Original article

The effects of climate factors, population density, and vector density on the incidence of dengue hemorrhagic fever in South Jakarta Administrative City 2016-2020: an ecological study

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Abstract. *Background and aim:* Dengue hemorrhagic fever (DHF) is an infectious disease caused by the dengue virus (DENV) and is transmitted through the bite of the *Aedes aegypti* and *Aedes albopictus* mosquitoes. This study aims to analyze the relationship between the incidence of DHF which can be influenced by climatic factors in the same month (non-time lag), climatic factors with a lag of 1 month (time lag 1), climatic factors with a lag of 2 months (time lag 2), population density, and vector density. *Methods:* The study design used is an ecological study. The data is sourced from the South Jakarta City Administration of Health, the South Jakarta City Administration of Central Statistics, and the Meteorology, Climatology and Geophysics Agency. Data were analyzed using correlation test. *Results:* The results showed that the incidence of DHF was related to non-time lag rainfall, time lag 1, and time lag 2, air temperature time lag 2, air humidity non-time lag, time lag 1, and time lag 2, population density, and numbers of mosquito's larvae free index (ABJ). *Conclusions:* DHF is still a disease that needs to be watched out for in the South Jakarta Administrative City, requiring the government and the people of the South Jakarta Administration to continue to increase efforts to prevent and control DHF. (www.actabiomedica.it)

Key words: Dengue hemorrhagic fever, climate, public health

Introduction

Dengue hemorrhagic fever (DHF) is an infectious disease caused by the dengue virus (DENV) and transmitted through the bite of vector mosquitoes *Aedes aegypti* and *Aedes albopictus*. Dengue fever symptoms include high fever, dizziness, soreness behind the eyes, muscle pain, nausea, vomiting, and rash. DHF is considered by WHO as one of the biggest international health problems; this is evident as the disease continues to spread. Before 1970, dengue disease only spread over 9 countries. However, at present, dengue fever has spread over more than 100 regions, including areas with sub-tropical climates previously free from dengue disease, such as the Eastern Mediterranean, Africa, Southeast Asia, the Americas, and the Western Pacific. The affected areas suffering the worst impact are the Western Pacific and Southeast Asia, which bear about 75% of the world's dengue hemorrhagic fever (1). Around 390 million people in the world are infected with dengue fever every year (2).

Indonesia is a tropical country; the climate is favorable for diseases, especially vector-borne diseases, to develop quickly. The rainy season provides optimal conditions for the mosquito vector to breed. Indonesia reported the second-highest number of dengue cases among 30 endemic countries (3). DHF in Indonesia was first discovered in Surabaya in 1968. Since then, dengue cases have been increasing and have spread to 472 regencies/cities in 34 provinces in Indonesia. Among all provinces, DKI Jakarta Province has consistently ranked seventh in total cases. South Jakarta Administrative City has held third place in total dengue cases among administrative cities and others in DKI Jakarta Province. In 2017 and 2018, South Jakarta Administrative City had the highest number of DHF cases.

This study was conducted in order to gain a clearer picture of and to understand the relationship among climate factors (rainfall, air humidity and air temperature), population density, and number of mosquito's larvae free index (ABJ) with *incidence rate* of dengue hemorrhagic fever in South Jakarta Administrative City in 2016-2020.

Method study

Study design

This study is designed as an ecological study. This study will analyze the connection among independent climate variables (rainfall, air humidity, and air temperature), demographics (population density) and vector density (ABJ) with the dependent variable (DHF *incidence rate*) *in* South Jakarta Administrative City in 2016-2020.

Study setting

The research location is the administrative city of South Jakarta. Time of data collection is the duration of the month of June 2021. This research uses secondary data from South Jakarta City Health Administration Sub-department, South Jakarta City Administration Central Statistics Agency, and Meteorology, Climatology and Geophysics Agency. The study was conducted in June-July 2021.

Population and sample

The study population and sample included individuals infected with Dengue Hemorrhagic Fever (DHF) in South Jakarta Administrative City in 2016-2020. The study used aggregated data; no individual samples were taken.

Data collection

The type of data taken in this research is secondary data. The data, obtained from a number of different related agencies include:

- Data on the incidence rate of DHF from 2016 to 2020, taken from reported incidence of DHF by the South Jakarta City Administration Health Sub-dept.
- Climatic data (precipitation, air humidity, and air temperature) from South Jakarta Administration City from 2016 to 2020 comes from reports by the Kemayoran Jakarta Meteorology, Climatology and Geophysics Agency (BMKG). Data can be accessed online via https://dataonline.bmkg.go.id/.
- Demographic data (population density) of South Jakarta Administrative City from 2016 to 2020 comes from a publication of the Central Statistics Agency for South Jakarta. Monthly population density data was obtained from calculating projected population based on population data per year.

$$P_t = P_0\,(1+ r)t$$

$$r = \left[\frac{P_t}{P_0}\right]^t -1$$

Description:
P_t = total population in period t
P_0 = total population at the beginning of the period
r = rate growth population
t = period time between period beginning and period end

- Density data vector (mosquito's larvae free index - ABJ) South Jakarta Administrative City from 2016 to 2020 comes from the monthly report of the activities of the mosquito's breeding surveyor (PSN) of the South Jakarta City Administration of Health Sub-department.

Data and statistical analysis

The study used a statistical test using a correlation test (*Pearson and Spearman*) and the data is presented in the form of tables and graphs. While the JASP statistical software was employed to conduct the data analysis, QuantumGIS was also used to analysis the spatial analysis technique. Both of this software are open sources or free license. Climate data testing was conducted three times for the test. In one test, the data on the incidence of DHF will be analysed with climate data in the same month; in another analysis, the data on the incidence of dengue will be analysed with climate data from one month previous, and in other analyses, the data on the incidence of DHF will analysed with climate data from two months earlier. This is based on the influence exerted by climate factors on the cycle life of mosquitoes, which can cause a delay in peak DHF incidence from climate fluctuations. From that, researchers analyse the time lag of 1 month and the time lag of 2 months. A number of relationships that will analysed using correlation test are as follows:

- Rainfall with the incidence rate of DHF per month 2016 to 2020 (60 data).
- Rainfall with the incidence rate of DHF per month 2016 to 2020 with a time lag of 1 month (59 data).
- Rainfall with the incidence rate of DHF per month 2016 to 2020 with a time lag of 2 months (58 data).
- Humidity with the incidence rate of DHF per month 2016 to 2020 (60 data).
- Humidity with the incidence rate of DHF per month 2016 to 2020 with a time lag of 1 month (59 data).
- Humidity with the incidence rate of DHF per month 2016 to 2020 with a time lag of 1 month (58 data).
- Air temperature with the incidence rate of DHF per month 2016 to 2020 (60 data).
- Air temperature with the incidence rate of DHF per month 2016 to 2020 with a time lag of 1 month (59 data).
- Air temperature with the incidence rate of DHF per month 2016 to 2020 with a time lag of 1 month (58 data).
- Population density with the incidence rate of DHF per month 2016 to 2020 (60 data).
- ABJ with the incidence rate of DHF per month 2016 to 2020 (60 data).

After the analysis is done, a P-value will be obtained that aims to show that there is or is no connection existing between variables. If the P-value obtained is 0.05, P signifies significant relationship between variables. The strength of association among the second variable is classified into the four, following categories:

- r = 0.00 – 0.25 → no connection or connection weak
- r = 0.26 – 0.50 → relationship relevant
- r = 0.51 – 0.75 → relationship strong
- r = 0.76 – 1.00 → very strong relationship or perfect

The ethics of this study were reviewed and accepted in letter of permission number Ket-431/UN2.F 10.D 11/PPM.00.02/2021.

Results

DHF incidence

Data on the incidence of DHF from 2016 to 2020 reveal that the highest incidence occurred in 2016, with a total of 4548 cases and an IR value of 206.10 new cases per 100,000 residents. The lowest incidence of DHF occurred in 2017, with as many as 642 cases; the RIR value was 29.09 new cases per 100,000. The highest incidence of DHF in one month occurred in March 2016, with 722 cases and an IR value of 32.72 new cases per 100,000 (Table 1).

Rainfall

From 2016 to 2020, rainfall in the Administrative City of South Jakarta ranged from 0.00-35.97 mm. Highest rainfall occurred in February 2020, with 35.97 mm. Lowest overall rainfall occurred in July,

Table 1. Distribution of DHF monthly in South Jakarta Administrative City 2016-2020.

Month	2016		2017		2018		2019		2020	
	Case	IR	Case	IR	Case	IR	Case	IR	Case	IR
January	294	13.32	133	6.03	42	1.90	329	14.53	62	2.73
February	594	26.92	71	3.22	52	2.36	388	17.13	188	8.27
March	722	32.72	77	3.49	61	2.76	445	19.65	285	12.54
April	656	29.73	76	3.44	89	4.03	222	9.80	170	7.48
May	451	20.44	61	2.76	138	6.25	238	10.51	111	4.89
June	345	15.63	34	1.54	74	3.35	157	6.93	95	4.18
July	317	14.37	34	1.54	59	2.67	79	3.49	46	2.02
August	274	12.42	19	0.86	46	2.08	36	1.59	13	0.57
September	232	10.51	11	0.50	32	1.45	9	0.40	12	0.53
October	252	11.42	31	1.40	24	1.09	20	0.88	11	0.48
November	256	11.60	43	1.95	41	1.86	24	1.06	8	0.35
December	155	7.02	42	2.36	97	4.40	28	1.24	15	0.66
South Jakarta	4548	206.10	642	29.09	755	34.21	1975	87.21	1016	44.71

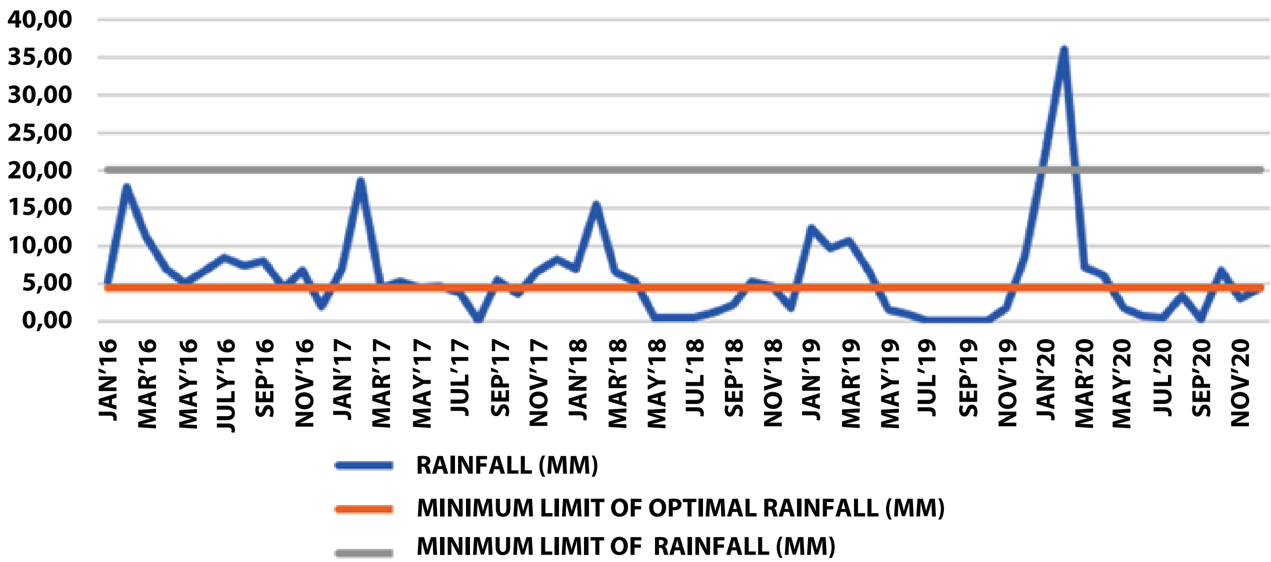

Figure 1. *Time Series* of Average Rainfall of South Jakarta Administrative City 2016-2020.

August and September 2019, with 0.00 mm. Optimal rainfall for mosquitoes is between 4.3-20 mm. Rainfall tends to be higher at the beginning of the year because that is when The South Jakarta Administrative City experiences the rainy season. Average rainfall rain from 2016 to 2018 continued to decrease; however, it increased from 2018 to 2020. Highest average rainfall occurred in 2020, with 7.63 mm, while the lowest average rainfall occurred in 2018, with 4.20 mm (Figure 1).

Air humidity

From 2016 to 2020, air humidity in the South Jakarta Administrative City ranged from 68.00% -84.07%. Highest air humidity was recorded happened in February 2020, with 84.07%. Lowest humidity occurred in September 2020, with 68.00%. Optimal air humidity for mosquitoes is above 60%. Average air humidity from 2016 to 2019 continued to decrease, but it increased from 2019 to 2020. Highest average air humidity occurred in 2016 with 78.64%, while the lowest average air humidity occurred in 2019 with 73.97% (Figure 2).

Air temperature

From 2016 to 2020, air temperature in the South Jakarta Administrative City ranged from 27,15°C to 29,64°C. Highest air temperature occurred in May 2019 at 29.64°C, whereas lowest air temperature was recorded in February 2018, at 27.15°C. Optimal air temperature for mosquitoes is between 25°C and 30°C. Average air temperature every year is volatile, with highest average air temperature in 2019 at 28.79°C, and lowest average air temperature recorded in 2017 at 28.45 °C (Figure 3).

Population density

Population density in the Administrative City of South Jakarta continued to increase from 2016 to 2019. However, in 2020, the population in the South Jakarta Administrative City decreased slightly from 16,020 people/km² in 2019 to 15,763 people/km². The district with the highest population density is Tebet, with 24,498 inhabitants/km² in 2020; meanwhile, the district with the lowest population density is Cilandak, which in 2016 had 11,031 inhabitants/km² (Table 2).

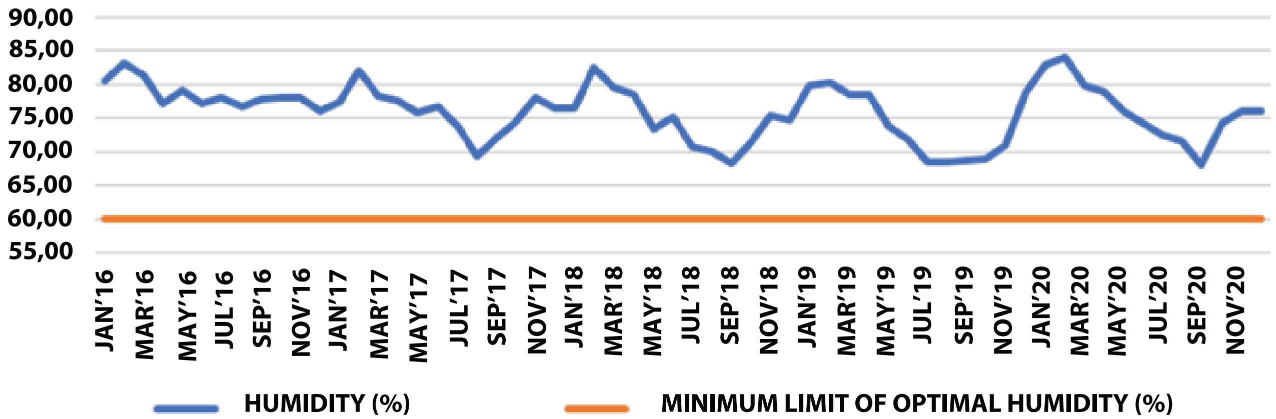

Figure 2. *Time Series* of Average Air Humidity in South Jakarta Administrative City 2016-2020.

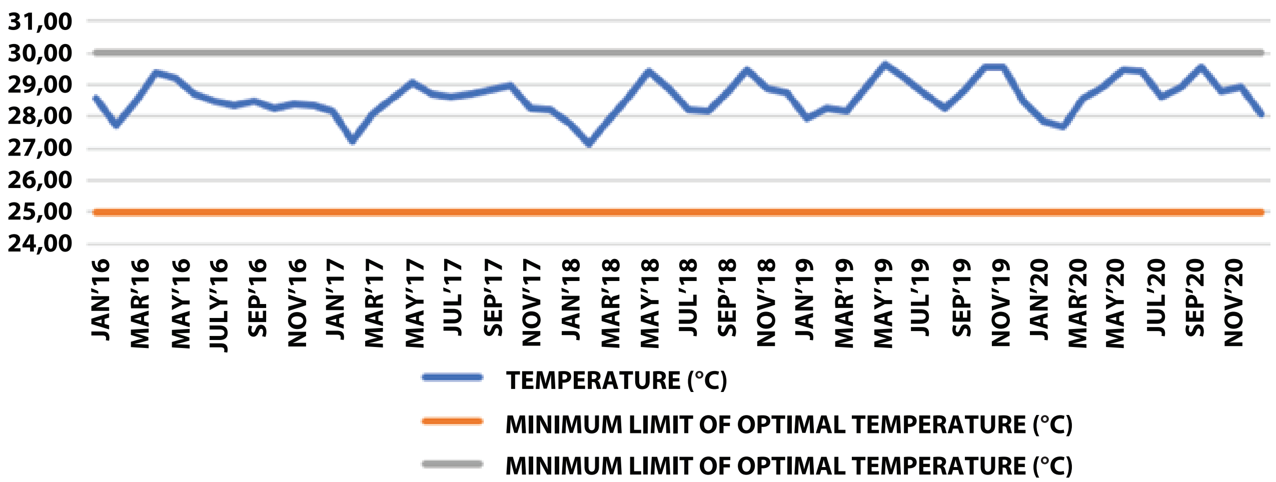

Figure 3. *Time Series* of Average Air Temperature in South Jakarta Administrative City 2016-2020.

Table 2. Population Density of South Jakarta Administrative City 2016-2020.

Sub-district	Population density (live/km²)				
	2016	**2017**	**2018**	**2019**	**2020**
Jagakarsa	15,236	15,695	16,155	16,616	15,416
Pasar Minggu	14,071	14,163	14,245	14,321	14,028
Cilandak	11,031	11,098	11,156	11,210	11,101
Pesanggrahan	17,371	17,445	17,506	17,551	19,348
Kebayoran Lama	18,336	18,407	18,464	18,509	18,453
Kebayoran Baru	11,108	11,124	11,138	11,148	10,794
Mampang Prapatan	18,902	18,982	19,058	19,134	18,805
Pancoran	18,037	18,140	18,240	18,122	19,764
Tebet	23,351	23,386	23,419	23,466	24,498
Setiabudi	15,776	15,934	16,080	16,215	12,138
South Jakarta	15,621	15,764	15,900	16,020	15,763

The numbers of mosquito's larvae free index (ABJ)

The ABJ in South Jakarta Administrative City fluctuates every month. It reached its highest peak in October 2018, at 98.70%. The lowest ABJ was in February 2016, at 96.15%. Average monthly ABJ scores in South Jakarta Administrative City from 2016 to 2020 consistently met the national target for ABJ value, which is 95%. Average ABJ fluctuated from year to year. The highest average ABJ occurred in 2018 at 98.32%, while the lowest average ABJ occurred in 2016 at 97.17%.

Correlation between climate, density population and ABJ with incidence rate (IR) DHF

There is a correlation between all climate variables (rainfall, air temperature, and humidity) and DHF *Incidence Rate.* Considering the variable overall rainfall (*non-time lag, time lag 1 and time lag 2*) there is a significant relationship between IR DHF (P-value=0.001) and closely connected positive pattern (r=0.452, r=0.599 and r=0.683). The strongest relationship is between bulk rain *time lag* 2 with IR DHF. The air temperature in *time lag* 2 has a significant relationship with IR DHF (p=0.024) and a moderately close relationship with pattern negative (r=-0.297). For the variable air humidity, *non-time lag, time lag* 1 and *time lag* 2 are significantly related with IR DHF (P-value=0.001) and closely connected with a pattern positive (r=0.607, r=0.738 and r=0.729). The connection between humidity air *time lag* 1 and IR DHF is the strongest (Table 3).

Table 3. Correlation between Climate, Density Population and ABJ with Incidence Rate (IR) DHF in South Jakarta Administrative City 2016-2020.

Variables		**r coefficient**	**P-value**
Rainfall	Non-TL	0.452	0.001*
	Time Lag 1	0.599	0.001*
	Time Lag 2	0.683	0.001*
Temperature	Non-TL	-0.207	0.113
	Time Lag 1	-0.189	0.151
	Time Lag 2	-0.297	0.024*
Humidity	Non-TL	0.607	0.001*
	Time Lag 1	0.738	0.001*
	Time Lag 2	0.729	0.001*
Population density		-0,314	0.014*
ABJ		-0,655	0.001*

*P-value<0.05 is considered as statistically significant.

The variable population density also shows the existence of a significant relationship with IR DHF (P-value=0.014), with strength connection medium and pattern negative (r=-0.314). The variable ABJ has a significant relationship with IR DHF (P-value=0.001), with closeness strong and pattern negative (r=-0.655) (Table 3).

Map of the relationship of population density and ABJ with distribution pattern incidence rate (IR) DHF

There exists no significant difference in the pattern of spread in the area with high population density

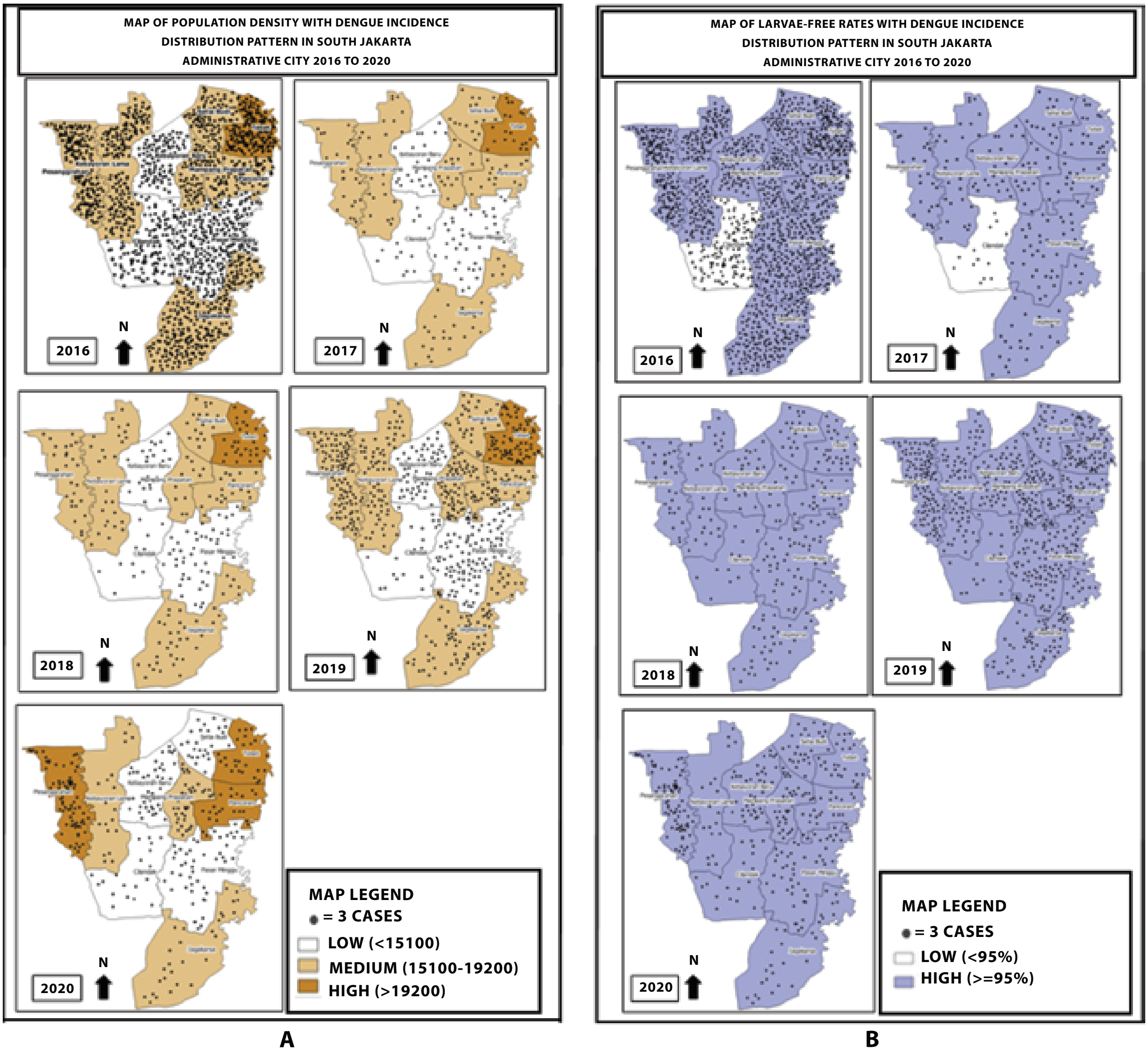

Figure 4. (a) Mapping of population density with DHF spread pattern in South Jakarta Administrative City 2016-2020; (b) Mapping of ABJ with DHF spread pattern in South Jakarta Administrative City 2016-2020.

medium population density, and low density population; in 2020 the District Pesanggrahan and District Pancoran experienced increased population density, which did not influence the spread of dengue. However, it can be seen that the district of Cilandak, included in the region with low population density, experienced lower spread of DHF compared to other sub-districts (Figure 4).

There is no difference in the pattern of spread of cases in the regions with high nor low ABJ rates. The distribution pattern of the cases tends to be equal between areas with both high and low ABJ rate. Although in 2016 and 2017 the District Cilandak included areas with low ABJ levels and then became a region with high ABJ levels 2018, there was still no change in the pattern of distribution (Figure 4).

Discussion

Rainfall in a given month, one month prior, and at two months prior have significant relationship with

IR DHF. Based on bulk measurement data from the rain station Meteorology Kemayoran, in South Jakarta Administrative City from 2016 to 2020, the rainfall rain tends higher at the beginning of the year. This is because at the beginning year, the South Jakarta Administrative City area experiences the rainy season. Rainfall is closely related to locations for mosquito breeding. Rainfall that is high but not too heavy could add breeding locations where, earlier, drought had prevented breeding, thus causing the population of mosquitoes to increase (5). However, fluctuation in overall rainfall has no influence on the incidence of DHF in the same month, because mosquito need time to develop from egg to adult mosquitoes who can transmit viruses. Then, after mosquitoes transmit the virus to humans, there is an incubation period before the person begins to feel symptoms (6). Therefore, the closeness connection to overall rainfall two months previously is the most powerful, This finding is in line with research conducted by Daswito (2019) in Yogyakarta (7).

A significant relationship between air temperature and IR DHF was only found with air that was measured two months previously. Temperature is a climate factor that can influence the life cycle of vector mosquitoes and viral replication. Optimal air temperature for vector mosquitoes is around 26-30°C. Therefore, more dengue transmission may occur in tropical and subtropical regions, because temperature that is too high or too low could interrupt the growth of mosquitoes, killing them. Such could occur if the temperature is below 10°C or above 46°C (8). Low temperatures could kill mosquito eggs and larvae. From 2016 to 2020, the air temperature in the South Jakarta Administrative City ranged from between 27,15-29,64°C, which should be the optimal temperature for vector mosquitoes; however, a significant relationship to IR DHF was only found with the air temperature recorded two months previously. This finding could occur because variation in temperature during one the year that doesn't too fluctuate causing no significant relationship between IR DHF with the air temperature (9), Air temperature only ranged between 25,76-29,64°C, The difference in temperatures in the region with climate deserts and sub-tropics can be up to 20°C (10). Besides that, negative patterned relationship implies; if air temperature rises, then the incidence of dengue will decrease, and vice versa. This occurs because if the temperature is too high, the mosquito will undergo physiological processes more slowly (11).

IR DHF has a significant relationship with air humidity in the same month, at one month earlier, and at two months earlier. Air humidity below 60% can shorten mosquitoes' lifespans, because in times of low humidity, fluid in the body of the mosquito will evaporate more, causing the mosquito to dry out. A shortened lifespan means that there is not enough time for the virus to move from the mosquito's stomach to its saliva glands, so the mosquito cannot become a vector. On the other hand, high air humidity could extend the lifespan of mosquitoes, making them potential vectors of the transmission of dengue (12). Furthermore, air humidity also affects the life cycle of the mosquito, especially in the egg phase. If air humidity is low, it takes the egg longer to hatch (13). Optimal air humidity for the *Aedes aegypti* mosquito's breeding is between 60-90% (14). The connection between air humidity one month previously and the incidence of DHF is the strongest. This is because high humidity will make mosquitoes lay more eggs, so that in the future, DHF will be transmitted faster due to a higher population of mosquitoes. These findings are in line with a study by Daswito (2019) which showed that the incidence of DHF is triggered by fluctuations in air humidity the previous month (7).

A significant relationship was also found between IR DHF and variable population density. Increased density and mobility of the population is one factor possibly influencing the risks of dengue disease. A region or area with high population density is an area that is vulnerable to DHF disease (15). The more densely populated an area, or the closer the residences, the more easily the *Aedes mosquito* will transmit dengue virus from one individual to others (1). This is because the *Aedes mosquitoes* are active mosquitoes, and the distance between houses is within *Aedes* mosquitoes' flight distance, which ranges about 50 meters (16). Besides that, in order to fill its stomach, the *Aedes* mosquito can bite several times in one gonotrophic cycle (17).

ABJ has a significant relationship to IR DHF, ABJ in a region describes vector density in the region;

if ABJ is high in an area, it means low vector density within the region will help lower dengue incidence. High rainfall and lack of hygiene and environmental behaviors could lead to more breeding sites for the *Aedes* mosquito.

Strength and limitations

This study's finding is adequate to represent the valid information regarding to the dengue magnitude trend aggregately. Precisely, the spatial mapping is also representing this issue geographically as it can produce the quality of policy intervention and implication in the real-world based policy recommendation.

Since this ecological's study is presented as aggregate data analysis, this research cannot maintain the bias of dengue's effect is coming from precise exposure of climate variables. It also cannot adjust exact measurement impact of incidence risk (IR) of dengue that is because the analysis is only bivariate (crude) manner when the data was un-normally distributed.

Conclusions

Peak DHF incidence from 2016 to 2020 occurred in 2016; there were 4,548 total cases of IR in 2016, which translates to 10 new cases per 100,000 people. Whereas the lowest incidence of DHF occurred in 2017, with 642 cases and an IR value of 29.09 new cases per 100,000 people. Factors related to the incidence of DHF are *non-time lag* rainfall, *time lag 1* rainfall, *time lag 2* rainfall, *time lag 2* air temperature, *non-time lag* air humidity, *time lag 1* air humidity, *time lag* 2 air humidity, population density, and ABJ.

Suggestions that can be made to the government, especially the South Jakarta City Health Sub-dept., are to increase public knowledge and awareness about clean living behavior (PHBS), increase public knowledge about the one house one *jumantik/PSN* movement, continue cooperation with the BMKG in an effort to monitor climate fluctuations which can affect the incidence of DHF, and improve the ABJ recording system in each sub-district. The suggestion for the community is to implement the 3+ measures program, which consists of draining water reservoirs, closing water reservoirs, and preventing household items from becoming mosquito breeding places. Additional precautions include the use of mosquito repellent, the use of mosquito nets, sowing of larvicide powder, the use of larvae preying fish, the use of plants that can repel mosquitoes, improving ventilation and light, and not hanging clothes in the house.

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