The correlation between temperature and dengue haemorrhagic fever in Malang Regency – Indonesia: A spatial – temporal analysis

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Abstract. Dengue is vital health issue in Indonesia, in which it is burdening health and economic among population. This study aims to analyse the relationship between temperature and dengue fever cases in Malang Regency, East Java Province- Indonesia, from 2014 to 2018. A quantitative ecological time-series design was employed. The dependent variable was dengue cases, and the independent variable was temperature. Data analysis involved descriptive spatial analysis using QGIS 3.0 and Spearman correlation tests with Stata. Correlations between dengue cases and temperature were assessed from lag 0 to lag 3 months. The dengue case was recorded 4,505 cases. Dengue cases peaked in 2015 (1,331 cases) and 2016 (1,140 cases), with the highest incidence observed in February 2015 and January 2016. A significant correlation was found between temperature and dengue cases at lag 2-3 months ($p<0.05$). The spatial analysis also indicates that dengue fever cases in Malang Regency exhibit a clustered pattern, with the clusters predominantly located in urban areas. Temperature significantly influences dengue incidence in Malang Regency, particularly with a lag of 2-3 months. These findings suggest the importance of integrating temperature data into early warning systems for targeted dengue prevention and control strategies in vulnerable areas for climate change.

1 Introduction

Climate change is a global challenge, manifesting through various environmental impacts such as extreme weather events, melting icebergs, rising sea levels, and increased ocean acidity. [1-2]. Watson et al. [3] projected that global temperatures could rise by 1.0-3.5°C by the year 2100, which may enhance environmental conditions that support the proliferation of vectors, such as *Aedes aegypti*, that transmit disease pathogens. Dengue fever poses a risk to everyone. According to Ferreira [4], an estimated 2.5-3.6 billion people are at risk of dengue infection. Furthermore, the Centers for Disease Control and Prevention reported that one-third of the world's population resides in areas prone to dengue outbreaks [5]. Therefore,

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climate change catalyze the transmission of dengue virus, in which it is causing high morbidity and mortality among population.

In Indonesia, dengue cases are reported almost annually, leading to outbreaks in various provinces. The Indonesian Ministry of Health (MoH) recorded 59,047 dengue cases in 2017 and 65,602 cases in 2018, with 444 and 462 fatalities, respectively [6-7]. Additionally, the incidence rate of dengue in 2018 was reported at 24.73 per 100,000 population [7]. Therefore, the data is highlighting a fluctuating pattern of dengue cases in Indonesia.

East Java, a province located on the eastern part of Java Island, frequently reports dengue cases. In 2018, East Java had the second-highest number of dengue cases in Indonesia after West Java, with a total of 8,449 cases [7], indicating East Java contribute high dengue case in Indonesia. Malang Regency, a district in East Java, is classified as a dengue-endemic area, experiencing dengue cases annually. Between 2008 and 2017, Malang Regency recorded 8,041 dengue cases, with five outbreaks occurring in 2009, 2010, 2015, and 2016, reporting 1,124, 1,358, 1,331, and 1,268 cases, respectively [8-10].

Studies on dengue using epidemiological approach have been conducted in Malang. Sihombing [22] and Putra & Lestari [23] are using climatic data to examine the relationship to dengue. Yet, spatial analysis is not conducted. Nurrachamah et al [24] and Masluhiyah et al [25] are using case control and descriptive approach to study dengue in Malang, respectively. Integrating spatial and temporal analyses offers a comprehensive insight into dengue transmission dynamics. Bayesian spatiotemporal models applied in Thailand have highlighted the substantial influence of both spatial and temporal factors on the spread of the disease [26]. This study aims to assess the correlation between temperature and the incidence of dengue haemorrhagic fever in Malang Regency from 2014 to 2018 with spatial and temporal approach.

2 Material and Methods

This research employed a quantitative approach with an ecological study design based on a time-series analysis. The study was conducted in Malang Regency, East Java Province-Indonesia. Geographically, Malang Regency is situated between 112°17'10.90" to 112°57'00.00" East Longitude and 7°44'55.11" to 8°26'35.45" South Latitude [11]. Covering an area of 2,977.05 km², Malang Regency is the second largest district in East Java after Banyuwangi Regency with 33 sub-districts.

2.1 Data and Variables

This study uses secondary data obtained from the Malang Health Office and Malang Meteorology, Climatology, and Geophysical Agency (BMKG). The data consisted of monthly dengue haemorrhagic fever cases and temperature in Malang Regency in 2014-2018. During 2014-2018, two dengue outbreaks in Malang regency were recorded, in which this issue should be addressed. The dependent variable is the dengue case, while the independent variable is temperature.

2.2 Ethical Clearance

This study received ethical approval by the Medical and Health Research Ethics Committee Faculty of Medicine, Public Health, and Nursing – Universitas Gadjah Mada (Ref No. KE/FK/02383/EC/2020)

2.3 Data Analysis

Descriptive spatial analysis was conducted by overlaying thematic maps of the independent variable (temperature) and the dependent variable (dengue cases). Temperature data were interpolated to estimate weather values for each sub-district using the Inverse Distance Weighting (IDW) method, as described in previous studies by Firdaus [12] and Nilasari [13]. The spatial analysis was performed using QGIS software.

Bivariate analysis was used to examine the temporally relationship between dengue cases and temperature. Data normality tests revealed non-normal distributions, leading to the use of the Spearman correlation test. Correlation analysis assessed the relationship between dengue incidence and temperature for the same month (lag 0) and up to three months prior (lag 3). The significance level (α) for hypothesis testing was set at 5% (0.05), with the null hypothesis rejected if the p-value exceeded 0.05. This bivariate analysis was conducted with Stata version 13 (College Station, Tx)

3 Result and Discussion

3.1 The association between temperature and dengue haemorrhagic fever

Figure 1 illustrates the temporal trend between dengue cases and temperature in Malang Regency from 2014 to 2018. The data indicate that dengue cases were highest in 2015 and 2016, with 1,331 and 1,140 cases, respectively. There was a significant decline in cases in 2017 to 451, followed by a rise to 751 cases in 2018. The temperature patterns associated with dengue incidence during this period are also depicted in Figure 1, showing that the highest dengue case counts occurred in February 2015, January 2015, March 2015, and January-February 2016, with temperatures of 23.8°C, 23.7°C, 24.2°C, 25.1°C, and 24.1°C, respectively.

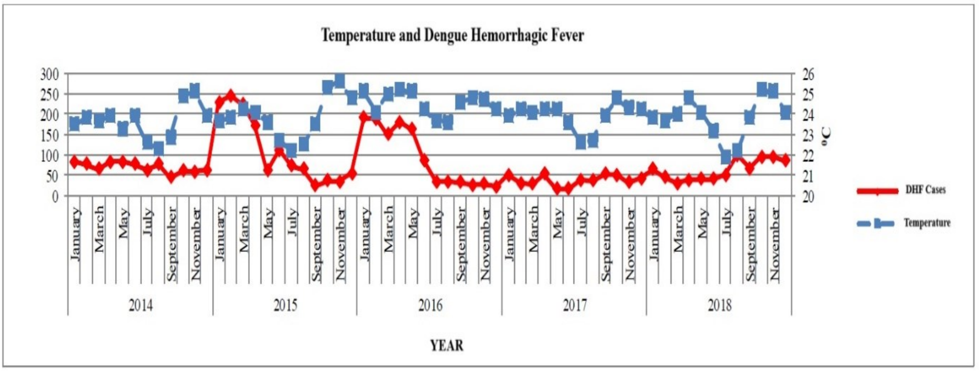

Fig. 1. The time trend of temperature and DHF in Malang during 2014-2018

Table 1 presents the results of the correlation analysis, indicating that temperature at a lag of 2-3 months is significantly related to dengue incidence in Malang Regency ($p<0.05$). The bivariate analysis was conducted using data from a two-year period (2014-2015) on temperature and dengue incidence. This timeframe was selected to examine the relationship between temperature and dengue during the initial or first outbreak phase within the broader period of 2014-2018. The rationale behind this choice is the assumption that after the first outbreak, substantial preventive measures would be implemented, which could potentially modify the impact of temperature on dengue incidence.

Table 1. The correlation between Temperature and DHF in Malang during 2014-2015

Temperature	Lag			
	0	1	2	3
r	-0.2616	0.0225	0.5210*	0.6883*
p-value	0.2519	0.9230	0.0154	0.0006

3.2 The spatial distribution of temperature and dengue haemorrhagic fever

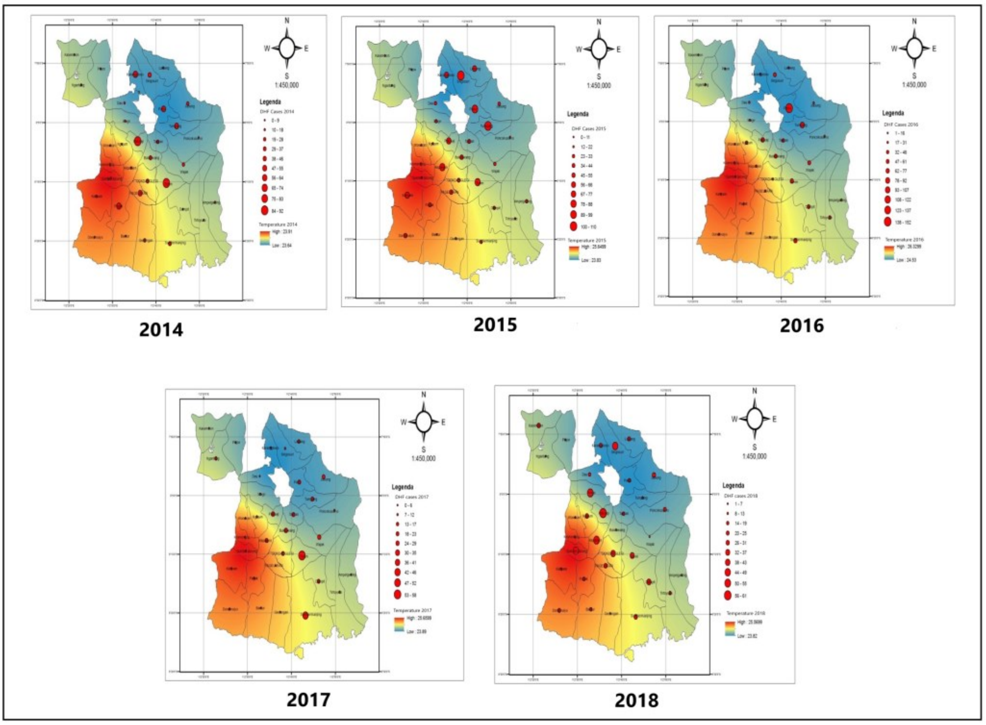

Fig. 2. The spatial distribution of Dengue cases by temperature

As visualize by Figure 2, the spatial distribution of dengue case by temperature during 2014-2018 was presented. Based on Fig. 2, the spatial distribution of the sub-districts with the highest dengue cases in 2014-2018 was Turen District (92 cases; mean temperature 23.76^{0}C), Tumpang sub-district (110 cases; mean temperature 24.76^{0}C), Pakis sub-district (152 cases; mean temperature 24.74^{0}C), Turen sub-district (58 cases; mean temperature 24.71^{0}C), Pakisaji sub-district (61 cases; mean temperature 24.62^{0}C), respectively. On the other hand, the spatial distribution of sub-districts with the lowest dengue cases in 2014-2018, namely Pujon sub-district (1 case; mean temperature 23.67^{0}C), Kasembon sub-district (0 cases; mean temperature 24.09^{0}C), Pujon sub-district (1 case; mean temperature 24.74^{0}C), Pujon sub-district (0 cases; mean temperature 24.11^{0}C), Pujon sub-district (1 case; mean temperature 23.85^{0}C), respectively.

The spatial analysis reveals that dengue cases in Malang Regency are concentrated in clusters, predominantly located in urban areas with moderate temperature. This observation aligns with findings from Dhewantara et al. [14]. Additionally, Akter et al. [15] identified several factors contributing to the spread of dengue cases around outbreak epicentres, including changes in community behaviour, population movement, the arrival of international travellers, and environmental changes such as new irrigation systems.

As visualized by Figure 1, the time-trend or temporal analysis reveals that the mean monthly temperature from 2014 to 2018 in Malang Regency was relatively low between May and August, ranging from 21.9°C to 23.6°C. Conversely, temperatures began to rise from September, peaking in October or November, with averages ranging from 24.7°C to 25.6°C, although the highest temperature also reported in April 2016 at 25.2°C. Elevated temperatures can enhance mosquito activity in previously unaffected areas [16]. The mosquito species *Aedes aegypti* is particularly sensitive to temperature fluctuations, affecting both its immature stages in aquatic environments and its adult stage. According to Githeko et al. [17], increased temperatures boost the biting activity of female mosquitoes, which can heighten the intensity of dengue transmission. Additionally, increased rainfall can expand mosquito breeding sites. Thus, climate change has the potential to elevate the transmission rates of vector-borne diseases such as dengue.

Temperature fluctuations significantly impact various aspects of *Aedes* mosquitoes, the primary vectors of dengue fever, including population size, growth periods, feeding behaviors, and survival rates [18]. As temperatures rise, mosquito populations can grow rapidly [18]. At temperatures between 15°C and 30°C, *Aedes* mosquitoes experience lower mortality rates, and under favorable environmental conditions, they can survive for up to 76 days [19]. Higher temperatures, above 32°C, lead to shorter reproductive cycles and doubled feeding frequency compared to temperatures around 24°C. The developmental period of mosquito pupae shortens from 4 days at 22°C to less than 1 day at temperatures between 32°C and 34°C. Additionally, the ratio of female to male offspring at 30°C is 4:3 [20]. Furthermore, the extrinsic incubation period of the dengue virus decreases from 12 days to 7 days at 30°C [21]. Therefore, temperature changes can significantly affect dengue fever vectors.

4 Conclusion

A statistically significant relationship was observed between temperature and dengue cases in the previous two to three months. Both graphical/time-trend and spatial analyses show that temperature patterns align with the trends in dengue cases in Malang Regency. The spatial analysis also indicates that dengue fever cases in Malang Regency exhibit a clustered pattern, with the clusters predominantly located in urban areas. Therefore, it is crucial to strengthen surveillance by monitoring both temperature and dengue trends in real-time. Targeted interventions should focus on enhancing mosquito control efforts in urban clusters where dengue is most prevalent. Increasing community awareness about dengue prevention and mosquito control is also essential.

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