Integration of climate, transmission, and spread of dengue hemorrhagic fever in endemic areas

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Abstract

Introduction. Dengue Hemorrhagic Fever (DHF) is still a public health problem even in the era of the COVID-19 pandemic in 2020, including in Indonesia. This study aimed to analyze the incidence of DHF based on the integration of climatic factors, including rainfall, humidity, air temperature, and duration of sunlight and their distribution.

Materials and Methods. This was an ecological time series study with secondary data from the Surabaya City Health Office covering the incidence of DHF and larva-free rate and climate data on rainfall, humidity, air temperature, and duration of sunlight obtained from the Meteorology and Geophysics Agency (BMKG). Silver station in Surabaya, the distribution of dengue incidence during 2018-2020.

Results and Discussion. The results showed that humidity was correlated with the larvae-free rate. Meanwhile, the larva-free rate did not correlate with the number of DHF cases. DHF control is estimated due to the correlation of climatic factors and the incidence of DHF, control of vectors and disease agents, control of transmission media, and exposure to the community.

Conclusions. The integration of DHF control can be used for early precautions in the era of the COVID-19 pandemic by controlling DHF early in the period from January to June in Surabaya. It is concluded that humidity can affect the dengue outbreak and it can be used as an early warning system and travel warning regarding the relative risk of DHF outbreak.

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Key words: climate integration; DHF susceptibility; DHF distribution; larva-free rate.

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Introduction

Dengue Hemorrhagic Fever (DHF) is a viral infectious disease transmitted by the Aedes aegypti mosquito, an important mosquito that affects populations in tropical and subtropical regions. This infection is caused by four unique strains of dengue virus (DENV-1 to DENV-4) belonging to the family Flaviviridae, transmitted by Aedes aegypti and Aedes albopictus mosquitoes. Every year, worldwide, about 390 million cases are reported and at least 2.5 billion people are at high risk, of which more than 70% of the population at risk live in Southeast Asia and the Western Pacific Region.[1–3] Dengue infection disproportionately affects children aged 5-14 years and adults over 15 years.[4]

In Indonesia, dengue fever outbreaks have been reported in 34 provinces and 514 districts, indicating that DHF remains a significant public health problem in the country.[5] To reduce the DHF burden, Indonesian health authorities are implementing strategies focusing on vector population control through community-based vector control measures (e.g., monitoring and eliminating potential breeding sites) and chemical-based control approaches (e.g., spraying larvicides and insecticides.[6] Surabaya city is one of the dengue-endemic areas. All four strains of dengue virus have been found circulating within the city, thereby emphasizing that Surabaya is an important place for dengue circulation in the region.

This is a very concerning situation because the city of Surabaya is also a destination for trade, industry, and education, which is popular in Southeast Asia.[7] The tendency of people to engage in economic activities and the impact of gas emissions is correlated with a shift in rainfall and an increase in the average earth temperature which is estimated to rise by 1-3.5°C.[8]

Changes in these environmental components will result in significant changes in the environment. Interaction of various species in ecosystems and distribution patterns of vectors and virus diseases, such as dengue fever.[9] In Indonesia, the first DHF case was reported in 1968 in Jakarta and Surabaya. In the following year, the number of cases of this disease continued to increase both in number and the area affected and periodically caused extraordinary events.[10] The largest, extraordinary event occurred in 2016, all provinces reported cases of DHF with an Incidence rate of 120 per 100,000 population with a case fatality rate (CFR) of around 1.9%.[11] Annual case data shows that the number of dengue cases has increased almost every five years since 1968. In Indonesia, dengue is an endemic disease transmitted by the Aedes aegypti mosquito, which is widespread throughout the country, even at an altitude of more than 1,000 meters above sea level.[12] The city of Surabaya is ideal for the breeding of Aedes aegypti mosquitoes because it has an average temperature of 27.85°C with an average humidity of 75.75%. [13,14] Both temperature and humidity factors affect each other for the reproduction of Aedes aegypti. Thus, climatic conditions (temperature and humidity) will support the increase in mosquito population density, which in turn has an impact on the transmission and spread of dengue disease. [15] These mosquitoes play a role in the transmission of DHF because they live in and around houses when people are active during the day.

Climatic factors, ecological changes, and socio-demographic factors play an important role in increasing and expanding dengue endemic areas of the 31 sub-districts and 154 sub-sub-districts in the city of Surabaya, 85% are included in the category of dengue endemic villages. It means that within 3 consecutive years, the residents of the *kelurahan* are at high risk of DHF. The increase in the number of villages that are endemic to DHF shows that the city of Surabaya is endemic to DHF. [16]

Until now, there is no exact medicine or vaccine for dengue fever, so an understanding of the epidemiological aspects of DHF

Table 1. Climate data recapitulation.

Months	Temperatures			Air humidity			Rainfall			Sunlight		
	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
January	27.9	27.8	27.5	78	80	82	376.1	298.0	180.5	60	52	39
February	27.4	28.4	27.7	82	80	80	371.0	434.4	145.2	48	64	42
March	28.6	28.6	28.0	79	81	80	216.0	322.4	461.2	70	59	58
April	29.1	28.6	28.2	78	82	80	122.0	333.9	274.9	72	58	46
May	28.5	28.9	28.6	79	82	78	58.0	147.3	70.0	64	49	72
June	28.3	28.5	27.6	76	78	71	50.0	57.7	27.6	90	55	88
July	27.6	28.6	27.6	71	75	71	0.1	66.1	0.1	93	69	96
August	27.9	28.9	27.5	69	73	66	0.2	29.9	0.0	97	85	94
September	29.1	28.7	28.4	66	77	65	0.0	156.3	0.0	99	65	95
October	30.0	28.9	29.8	66	77	64	0.0	252.0	22.6	93	61	88
November	30.3	29.0	29.0	69	77	75	128.0	85.7	205.1	71	56	57
December	27.4	27.9	28.3	73	78	78	220.0	314.2	356.0	64	32	47
Mean	28.5	28.6	28.2	74	78	74	128.5	208.2	145.3	77	59	69

Source: Meteorology, Climatology, and Geophysics Agency of Perak Station Surabaya 2018-2020.[20–22]

Table 2. Recapitulation of DHF patient data.

Months	2018		2019		2020	
	Sufferers	Die	Sufferers	Die	Sufferers	Die
January	42	0	33	1	2	0
February	48	0	66	1	7	0
March	46	0	67	1	18	0
April	56	1	53	0	15	0
May	53	0	40	0	17	0
June	39	0	13	0	6	0
July	14	0	2	0	4	0
August	7	0	3	0	1	0
September	6	0	0	0	1	0
October	4	0	0	0	1	0
November	4	0	0	0	1	0
December	0	0	0	0	0	0
Total	319	1	277	3	73	0

Source: Profile of Surabaya City Health Office 2018-2020.[17–19] is needed to prevent and overcome the incidence of DHF so that it is efficient for implementing an early warning system and is also expected to be able to determine priority areas for implementation.[13] Anticipation and prevention programs for DHF events in the city of Surabaya are to be more precise, accurate, and useful and can be used to achieve the global vision of a world free of DHF in 2030. This study aimed to assess DHF susceptibility based on larva-free rate through the integration of climatic factors (rainfall, humidity, air temperature, and duration of sunshine) in the distribution of DHF cases in the city of Surabaya in 2018-2020.

Materials and Methods

This was quantitative analytical research using a time trend ecological research design to examine the correlation of climatic factors (temperature, humidity, rainfall, and duration of sunshine) to the larva-free rate and the correlation of the larva-free rate to the number of cases of Dengue Hemorrhagic Fever and their distribution in 2018-2020 in the city of Surabaya. All data on dengue cases in the city of Surabaya for the period 2018-2020 were used as subjects in this study.[17–19]

Research variables were independent variables (climate data including temperature, rainfall, humidity, and duration of sun exposure), intermediate variables (Larve-free rate data), and dependent variable (data on the number of dengue cases). Data collection was carried out by reviewing report documents from the Surabaya City Health Office, and the Meteorology, Climatology, and Geophysics Agency at Juanda Station and Perak Station in Surabaya City.

The analysis of the major climate correlations on cases of DHF and larva-free rate is carried out quarterly because larva-free rate data is available in the form of three months. Simple linear regression analysis was used to test the correlation of climatic factors, including rainfall, air temperature, humidity, and duration of sunlight on the larva-free rate as well as the correlation analysis of the larva-free number on the number of dengue fever events in the city of Surabaya in 2018-2020.

Results

The climate conditions depicted in the distribution of air temperature, humidity, rainfall, and sunlight in the city of Surabaya in the period from January to December of 2018-2020, the data showed the average air temperature ($28.4^{o}C$), humidity (76%), rainfall (160 mm), and duration of sunshine (68) (Table 1).

The larva-free rate in the city of Surabaya in 2018 was highest in September (88.15%), and the lowest in March (84.05%). The average larva-free rate in Surabaya in 2018 (86.74%). The larva-free rate in the city of Surabaya in 2019 was the highest in January (88.94%), and the lowest in October (86.40%). The average larva-free rate in Surabaya in 2019 was 88.0%. The average larva-free rate in 2018 was 86.74%, in 2019 it was 88.0%, and in 2020 it was 88.67%. The distribution of DHF incidence in the city of Surabaya from January to December of 2018-2020, data showed that in 2018 the number of dengue cases in Surabaya was the highest.

In 2018 there were 319 DHF sufferers and 1 died, in 2019 there were 277 patients and 3 died, and in 2020 the number of sufferers was 73 and no one died (Table 2). The average larva-free rate routine/month during 2018 was 93, in 2019 was 94, and in 2020 was 96. Before providing statistical test results using linear regression analysis, several results of the classical assumption test results of linear regression analysis are shown, such as the data normality test. In the normality test of data by Kolmogorov Smirnov, all types of data have a probability value of more than 0.05 ($p > 0.05$) so it can be concluded that all data are normal or meet the requirements of the normality test. Furthermore, the autocorrelation test is carried out using the Durbin-Watson test value to test the freedom of the remainder which is one of the assumptions that must be met. The Durbin Watson value is 0.845, DL = 1.236, and DU = 1.72 (D value < DL < DU), then the autocorrelation condition or assumption is positive After being tested with some of these conditions, the research data can be tested using the linear regression method (Table 3). From Table 3, there was a significant correlation between suffering and air humidity, it has a strong positive correlation or the higher the air humidity, the higher the suffer of DHF.

Surabaya's topography is between 0-30 M above sea level, with a population density of 8,975 people/km[22]. Population density is a variable that has had an effect of 40% on DHF cases for the last 3 years (2018-2020), with a statistically significant population density autoregression coefficient test. The incidence of DHF

Table 3. Data from Spearman's correlations.

Correlations			suffer	die	temperature	air_humidity	rainfall	sunlight
Spearman's rho	suffer	Correlation Coefficient	1.000	.487**	-.045	.552**	.266	-.039
		Sig. (2-tailed)	.	.003	.795	.000	.117	.822
		N	36	36	36	36	36	36
	die	Correlation Coefficient	.487**	1.000	.068	.321	.307	-.081
		Sig. (2-tailed)	.003	.	.693	.056	.069	.639
		N	36	36	36	36	36	36
	temperature	Correlation Coefficient	-.045	.068	1.000	-.212	-.163	.180
		Sig. (2-tailed)	.795	.693	.	.215	.342	.292
		N	36	36	36	36	36	36
	air_humidity	Correlation Coefficient	.552**	.321	-.212	1.000	.766**	-.787**
		Sig. (2-tailed)	.000	.056	.215	.	.000	.000
		N	36	36	36	36	36	36
	rainfall	Correlation Coefficient	.266	.307	-.163	.766**	1.000	-.754**
		Sig. (2-tailed)	.117	.069	.342	.000	.	.000
		N	36	36	36	36	36	36
	sunlight	Correlation Coefficient	-.039	-.081	.180	-.787**	-.754**	1.000
		Sig. (2-tailed)	.822	.639	.292	.000	.000	.
		N	36	36	36	36	36	36

**Correlation is significant at the 0.01 level (2-tailed).

showed a p-value of <0.05, indicated that population density affects the number of cases of DHF. Based on the mapping identification that the population density of Surabaya City increases every year except in 2020, and mobility also decreases because of the Community Activities Restrictions Enforcement policy related to COVID-19.[17–19]

Discussion

The results of the linear regression to explain the correlation mechanism between rainfall, humidity, air temperature, and larva-free rate in Surabaya are as follows: the correlated variable is air humidity; the rainfall variable increases with increasing air humidity and this leads to an increase in the incidence of DHF.[14,16,23,24]

According to WHO, humidity gives the greatest correlation to disease incidence because vectors include dengue fever, so humidity is a critical factor in this disease. As with other vector-based diseases, DHF has a pattern related to climate integration, especially humidity, because high humidity will increase the breeding of Aedes aegypti resulting in the increasing transmission of the virus from one human to another. Humidity is the most critical factor correlated between climate and vector-based diseases, such as DHF.[25,26]

The use of second node management (control on transmission media) regarding environmental management and vector control, through inspection and counting of mosquito larvae recapitulated in larva-free rate can be used to anticipate the occurrence of extraordinary events (KLB) in an area. then routine larva-free rate does not correlate with the number of cases of DHF sufferers during 2018-2020 at a 95% confidence level. It was concluded that routine larva-free rate was not significantly correlated with the number of cases of DHF sufferers. Status high DHF entomology (vector) such as larva-free rate supported by high rainfall can encourage the incidence of DHF.

Another epidemiological aspect that plays a role in the incidence of DHF is the mechanism of transmission of the dengue virus.[25] Transmission of the Virden can occur horizontally, from humans carrying the dengue virus by the vector mosquito transmitted to the recipient human or vertically (transovarial), namely from the Aedes aegypti mosquito, gravid female infected with Virden as parent to the ovum (eggs) in the mosquito uterus.[27]

Mosquito nest eradication, fogging, periodic larval eradication, and selective abatization are required according to the rainfall pattern that occurred that year[9,28]. Rainfall variability can have direct consequences on infectious disease outbreaks. High rainfall can be correlated with mosquito vectors through increased air humidity, so it is correlated with vector age. Humidity is not directly correlated with cases of DHF but is correlated with mosquito age. Humidity can affect the transmission of vector-borne diseases, especially insect vectors. The ability of mosquitoes to survive decreases in dry conditions. Mosquito vectors are sensitive to humidity DHF vectors live in an environment with an average temperature of 25.0°C-27.0°C which is the optimal temperature for larval development of the dengue vector[14,29].

The average air temperature in the city of Surabaya during the 2018-2020 period is 28.4°C so it is not included in the optimal temperature for the development of DHF vector larvae.[26] Temperature changes can change the transmission season; WHO states that temperature is correlated with vector survival.[2] The correlation between the duration of sunlight and dengue cases is indirect because light affects the bionomic of mosquitoes to find food or a place to rest. There are also mosquito species that leave the resting place after 20-30 minutes of sunset. The Aedes aegypti mosquito has a habit of resting in a dark place and hiding from sunlight, as well as in their habit of laying eggs.[3,30]

This case of DHF can be caused by direct or indirect interventions on mosquitoes and their habitats such as environmental factors, implementation of the mosquito nest eradication program, and albitization[31]. With the autoregressive coefficient test, population density has a statistically significant effect on DHF cases (in 2018 and 2019) because the p-value is < 0.05, meaning that population density also affects the number of DHF cases in Surabaya.

Conclusions

The air humidity variable is an environmental factor that has a significant correlation with the larva-free rate in the city of Surabaya. The larva-free rate does not correlate with the number of cases of DHF sufferers and cannot be used to predict the number of cases of DHF patients in the future.

So, it is concluded that humidity can affect the dengue outbreak and it can be used as an early warning system and travel warning regarding the relative risk of DHF outbreak.

Abbreviations

DHF: Dengue Hemorrhagic Fever.
LFN: Larva Free Numbers .
CFR: Case Fatality Rate.
IR: Incidence Rate.
Abatization: giving abate powder to places where there is stagnant water including bathtubs, flowerpots, and so on with the aim of killing Aedes aegypti mosquito larvae and preventing dengue outbreaks.

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