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TEMPORAL AND SPATIAL PATTERNS OF DENGUE GEOGRAPHICAL DISTRIBUTION IN PADANG, INDONESIA

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ABSTRACT
Dengue fever (DHF) is an environmentally-based public health problem that is currently a major concern. DHF is a significant health problem in tropical and sub-tropical countries, with 70% of the global burden, countries in Asia are the worst affected. The aim of the study is to describe the relationship between population density, rainfall, and temperature with the incidence of DHF in Padang, Indonesia. The study was analytical descriptive with an ecological study design. The data analysis involved the use of statistical software and QGIS. Research data were obtained from the Health Office, BPS, and the Padang City Meteorology and Climatology Agency. The data was analyzed univariate and bivariate by Spearman test and then the data was assessed and analyzed to produce vulnerability level using the QGIS application. The results shows that there are 17 villages with high vulnerability level, 50 villages with medium vulnerability level, and 37 villages with low vulnerability level to DHF incidence. According statistical test, the p value rainfall and temperature with DHF incidence is 0.001 and 0.001 (α=0.05) in Padang, respectively. Knowing the distribution of dengue-prone areas, it is hoped that it will make it easier for the Padang City Health Service to take preventive measures and handle DHF cases by prioritizing villages with a high level of vulnerability.

Keywords: *DHF incidence; rainfall; spatial; temperature*

INTRODUCTION

Aedes aegypti is a species of mosquito that can transport the Dengue virus, which can lead to Dengue Hemorrhagic Fever (DHF). In addition to dengue, Aedes aegypti is also a transmitter of the Yellow Fever and Chikungunya viruses. The spread of this mosquito is widespread, covering almost all tropical regions of the world. As a carrier of the dengue virus, Aedes aegypti is the main vector, and together with Aedes albopictus, they form the dengue transmission cycle in urban and rural areas (Muh. Kamil & Arief, 2020).

Dengue fever (DHF) is a very important public health problem today, rooted in environmental factors. Disease outbreaks often occur due to its rapid and potentially fatal spread. The disease is caused by one of four different dengue viruses, and is transmitted through the bite of the Aedes aegypti mosquito. From an epidemiological standpoint, it is estimated that more than 50 million people are infected with dengue every year, with about two and a half billion people worldwide at risk of contracting it. Although most dengue deaths are preventable, about 1% of cases have a higher fatality rate (CFR). Dengue is estimated to cause around 10,000 deaths in more than 125 countries. Recent data estimates that by 2080, 60% of the global population will be at risk of dengue (Messina et al., 2019).

DHF is an important health problem in tropical and sub-tropical regions, particularly in Southeast Asia and the Western Pacific. More than 70% of the total dengue cases worldwide occur in Asian countries, making this region the most affected (WHO, 2020).

The fluctuating number of dengue fever (DHF) cases each year can be influenced by a number of factors, including climate, people's behavior, and the level of awareness of environmental hygiene. The environment plays an important role in the spread and increase of dengue, with physical factors such as rainfall, humidity, air temperature, altitude and population density being the main factors influencing the transmission of the disease.

Temperature and precipitation have been noted as important contributing factors in previous studies (Yuan et al., 2020). previous studies have assumed that the effects of climate factors are constant throughout the year. However, the effects of climate variables can change over time. Various studies have shown various impacts of rainfall on Dengue incidence (Langkulsen & Sakolnakhon, 2022). Many studies have shown that the influence of rainfall on the incidence of Dengue can change throughout the year. For example, heavy rainfall during the rainy season can disrupt potential mosquito habitats, which in turn can negatively impact mosquito population growth. Conversely, rainfall during the winter months can create stagnant water that is ideal for mosquito breeding. All of these factors have been linked to mosquito reproductive habitats that play an important role in the spread of disease (Dinkes Padang, 2022).

Currently, epidemiological information on the spread of Dengue Fever (DHF) cases in Padang City is still processed manually using tables and graphs. However, the use of map-based visualization using Geographic Information Systems (GIS) is still limited. The adoption of this geographic study is essential to understand the spatial distribution patterns of infectious diseases, and the resulting data will be the foundation for analysis that supports efforts to prevent the spread of certain diseases.

Utilizing Geographic Information Systems (GIS) can play a crucial role in pinpointing regions and populations susceptible to diseases, particularly Dengue Hemorrhagic Fever (DHF). GIS facilitates the creation of DHF susceptibility maps for specific areas within a district or city, enabling the acquisition of disease distribution data. Such tools are invaluable for the Padang City Government in implementing effective preventive and treatment measures for DHF cases.

A previous study investigating the clustering and mapping of sub-districts in Padang City in 2016, with a focus on contributing factors to DHF such as health and demographic factors, revealed differences in characteristics and vulnerability levels between sub-district groups in the region.

In this context, the objective of this study is to explore dengue incidence by neighborhood and assess the distribution of vulnerability to dengue based on several factors such as dengue incidence rate, rainfall, temperature, and population density in Padang City during 2021. This study aims to contribute to the efforts of the Padang City Government in efficiently allocating resources to areas identified as high risk areas for dengue fever. Thus, it is expected that prevention efforts against dengue fever cases can be improved.

RESEARCH METHODS

This research is an analytical descriptive research with an ecological study design. Ecological study is an observational study with population as the unit of analysis.

Utilizing a spatial perspective and geographic information system (GIS) tools, the research relies on secondary data. The spatial unit of analysis is the administrative level of urban villages in Padang City, comprising 11 sub-districts with a total of 104 urban villages. The data sources include DHF incidence data from the Padang City Health Office, population density data from BPS Padang City, and meteorological information from BMKG Padang City, encompassing rainfall and wind speed. Additionally, air temperature data for Padang City in 2021 is sourced from the United States Geological Survey.

The data analysis involved the use of statistical software and QGIS. Univariate analysis was conducted to provide a detailed overview of population density, rainfall, air temperature, and DHF cases in Padang City in 2021. Bivariate analysis aimed to explore the correlation between population density, rainfall, and temperature with the incidence of DHF, utilizing the Spearman correlation test. DHF incidence is obtained from the number of dengue cases divided by 100,000 population. Spatial distribution analysis was carried out for the variables of DHF incidence, population density, rainfall, and air temperature. This analysis depicted the spatial arrangement by assigning unique colors to various categories. The color symbols and their corresponding classifications are outlined in the accompanying legend. This research has undergone ethical testing at the Health Research Ethics Commission (KEPK) of Fort De Kock University Bukittinggi and has obtained a certificate of ethical approval with number 107/KEPK/II/2024.

Table 1. Color Symbols and Classification of Spatial Distribution Maps

Variable	Classification	Color
Dengue Incidence	Low (IR <20.2 per 100.000 population)	Green
	Moderate (20.2 – 39.5 per 100.000 population)	Yellow
	High (39.5 – 110.5 per 100.000 population)	Red
Population Density	Low (<3.000 people/km^2)	Green
	Moderate (3.000 – 12.000 people/km^2)	Yellow
	High (>12.000 people/km^2)	Red
Rainfall	Low (<321 mm)	Green
	Moderate (321 – 330 mm)	Yellow
	High (>330 mm)	Red
Temperature	Low (<25.2 ^{o}C)	Green
	Moderate (25.2 – 27.17 ^{o}C)	Yellow
	High (>27.17 ^{o}C)	Red

RESULTS AND DISCUSSION

Spatial Distribution of DHF Incidence in Padang City in 2021

The distribution of DHF incidence by neighborhood in Padang City in 2021 is presented in the spatial distribution map in Figure 1.1. The incidence of DHF is divided into 3 categories: low (IR < 20 per 100,000 population) marked in green, medium (IR 20 - 55 per 100,000 population) marked in yellow, and high (IR > 55 per 100,000 population) marked in red.

Figure 1 shows that the incidence of DHF in Padang City in 2021 is classified into 3 zones. High DHF IR zones in Surau Gadang, Air Tawar Timur, Kampung Lapai Baru, Ulak Karang Selatan, Gurun Laweh, Lubuk Lintah, Korong Gadang, Jati Baru, Jati, Ujung Gurun, Flamboyan Baru, Kampung Jao, Binuang Kampung Dalam, Pisang, Kampung Baru Nan XX, Pagambiran

Ampulu Nan XX, Bungus Barat. Moderate DHF IR zones in Balai Gadang, Lubuk Buaya, Batang Kabung, Koto Pulai, Bungo Pasang, Parupuk Tabing, Dadok Tunggul Hitam Tunggul Hitam, Kampung Olo, Sungai Sapih, Tabiang Banda Gadang,

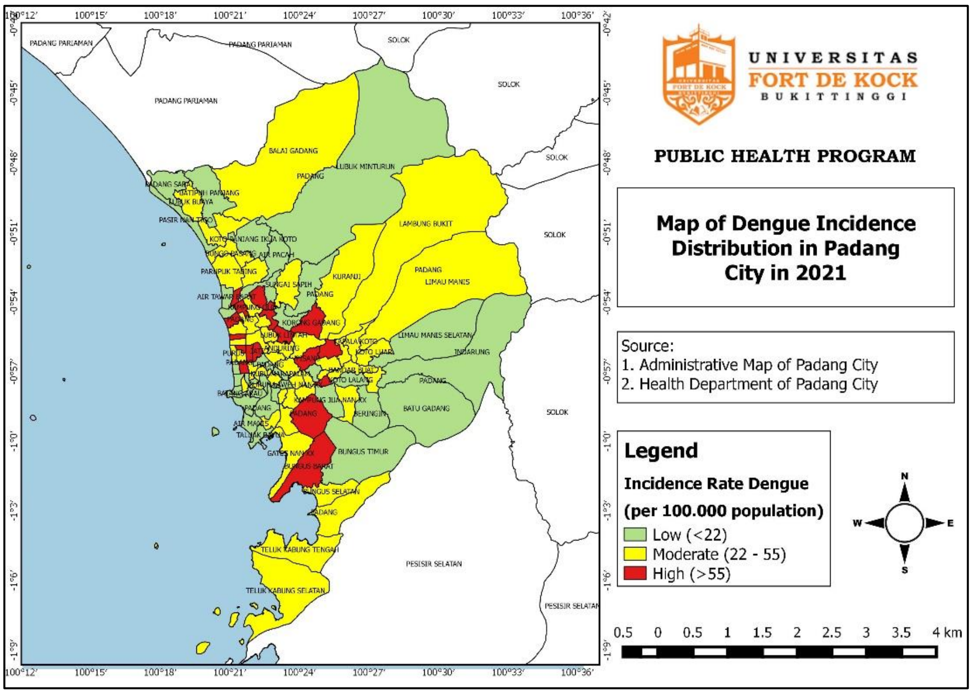

Figure 1. Results of Secondary Data Analysis of DHF Incidence in Padang City in 2021

Gunung Pangilun, Lolong Belanti, Rimbo Kaluang, Alai Parak Kopi, Ampang, Purus, Padang Pasir, Anduring, Pasar Ambacang, Kuranji, Andalas, Kubu Parak Karakah, Sawahan, Ganting Parak Gadang, Alang Laweh, Pasa Gadang, Kampung Pondok, Parak Gadang Timur, Banuaran Nan XX, Lubuk Begalung Nan XX, Tanjung Saba Pitameh Nan XX, Batuang Taba Nan XX, Parak Laweh Pulai Air Nan XX, Pampangan Nan XX, Rawang, Gates Nan XX, Bungus Selatan, Teluk Kabung Utara, Teluk Kabung Tengah, Teluk Kabung Selatan, Tarantang, Padang Besi, Cengkeh Nan XX, Piai Tangah, Cupak Tangah, Kapalo Koto, Bandar Buat, Koto Luar, Limau Manis, and Lambung Bukit, and the rest fall into the low zone.

Spatial Distribution of Population Density in Padang City in 2021

The distribution of population density by urban village in Padang City in 2021 is presented in the spatial distribution map in Figure 2. Population density is divided into 3 categories, namely low (<3000 people/km^2) marked in green, medium (3000 – 12000 people/km^2) marked in yellow, and high (>12000 people/km^2) marked in red.

Figure 2 shows that the population density in Padang City in 2021 is classified into 3 zones. The high population density zone is in the villages of Air Tawar Barat, Kampung Lapai Baru, Gunung Pangilun, Jati, Ganting Parak Gadang, Parak Gadang Timur, Pasa Gadang, Berok Nipah, Batang Arau, Seberang Palinggam, Mato Aie, and Rawang. Medium population density zones in Ulak Karang Utara, Ulak Karang Selatan, Lolong Belanti, Flamboyan Baru, Rimbo Kaluang, Ujung Gurun, Purus, Padang Pasir, Jati Baru, Olo, Air Tawar Timur, Kampung

(10-21)

Olo, Surau Gadang, Kurao Pagang, Gurun Laweh, Tabiang Banda Gadang, Batang Kabung, Lubuk Buaya, Balai Gadang, Kuranji, Pasar Ambacang, Sawahan,

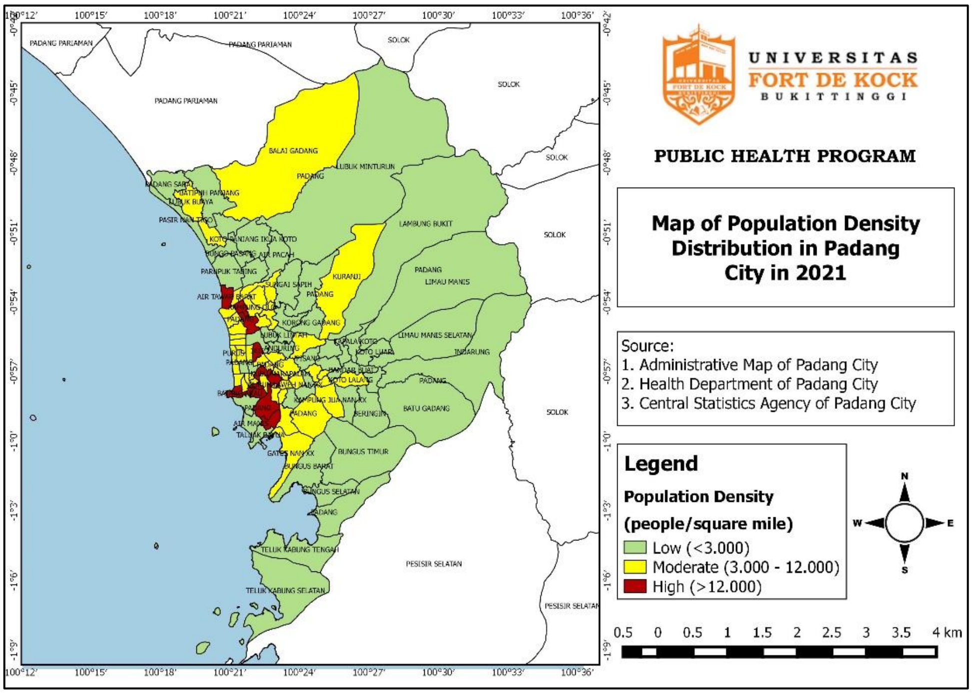

Figure 2. Results of Secondary Data Analysis Population Density in Padang City in 2021

Andalas, Simpang Haru, Kubu Parak Karakah, Kubu Marapalam, Gurun Laweh Nan XX, Lubuk Begalung Nan XX, Belakang Tangsi, Kampung Pondok, Belakang Pondok, Alang Laweh, Ranah Parak Rumbio, Seberang Padang, Koto Baru Nan XX, Banuaran Nan XX, Pampangan Nan XX, Pagambiran Ampulu Nan XX, Tanah Sirah Piai Nan XX, Cengkeh Nan XX, Kampung Baru Nan XX, Koto Lalang, Kampung Jua Nan XX, and Gates Nan XX, and the rest fall into the low zone.

Spatial Distribution of Rainfall in Padang City in 2021

The distribution of rainfall by village in Padang City in 2021 is presented in the spatial distribution map in Figure 3. Rainfall is divided into 3 categories: low (<321 mm) marked in green, medium (321 - 330 mm) marked in yellow, and high (>330 mm) marked in red.

Figure 3 shows that rainfall in Padang City in 2021 is classified into 3 zones. High rainfall zone in Lubuk Buaya Village, Batang Kabung, Gunung Pangilun, Alai Parak Kopi, Jati, Jati Baru, Ujung Gurun, Purus, Olo, Kampung Jao, Sawahan, Ganting Parak Gadang, Parak Gadang Timur, Seberang Padang, Pasa Gadang, Batang Arau, Kampung Pondok, Kuranji, Gunung Sarik, Korong Gadang, Kalumbuk, Lubuk Lintah, Pasar Ambacang, Binuang Kampung Dalam, Cupak Tangah, Kapala Koto, Piai Tangah, Pisang, Kubu Parak Karakah, Andalas, Tanah Sirah Piai Nan XX, Tanjung Saba Pitameh Nan XX, Cengkeh Nan XX, Bandar Buat, Koto Baru Nan XX, Banuaran Nan XX, Parak Laweh Pulai Air Nan XX, Batuang Taba Nan XX, Mato Aie, Rawang, Pampangan Nan XX, Pagambiran Ampulu Nan XX, Gates Nan XX, Bungus Barat, and Teluk Kabung Selatan. The medium rainfall zone is in Parupuk Tabing, Air Tawar Barat, Kurao Pagang, Ulak Karang Selatan, Lolong Belanti, Ampang, Anduring, Padang Pasir, Simpang Haru, Kubu Marapalam,

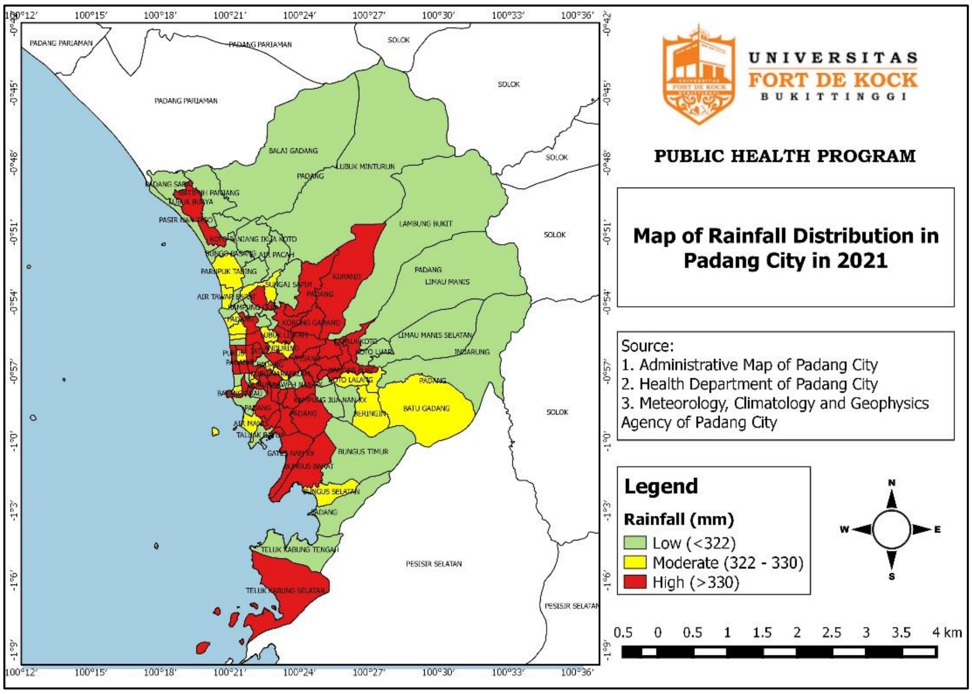

Figure 3. Results of Secondary Data Analysis Rainfall in Padang City in 2021

Alang Laweh, Ranah Parak Rumbio, Berok Nipah, Air Manis, Koto Lalang, Padang Besi, Beringin, Batu Gadang, and Bungus Selatan, and the rest fall into the low zone.

Spatial Distribution of Temperature in Padang City in 2021

The distribution of air temperature by urban village in Padang City in 2021 is presented in the spatial distribution map in Figure 4. Air temperature is divided into 3 categories, namely low (<25.2ºC) marked in green, medium (25.2 - 27.17ºC) marked in yellow, and high (>27.17ºC) marked in red.

Figure 4 shows that the air temperature in Padang City in 2021 is classified into 3 zones. High air temperature zones in Padang Sarai, Lubuk Buaya, Batang Kabung, Bungo Pasang, Parupuk Tabing, Dadok Tunggul Hitam, Air Tawar Barat, Kurao Pagang, Surau Gadang, Kampung Olo, Ulak Karang Selatan, Gunung Pangilun, Alai Parak Kopi, Flamboyan Baru, Jati, Jati Baru, Padang Pasir, Ujung Gurun, Purus, Olo, Kampung Jao, Alang Laweh, Ranah Parak Rumbio, Kampung Pondok, Andalas, Kubu Parak Karakah, Simpang Haru, Parak Gadang Timur, Lubuk Lintah, Pasar Ambacang, Korong Gadang, Kuranji, Banuaran Nan XX, Pampangan Nan XX, and Pagambiran Ampulu Nan XX. Moderate rainfall zone in Balai Gadang Village, Lubuk Minturun, Batipuh Panjang, Koto Pulai, Koto Panjang Ikua Koto, Pasir Nan Tigo, Gunung Sarik, Kalumbuk, Gurun Laweh, Kampung Lapai Baru, Lolong Belanti, Berok Nipah, Belakang Pondok, Pasa Gadang, Sawahan Timur, Sawahan, Ganting Parak Gadang, , Seberang Padang, Kubu Marapalam, Binuang Kampung Dalam, Pisang, Tanah Sirah Piai Nan XX, Cengkeh Nan XX, Tanjung Saba Pitameh Nan XX, Bandar Buat, Koto Lalang, Batuan Taba Nan XX, Kapalo Koto, Padang Besi, Limau Manis Selatan, Batu Gadang, Rawang, Bungus Barat, and Bungus Selatan, and the rest fall into the low zone.

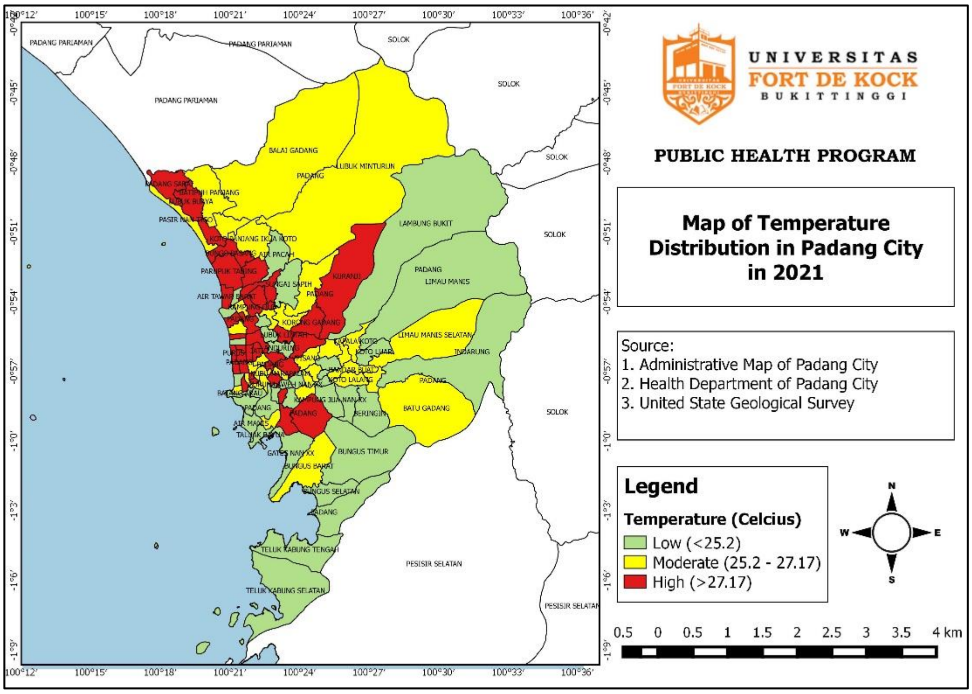

Figure 4. Results of Secondary Data Analysis of Temperature in Padang City in 2021

Correlation between Population Density, Rainfall, and Temperature with DHF Incidence in Padang City in 2021

Based on statistical test, the p value of population density, rainfall, and temperature with DHF incidence is 0.512, 0.001, and 0.001. Therefore, there are correlations between rainfall and temperature with DHF incidence ($p < \alpha$), while there is no correlation between population density with DHF incidence ($p \geq \alpha$).

Table 2. Correlation Test Results between Independent Variables and the Incidence of DHF in Padang City in 2021

Variable	p-value	r
Population Density	0.512	0.065
Rainfall	0.001	0.320
Temperature	0.001	0.314

Relationship between Rainfall and DHF Incidence in Padang City in 2021

The results showed a significant association between rainfall and dengue fever, with a p-value of 0.001. This relationship has been an interesting topic of research in the field of public health. Many studies have revealed a positive correlation between rainfall and the prevalence rate of DHF cases. This finding indicates that high rainfall can create a favorable environment for the breeding of mosquitoes, which are the main vectors of dengue transmission (Ali & Ma'Rufi, 2018).

These breeding environments can include stagnant water in containers, puddles, and other areas where mosquitoes lay their eggs (Islam et al., 2023). Moreover, the presence of clear water reservoirs post-rainfall creates optimal conditions for mosquito breeding, resulting in a surge in the mosquito population and consequently heightening the risk of DHF transmission (Akter et al., 2017; Ali & Ma'Rufi, 2018).

Several studies have proposed that rainfall may indirectly impact DHF transmission by influencing other variables like temperature and humidity (Campbell et al., 2015; Ehelepola et al., 2015). For example, heavy rainfall can increase humidity and temperature, which in turn accelerates the growth of mosquito larvae and reduces the incubation period of the dengue virus in the mosquito body (Akter et al., 2017; Chen et al., 2018).

The relationship between rainfall and DHF emphasizes the importance of understanding and predicting climate patterns in order to implement effective prevention and control strategies. In addition, it highlights the need for intensified vector control measures and public health interventions during periods of high rainfall, with the aim of reducing the spread of dengue (R. Li et al., 2019; Liu et al., 2023; Wang et al., 2019). To conclude, the link between rainfall and DHF indicates that increased rainfall can foster favorable conditions for mosquito breeding and elevate DHF transmission risk (Abdullah et al., 2022; Sintorini, 2018). Hence, monitoring rainfall patterns and implementing suitable preventive measures can play a pivotal role in averting and managing DHF spread (Nair & Aravind, 2020; Tilwani et al., 2018).

Numerous preventive measures for DHF exist, including the establishment of effective drainage systems and routine inspection of stagnant water sources to diminish mosquito breeding sites, thus mitigating DHF risk, particularly during periods of heavy rainfall (Campbell et al., 2013; Gu et al., 2016). In addition, public health campaigns that emphasize personal protective measures such as the use of anti-mosquito medication, the use of long-sleeved clothing and long pants, and avoiding outdoor activities during peak rainfall periods can also help prevent dengue infections. In addition, timely and accurate predictions of rainfall patterns can enable the implementation of proactive measures, such as targeted vector control efforts and public health campaigns, which can effectively reduce the risk and impact of dengue outbreaks during periods of increased rainfall (Benedum et al., 2018; Wang et al., 2019).

The spread of dengue cases is strongly influenced by rainfall and temperature as rainfall can cause stagnant water that goes undetected by the community, creating ideal conditions for the breeding of Aedes aegypti mosquitoes. Environmental factors such as temperature, rainfall, and humidity play an important role in the dengue transmission cycle and contribute to the increase in cases. The dengue virus and mosquitoes as its vectors are highly responsive to environmental changes. Certain temperatures and humidity can stimulate mosquitoes to copulate, making them more aggressive in searching for prey, and increasing the frequency of biting, thus increasing the risk of disease transmission.

Relationship between Temperature and DHF Incidence in Padang City in 2021

Temperature is an important environmental factor that can influence the transmission and prevalence of many vector-borne diseases, including DHF. Studies have shown a correlation between temperature and the incidence of DHF (Huber et al., 2018; Siraj et al., 2017). For instance, higher temperatures can accelerate the virus replication and shorten the incubation period within mosquito vectors, leading to increased transmission rates. Additionally, warmer temperatures can also affect the behavior and survival of mosquito vectors, expanding their geographic range and prolonging their activity season (Mordecai et al., 2017; Sintorini, 2018). Therefore, monitoring temperature patterns and fluctuations is crucial in understanding and predicting the spread of DHF (Fan et al., 2014; Siraj et al., 2017).

Research has shown that temperature plays a significant role in the transmission and prevalence of DHF. Therefore, it is important to consider both rainfall and temperature when studying the correlation and predicting the occurrence of DHF. Additionally, studies have found that temperature alone is not sufficient in predicting the distribution of DHF occurrence at a national scale (Y. Li et al., 2020; Tran et al., 2020). Other factors, such as humidity and vector abundance, must also be taken into account. In conclusion, both rainfall and temperature have been found to be correlated with the occurrence and transmission of DHF (Mordecai et al., 2017; Vishnampettai G. Ramachandran et al., 2016).

Another theory suggests that there is a negative correlation between temperature and DHF incidence (Liu et al., 2018). In this theory, it is believed that higher temperatures can limit the survival and reproductive capabilities of the Aedes mosquitoes, which are the primary vectors for DHF (Ferreira et al., 2017; Tran et al., 2020). This can result in a decrease in the density of mosquito populations and ultimately lead to a decrease in the transmission of DHF (Tilwani et al., 2018).

Research has consistently shown a correlation between temperature and the occurrence of DHF with p-value 0.0001 (Abualamah et al., 2021). Warmer temperatures are associated with higher transmission rates and increased prevalence of the disease (Campbell et al., 2013; Siraj et al., 2017). The correlation between temperature and DHF was significant, with higher temperatures associated with increased transmission rates and disease prevalence. In addition, the study also highlighted the potential delayed effect of temperature on dengue transmission, where warmer temperatures in earlier months may lead to higher incidence in later months (Y. Li et al., 2020; Sintorini, 2018).

Although temperature variables cannot be changed, this information still has significant relevance. Although it cannot be manipulated, temperature data can act as an early warning indicator, allowing for immediate intervention measures. This is particularly important in detecting the spread of dengue disease early. If this approach is applied effectively and widely, providing early warning of the likelihood of a rainy season in a particular region can provide clear guidance for actions that need to be taken.

CONCLUSION

The results shows that there are 17 village with high vulnerability level, 50 village with medium vulnerability level, and 37 village with low vulnerability level to the DHF incidence. Based on Spearman test, the p value of rainfall and temperature with DHF incidence is 0.001 and 0.001 (α=0.05; p< α), respectively. Therefore, there are correlations between rainfall and temperature with DHF incidence in Padang on 2021, where rainfall (r=0.320) and temperature (r=0.314) have moderate correlation with DHF incidence. Rainfall and temperature is one of climate change indicators that contribute to an increase in dengue incidence. It is anticipated to streamline the prevention and management of Dengue Hemorrhagic Fever (DHF) cases in Padang City. Furthermore, the local government of Padang City can allocate greater focus to regions categorized as high-risk areas for DHF.

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