords: *Dengue Hemorrhagic Fever (DHF), Time-Series, Geographic Information Systems*

I. INTRODUCTION

Dengue Hemorrhagic Fever (DHF) is a disease that caused by dengue virus which is classified as Arthropod-Borne Virus, genus Flavivirus, and family Flaviviridae. DHF is transmitted through mosquito bites from the Aedes genus, especially Aedes aegypti or Aedes albopictus. DHF could occur throughout the year and can affect all age. Data from all over the world shows that Asia has the highest number of dengue sufferers each year. The World Health Organization (WHO) data showed that Indonesia is the country with the highest DHF cases in Southeast Asia in 2009.[1,2]

DHF is one of the main public health problems in Indonesia since the discovery of this disease in 1968 at Surabaya with a mortality rate of 41.3%. Since then, the number of cases and the spread has lifted with the increase of mobility and population density in Indonesia.[2] Based on reports from the Ministry of Health of Indonesia in 2018, in 2017 the number of dengue cases is 68,407 with 493 deaths. The number decreased quite dramatically from the previous year, which is 204,171 cases, and 1,598 deaths. Incidence rate in 2017 decreased compared to 2016, from 78.85 to 26.10 per 100,000 populations. However, the case fatality rate (CFR) just slightly decreased from previous year, 0.78% in 2016, to 0.72% in 2017.[1] CFR is a percentage of the people who experiencing death from a particular disease which is usually used as infectious diseases indicator. CFR of DHF in Special Region of Yogyakarta is 1.27% and is still higher than the national CFR of 0.72%. DHF spread in 433 districts / cities across Indonesia, and Yogyakarta City is one of areas that still endemic for DHF.[1]

Based on data from the Yogyakarta City Health Office, it is known that the number of dengue fever in Yogyakarta City has fluctuated since 2008 until now, although there was a decrease in 2016 - 2018. But in early 2019 DHF cases escalated with the number 97 cases (January 67 cases and February 30 cases). Whereas, the highest incidence per month at the previous year only reached 20 cases. This means there is a significant increase if we compared to the same period at the previous year. Climate change and high rainfall in early 2019 are expected to be one of the causes of the increase in dengue cases in the city of Yogyakarta.[3]

The incidence of DHF still fluctuated in the last few years in Yogyakarta City. Increased cases of DHF mainly occur in the rainy season. Based on several studies, the incidence of DHF is influenced by weather and climate conditions. According to Mc. Michael (2006), climate change causes the changes in rainfall, temperature, humidity, and air direction, so it affects the terrestrial and oceanic ecosystems. It also affects the occurrence of disease, particularly vector borne disease such as DHF, malaria and any others. Various DHF control programs have been carried out, but have not been effective in reducing the number of DHF events in the city of Yogyakarta.[2]

Many factors that can cause the increase of DHF. There are mosquitoes as vectors, environmental, and climate both spatial and temporal aspects. To be aware of the DHF outbreak cycle, it is necessary to model risk factors with spatial epidemiology based on geographic information systems that will produce maps of DHF area vulnerability. Map of vulnerability can be used as valuable input in planning prevention and eradication of dengue cases and assisting in decision making.

This study aims to conduct a time-series analysis to identify the effect of climate change towards the increase of Dengue Hemorrhagic Fever (DHF) with a geographic information system approach in Yogyakarta City in time period 2013-2019.

II. METHOD

This research was an observational analytic study which used an ecological study design with times series approach. Times series study is a study design to find out the relationship between the frequency of morbidity or death by an illness that occurs in the community from time to time, and its relation to health programs or risk factors found in the community. This study examines the impact of climate change towards DHF case.

The study was conducted in the Yogyakarta City in April – November 2019 by collecting data on climate conditions and DHF events from 2013 until 2019. This study uses secondary data sourced from DHF surveillance reports at Yogyakarta City Health Office. Climate factors data such as air temperature, humidity and rainfall were obtained from BMKG of Yogyakarta.

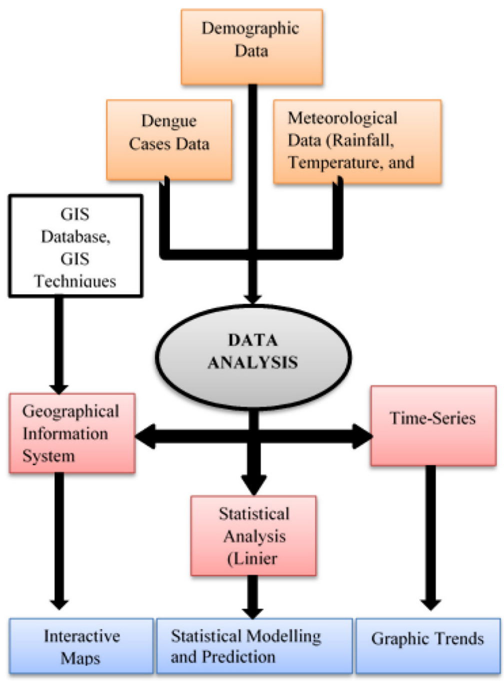

Fig. 1. Workflow of Time-Series Analysis with GIS for DHF

Time series data analysis of climate variables and DHF cases in 2013-2019 are presented in graphs, tables and maps. The impact of climate change (air temperature, humidity and rainfall) on the incidence of DHF is known through statistical tests, correlation and regression analysis. This analysis aims to determine the direction of the relationship between the independent variable with the dependent variable whether each independent variable is positively or negatively related and to predict the value of the dependent variable if the value of the independent variable has increased or decreased. As for spatial analysis with a geographic information system approach using overlay techniques.

III. RESULTS

Time series data is data collected from time to time to see the development of an event. If the data show fluctuations, it can be used as baseline of the trend. Trend used as material for predictions/ forecasting so that it can help in planning and decision making. Analysis that utilizes time series data is called a time series analysis discovered by Box and Jenkins in 1970. Time series analysis is very helpful in the field of health such as predicting the incidence of disease.

Based on Fig. 2, known that the distribution of dengue cases from 2013 - 2019 is spread in all areas of Yogyakarta City. This indicates that all districts in the city of Yogyakarta are endemic areas for dengue cases. Endemic is a term for diseases that have long existed in some particular area. The long time that had mention could be annual, monthly, or weekly depending on the lifestyle and the disease that is considered endemic. If the incubation period of the disease is very short for instance a few days or a few hours, then the disease can be said to be endemic if the disease has occurred after a month or several incubation periods. Factors that can cause an endemic area for dengue cases are environmental factors, climate factors, community behavior factors, and others.

Fig. 3 show 4 times of dengue outbreak, in mid-2013, mid-2015, mid-2016, and mid-2019. The pattern of increasing DHF cases is in line with the increase on rainfall, temperature, and humidity. In 2017-2018 there was an anomaly that the increase in rainfall, temperature and humidity was not followed by an increase in dengue cases. This is likely to occur due to other factors that prevent transmission of dengue cases such as community behavior factors and DHF control programs that have been successfully carried out by the Health Office and related agencies.

DHF cases that occurred between 2013 - 2019 were 5,542 people. In table 1, it showed that the average number of dengue cases every month in 2013-2019 is 69.28 cases with a variation 58.8 cases. The lowest case in one month is 3 cases and the highest case is 208 cases. The results of the analysis concluded that 95% believed that the average number of cases each month was between 56.19 cases to 82.36 cases.

The average rainfall every month is 190.46 mm with a variation of 175.43 mm. The lowest rainfall in one month is 0 mm and the highest is 693 mm. The analysis results can be concluded that 95% are believed that the average rainfall in each month is between 151.42 mm to 229.5 mm.

Based on table 1, the average temperature in Yogyakarta City in 2013 - 2019 each month is 26.21 ‘C with variations of 0.76’ C. The lowest temperature in one month is 24.2 ‘C and the highest is 27.8‘C. It can be concluding that 95% are believed that the average temperature in each month is between 26.04 ‘C to 26.38‘C.

The average humidity every month in Yogyakarta City between 2013 - 2019 is 84.63% with a variation of 3.36%. The lowest humidity is 76% and the highest is 90%. The results of the analysis can be concluded that 95% are believed that the average humidity in each month is between 83.88% to 85.38%.

Table 1. Distribution Of Dhf Cases, Rainfall, Temperature, And Humidity In Yogyakarta City, 2013-2019

Variable	Mean	Standard of Deviation	Min – Max	95% CI
DHF Cases	69.28	58.80	3 – 208	56.19 – 82.36
Rainfall	190.46	175.43	0 – 693	151.42 – 229.5
Air Temperature	26.21	0.76	24.2 – 27.8	26.04 – 26.38
Humidity	84.63	3.36	76 – 90	83.88 – 85.38

DHF and climate factors (air temperature, humidity and rainfall) in 2013-2019 showed fluctuations, more details in figure 3. Based on the data from the graph, incidence of DHF has outbreaks as much as 4 times, in June 2013, February 2015, June 2016, and May 2019. The pattern of dengue cases tends to has similar pattern with climate factors (rainfall, air temperature, and humidity).

Table 2. Analysis Of Correlation And Regression Of Rainfall, Temperature, And Humidity Toward Dhf In Yogyakarta City, 2013-2019

Variable	r	R Square	Regression equation	p-value
Rainfall	0.170	0.029	Y = 58.414+0.057 X1	0.131
Air temperature	0.197	0.039	Y = -332.015+15.310 X2	0.079
Humidity	0.449	0.201	Y = -595.868+7.859 X3	0.000

Based on table 2 known that rainfall did not have a significant effect on DHF cases in Yogyakarta City in 2013-2019 with p-value = 0.131. Rainfall with DHF cases showed a weak relationship (r = 0.170) and positive patterned which means that the higher the rainfall, the DHF cases were also higher. The coefficient of determination (R square = 0.029) means that the regression line equation (Y = 58,414 + 0.057 X1) can explain 2.9% of the variation in rainfall figures. Or in other words the effect of rainfall on dengue cases by 2.9%.

The temperature also had no significant effect on dengue cases in Yogyakarta City in 2013-2019 with a P value = 0.079. The air temperature with DHF cases showed a weak relationship (r = 0.197) and was positively patterned which means that the higher the air temperature, the DHF cases were also higher. The coefficient of determination (R square = 0.039) means the regression line equation (Y = -332,015 + 15,310 X2) can explain 3.9% of the variation in rainfall figures, in other words the effect of air temperature on DHF cases by 3.9%.

Humidity has a significant effect on DHF cases in Yogyakarta City in 2013-2019 with P value = 0,000. Moisture with DHF cases shows a moderate relationship (r = 0.449) and has a positive pattern, which means that the higher the humidity, the higher DHF cases. The coefficient of determination (R square = 0.201) means the equation of the regression line (Y = -595,868 + 7,859 X3) can explain 20.1% of the variation in rainfall rate, in other words the effect of air temperature on DHF cases of 20.1%.

The influence of rainfall, air temperature, and humidity simultaneously on the DHF cases in 2013-2019 can be seen in table 4 below.

Table 3. Analysis Of Multiple Linier Regression

Variable	Coefficient (B)	T-count	Sig.
Constanta	**-1081.475**		
Rainfall	-0.102	-2.170	0.033
Air temperature	8.794	1.103	0.274
Humidity	11.103	4.525	0.000
F count = 8.686			0.000
R Square = 0.255			

Based on the statistical test results in table 3, known that rainfall, air temperature and humidity simultaneously has significant effect on to the DHF cases in the city of Yogyakarta (p value = 0.000). The coefficient of determination (R square = 0.255) which means rainfall, air temperature and humidity simultaneously affect the DHF case in the city of Yogyakarta by 25.5%.

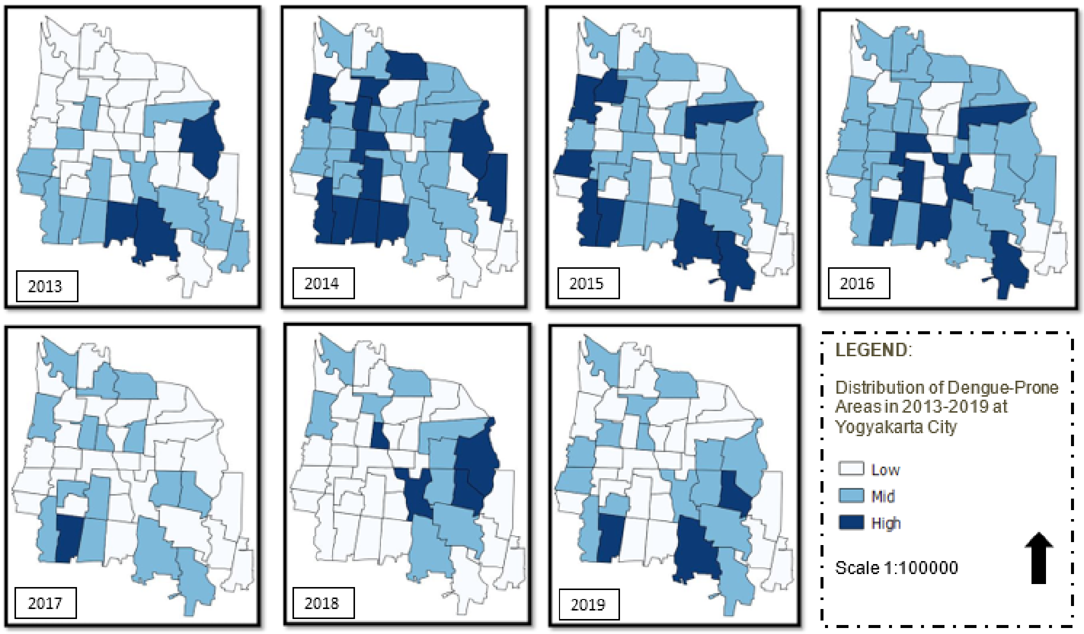

Fig. 2. Distribution of Vulnerable Area of Dengue In Yogyakarta City, 2013-2019

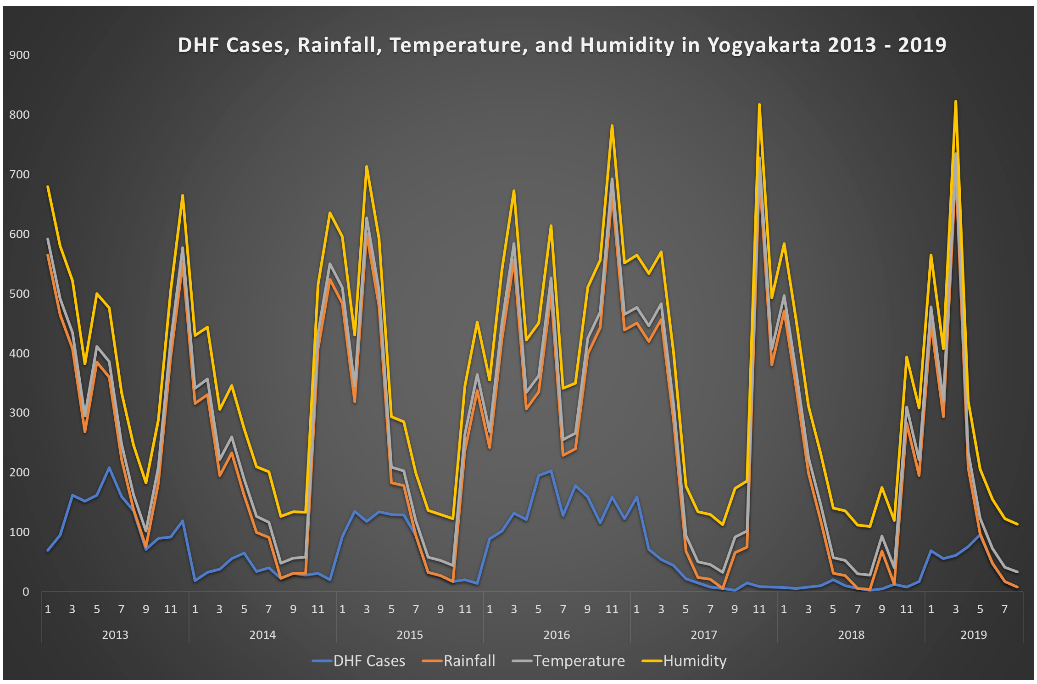

Fig. 3. Trend of DHF Cases, Rainfall, Air Temperature and Humidity

IV. DISCUSSION

In this paper, we have determined the association between DHF cases and rainfall, air temperature and humidity with analysis of multiple linier regression. GIS techniques was used to determine endemic areas of DHF cases in Yogyakarta 2013-2019. GIS and other related tools have been used in vector-borne disease surveillance and control. Several studies have reported the geographical distribution of dengue outbreaks in space and time along with prospective hotspot predictions.[4] Several studies are successful in detecting the spatial-temporal clusters of dengue incidence in Pakistan, India, Indonesia and China. The hotspots could be associated with other environmental risk factors. Population density has been shown to be an important factor for dengue transmission because the vector prefers to inhabit surrounding urban regions.[5–8] GIS help to identify the spatial targets of intervention to effectively combat the spread of dengue in Yogyakarta.

During 2013-2019, known that there are 4 times of dengue outbreak, in mid-2013, mid-2015, mid-2016, and mid-2019. DHF outbreaks can be prevented if the early warning system and vector control are carried out properly, integrated and continuously. Vector control through vector surveillance is regulated in Regulation of the Minister of Health No. 581 in 1992 which stated that the eradication of mosquito nests was carried out periodically by the community coordinated by the RT/ RW with core message “3M Plus” (close, drain, and bury plus mosquito’s bite prevention activities). The success of its activities can be measured by the larvae free rate. If it is more or equal to 95%, it is expected that dengue transmission can be prevented or reduced.[2]

Globalization, trade, travel, demographic trends, and warming temperatures are associated with the recent spread of the primary vectors of dengue (Aedes aegypti and Aedes albopictus). The migration of Farmers, Businessmen, and Students is the main reason for the importation of dengue fever. The rate of male cases was significantly higher than that of female cases for imported dengue, and the population in 21-50 years was the main imported source. [8] Aedes aegypti and Aedes albopictus are the two important vectors involved in dengue transmission and are broadly found in the subtropics and tropics country. Aedes aegypti is an urban mosquito and likes to dwell and breed in artificially created habitats rather than natural environments.[4] Since the 1970s, mosquito-borne pathogens have spread to previously disease-free areas, as well as causing increased illness in endemic areas.[9]

According to Mc Michael (2006) in Bulletin Jendela Epidemiologi Kementerian Kesehatan stated that climate change causes changes in rainfall, temperature, humidity, and wind direction so they could affect the terrestrial and oceanic ecosystems also influences health especially on the proliferation of disease vectors such as Aedes mosquitoes, anopheles and many others. Behavioral factors and community participation in the activities to eradicate mosquito nests are needed. In addition, the increase of population and population mobility are in line with the development of transportation facilities that makes the spread of DHF become easier and wider.2,10,[11]

Rainfall, air temperature and humidity are potential factors for the development of mosquitos. Increased rainfall results puddle in natural containers or unused water container that. It will become a breeding ground for Aedes aegypti mosquitoes so that will increase mosquito’s population which mean higher possibility for dengue virus transmission.[12]

The daily mean temperature and the variation temperature are two of the most important drivers of the current distribution and incidence of dengue. Rainfall and rainfall extremes, whether related to drought or excess rainfall, also affect the mosquito abundance and arbovirus incidence. Temperatures continue to rise and rainfall patterns change are opportunities to increase geographical expansion of Aedes vectors and dengue. It is because in some areas where conditions would no longer be suitable for Aedes reproduction and growth.[10]

Many studies have highlighted the relationship between climate and dengue transmission. The increase of temperature has been found associated with dengue. The arrival of summer and autumn, the temperature in central and northern China has gradually increased, the rainfall has increased, mosquito vectors have gradually become active, and dengue fever cases have increased. Temperature improves dengue outbreaks forecasts better than humidity and rainfall.[8,13,14]

According to Sukowati in "Buletin Jendela Epidemiology" explained that since the mid-1970s compared with 100 years ago El Nino episodes were more frequent, permanent and intensive. Climate change can prolong the transmission of vector-borne diseases and change the shape geography, with the possibility of spreading to areas with low population immunity or lacking public health infrastructure. In addition to climate change, the risk factors that might affect DHF transmission are environmental factors, urbanization, population mobility, population density and transportation.[2]

The weather significantly affected the incidence of dengue in Mexico and that such a relationship was not very linear. Climate change can contribute to an increased incidence of dengue fever. Increased access to piped water can worsen the incidence of dengue if it leads to an increase in domestic water storage. Therefore climate change can affect the success or failure of future efforts to fight dengue fever.[14]

Rainfall Index is the multiplication of rainfall and rainy days divided by the number of days in the month. The Rainfall Index does not directly affect the breeding of mosquitoes, but it does affect the ideal rainfall. Ideal rainfall means that rainwater does not cause flooding and stagnant water in a container / media which is a safe and relatively clean breeding ground for mosquitoes (for example, basins on bamboo fences, trees, old tin cans, old tires, roofs or gutters of houses). The availability of water in the container will cause mosquito eggs to hatch and after 10 - 12 days will turn into mosquitoes. If humans are bitten by mosquitoes with dengue virus, then within 4 - 7 days' later symptoms of DHF will occur. So if only considerate the risk factors for rainfall, then the time needed from the start of the rainy season to the occurrence of dengue is about 3 weeks.[2]

The air temperature also affects the development of Aedes aegypti mosquito larvae and influences the development of viruses that exist in the mosquito's body. In general, mosquitoes will lay their eggs at a temperature of around 20-30'C. Tolerance to temperature depends on mosquito species and geographical location such as tropical, sub-tropical, equatorial and cold regions. The optimum temperature followed by high relative humidity will affect the level of ovipositional and also the survival of the Aedes aegypti mosquito vector. At lower temperatures of 25' Celsius and a higher relative humidity of 80% these conditions affect mosquito ovipositional levels to be higher.[12]

Research on climate change and the spread of viruses found average temperatures and rainfall associated with DHF Cases. Rainfall is one of the main predictors of dengue transmission. Because high rainfall will increase relative humidity for longer. Increasing rainfall can increase larva habitat and populations and also create new habitats for mosquito populations.[15]

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Meteorological conditions are considered as some of the most important factors of dengue in outbreaks occurrence. A study in Delhi found DHF cases reporting sufferers aged 16-30 years and the percentage were male (63%) and female (37%). Negative Association between wind speed and DHF incidence. Thus, confirming environmental factors in addition to other socio-economic, demographic and physiographic factors are responsible for the change in the trends of DHF incidences over the study period. This study also used spatial-temporal analysis with clustering techniques to find outbreak locations.[6]

V. CONCLUSION

Climate factors (rainfall, air temperature, and humidity) simultaneously influence on the incidence of DHF, while based on time series analysis shows that the incidence of DHF experienced fluctuations from 2013 - 2019 in Yogyakarta. These results are expected to plan DHF prevention and control program.

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