Mapping of Dengue Fever Disease Based on Satellite Images (Case Study: Bandung City, West Java)

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ABSTRAK

Kota Bandung merupakan salah satu pusat perekonomian di Indonesia, hal tersebut berdampak terhadap laju kependudukan yang terus meningkat setiap tahunnya. Dampak tersebut berbanding lurus dengan banyaknya penggunaan lahan yang digunakan untuk pemukiman. Apabila dampak tersebut dibiarkan, maka akan timbul masalah perkotaan seperti kemacetan, banjir, tanah longsor, dan wabah penyakit. Salah satu yang paling berbahaya adalah munculnya wabah penyakit yang dapat disebabkan oleh berbagai macam organisme salah satunya adalah nyamuk. Nyamuk dapat menyebabkan berbagai macam penyakit seperti malaria, chikungunya dan demam berdarah. Khusus penyakit demam berdarah yang disebabkan oleh nyamuk Aedes aegypti dan Aedes albopictus paling banyak menimbulkan kasus penyakit yang disebabkan oleh nyamuk. Penelitian ini bertujuan untuk memetakan penyakit demam berdarah di Kota Bandung Tahun 2018 berbasis citra satelit dengan bantuan Sistem Informasi Geografis model Weighted Linier Combination. Menggunakan parameter curah hujan, suhu, tutupan lahan dan elevasi di Kota Bandung. Hasil dari penelitian ini menunjukan bahwa daerah dengan tingkat kerawanan tinggi di Kota Bandung mencapai persentase 41,1 %, daerah kerawanan sedang 52,1%, dan daerah kerawanan rendah 6,8%.

Kata kunci: *demam berdarah, pengindraan jauh, sistem informasi geografis*

ABSTRACT

Bandung City is one of the economic centres in Indonesia. Consequently, it has an impact on the population rate, which increases every year. The impact is also directly proportional to the amount of land used for settlement. There are some urban problems, such as congestion, floods, landslides, and some epidemic diseases. One of the most dangerous is DBD, which can be caused by various types of organisms, one of which is mosquitoes. It can cause various diseases, such as malaria, chikungunya, and dengue. Dengue fever is caused by Aedes aegypti and Aedes albopictus mosquitoes, and most cases cause diseases caused by mosquitoes. This study aims to map the dengue fever distribution in Bandung city in 2018 based on satellite imagery with the help of the Geographic Information System Weighted Linear Combination model. Using parameters of rainfall, temperature, land cover, and elevation in the city of Bandung. The results of this study show that areas with a high level of vulnerability in Bandung reached a percentage of 41.1%, moderate vulnerability areas were 52.1%, and areas of low vulnerability were 6.8%..

Keywords: *dengue fever, remote sensing, geographic information system*

1. INTRODUCTION

Bandung City is one of the major cities in Indonesia and is divided into eight sub-cities, namely Arcamanik, Cibeunying, Kerees, Kordon, Gedebage, Ujungberung, Bojonagara, and Tegalega (Regional Regulation No. 10 of 2015, Bandung City). Bandung City has a population that continues to increase; the ratio of the average increase in the population rate reaches 0.29% per year [1]. One factor being the centre of the economy, many people are looking for work and settled in the city of Bandung. Another impact of population growth is increasing land use for settlements. If there are no regulations governing land use for settlements, urban problems such as traffic jams, floods, landslides, and disease outbreaks will arise.

Outbreaks of a disease can be caused by a variety of organisms, one of which is a mosquito. Mosquitoes can cause serious diseases in humans, such as dengue fever, malaria, and chikungunya. Dengue fever is caused by Aedes aegepti (Ae) mosquitoes as the main disease vector [2]. Besides Ae mosquitoes, Albopictus is the second vector of the disease [3]. Environmental factors such as temperature, rainfall intensity, and the type of land use can trigger the development of the vector population of dengue fever [4]. By knowing the characteristics and factors that cause dengue fever, mapping of dengue-prone areas can be done by utilising remote sensing technology[5]. Mosquito-borne diseases like dengue fever, malaria, and chikungunya continue to be significant public health concerns. The integration of remote sensing technology in monitoring and controlling these diseases offers a promising approach to mitigate their impact. By providing valuable environmental data, remote sensing enhances our ability to predict, prevent, and respond to outbreaks, ultimately contributing to better health outcomes. Dengue Mapping can help identify areas with high dengue transmission rates (hotspots). This information is important to direct more effective and targeted prevention and intervention efforts. By utilizing dengue mapping conducted in 2018, the City of Bandung can increase the effectiveness of disease prevention and control efforts, as well as provide a strong basis for further research in the fields of epidemiology and public health.

Remote sensing technology is currently developing rapidly, as shown by the many types of research on health based on remote sensing. Availability, convenience, and fast data processing make this technology increasingly developed. Remote sensing technology is experiencing rapid development, significantly impacting health research and applications. This advancement is fueled by the availability of high-resolution satellite imagery, the convenience of accessing diverse data sources, and the speed of data processing. These factors collectively enhance the scope and efficiency of remote sensing applications in the health sector Various kinds of data about spatial and geographic information can be easily accessed. The integration of remote sensing with Geographic Information Systems (GIS) further enhances its applicability in health research. GIS allows for the visualization, analysis, and interpretation of spatial data, providing valuable insights for health professionals and policymakers. The completion of the malaria life cycle depends critically on the mosquito developmental cycle thatcan only be completed under favourable conditions. Surface water collections, whose availability is mainly driven by land use/land cover characteristics and rainfall are a must but water bodies can only harbor. Anopheles mosquito larvae if conditions (salinity, turbidity, sunlight, temperature, etc.), are acceptable [6]. One of them is data on climate parameters, namely temperature [7] and rainfall intensity. Temperature also can affect pathogen development within vectors and interact with humidity to influence vector survival and, hence, vectorial capacity. The seasonality and amounts of precipitation in an area also can strongly influence the availability of breeding sites for mosquitoes and other species that have aquatic immature stages [8]. Mapping dengue fever disease using satellite images, focusing on rainfall, temperature, elevation, and land cover, is a multidisciplinary approach combining remote sensing, GIS, and epidemiology [9], [10],[11], [12].

This study aims to map dengue fever areas based on parameters of rainfall, temperature, elevation, and land cover using remote sensing technology and geographic information systems. Also, the results of this study will show the effect of temperature and rainfall on wet months (January, February, and March) and months (July, August, and September) on areas of dengue fever.

2. DATA AND METHOD

2.1 Study Area

The research location is in Bandung City, West Java Province (Figure 1), with a geographical location of Longitude 107° 25' 8"–108° 7' 30" East and Latitude 6° 56' 49"–7° 45' 00" South and an administrative area of 167.3 km². Bandung City is divided into 8 sub-cities, namely Arcamanik. Bojonegara, Cibeunying, Gede Bage, Karees, Kordin, Tegalega, and Ujung berung [1].

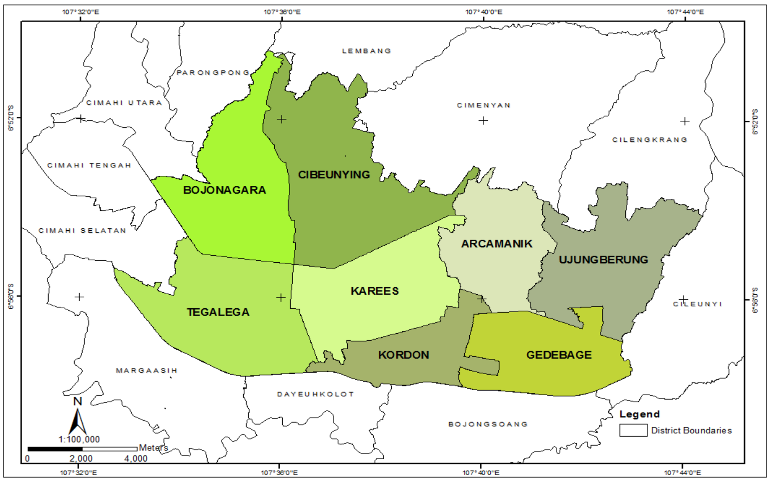

Figure 1. Study area

2.2 Data

Dengue fever is influenced by various parameters related to the environment, vector biology, socio-economic conditions, and human behavior. Higher temperatures can accelerate the life cycle of the Anopheles mosquito and the development of the Plasmodium parasite in the mosquito. Rain can create breeding grounds for mosquitoes, such as puddles. High humidity can prolong the life of mosquitoes. Altitude can affect mosquito distribution; mosquitoes are less likely to be present at very high altitudes. Land Cover: Forests, swamps, and agricultural areas can provide habitat for mosquitoes. The data used in this study is shown in Table 1 and for the preprocessing, processing and layout of research results used ArcGis 10.3 software.

Table 1. Data Used in This study

Data	Availability	Instrument	Sources
Terra satellite images	2018	1. Modis satellite sensor 2. Images name MOD11C3 3. Monthly Temporal resolution (Jan-Dec 2018)	Ers.cr.usgs.gov
TRMM satellite images	2018	1. Radar satellite sensor	Ers.cr.usgs.gov

		2. Images name 3B43 3. Monthly Temporal resolution (Jan-Dec 2018)	
SRTM satelilite images	2018	1. Synthetic Aparture Radar sensor 2. Images name SRTM_58_14	Srtm.csi.cgiar.org
District boundaries and land cover data	2018	1. Scale 1:25.000 2. Data format *Shapefile* (shp)	Geospatial Information Agency Indonesia
Dengue Fever (DF) cases	2018	1. Every district in Bandung 2. Database	Bandung Department of health services

2.3 Data Weighted Linier Combination

Weighted Linear Combination (WLC) is used to represent the level of closeness, interconnectedness, or severity of a particular impact on a phenomenon spatially. Each input parameter will be given a score and then added to obtain the level of relevance. This model can be applied to all GIS applications that have an overlay system. The final result of this model is to classify the level of parameter interrelationships. Classification is based on the total score of each parameter included [13]. Weighted Linear Combination model is widely used in making decisions in the GIS process [14]. Therefore, a deep insight is needed related to a phenomenon to be able to provide optimal results using this model [15]. Equation 1 shows the algorithm for calculating the range of scores (RS) to be determined in the final results of the study. The equation is based on a journal article written by [13] . With X_{max}: the highest total score, X_{min}: the lowest total score, and m: the number of classes desired.

$$RS = \frac{X_{max} - X_{min}}{m} \tag{1}$$

2.3 Methodology

The first step of this research is downloading all the data that is used as a parameter. Furthermore, the preprocessing stage is carried out, namely the process of extracting from each piece of data downloaded, and then the data is weighted using WLC method to obtain the area of dengue fever vulnerability. The flow diagram of the research method is shown in Figure 2.

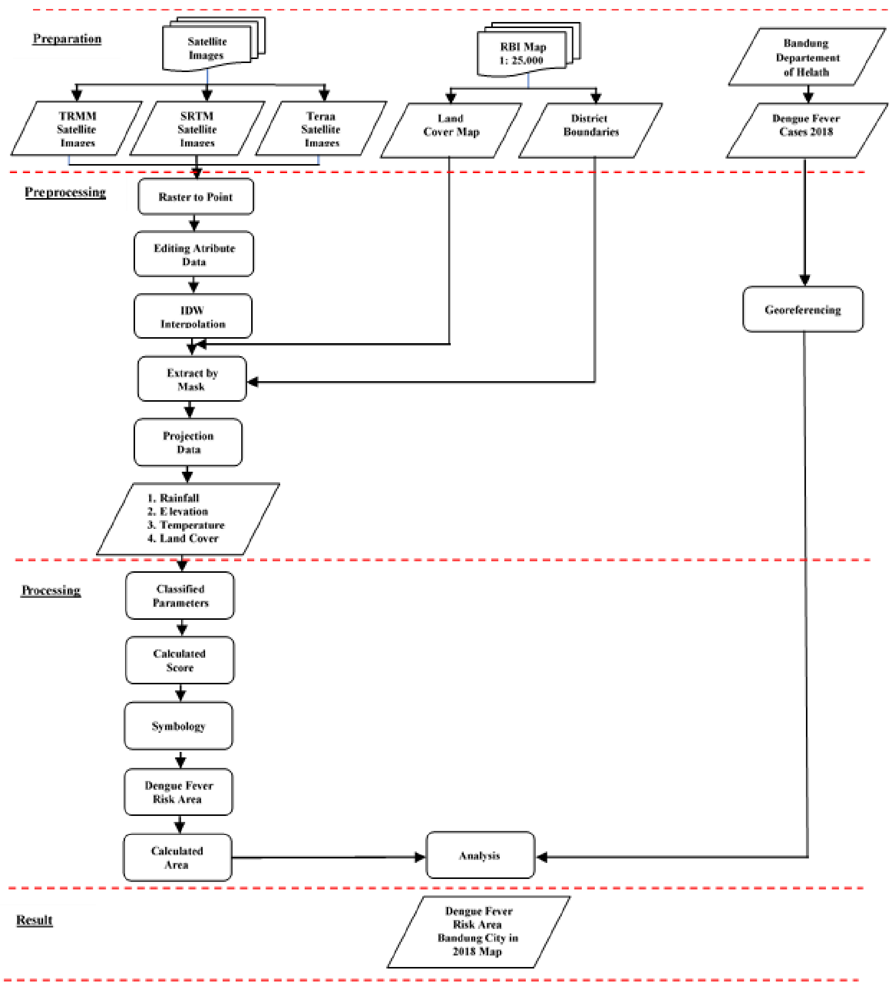

Figure 2. Research Methodology Flow Chart

1. **Preprocessing**
   The process of extracting information from data from satellite imagery and data from the Geospatial Information Agency. Data from satellite imagery is interpolated to obtain data or information that covers the area of the research study. The results of this process are data on rainfall, temperature, elevation, and land cover in the city of Bandung in 2018. In addition, at this stage, the georeferencing process of the Bandung Dengue Fever case in 2018 can be made later to be compared with the results of the study.

2. **Processing**
   Application of the WLC method to each parameter included by assigning a weight value. The process of assigning weights to each parameter is based on previously published journals on dengue fever. Because of the assignment of weight values to the parameters of temperature, rainfall, elevation, and land cover, there are no specific references or standard rules as a reference for conducting mapping studies of areas prone to dengue fever. Therefore, a simulation of weighting values was given for each parameter so that the results obtained were close to data from the Bandung City Health Office related to sufferers of dengue fever in 2018. Here is a scenario illustrating how rainfall, temperature, and land cover parameters can be weighted for dengue risk mapping:

   Implementation of Weighting in Risk Mapping is to map dengue risk, we can combine the weights from each parameter for each location. Here is an example of how this can be done. Determine parameter values for each location: Collect data on rainfall, temperature, and land cover for the locations to be mapped. Apply weights to parameters: Assign weights according to the predetermined categories.Calculate total risk score: Sum the weights of the three parameters to get the total risk score for each location.Classify risk: Use the total score to classify dengue risk (e.g., low, medium, high). Example Risk Calculation Suppose we have data for a location as follows:

Rainfall : 180 mm/month
Temperature: 32°C
Land cover : Residential area

Rainfall : 180 mm/month falls into the $175 \leq x \leq 191$ category with a weight of 10.
Temperature : 32°C falls into the $y \leq 33$ category with a weight of 20.
Land Cover : Residential area with a weight of 10.
Total risk score : Total Score =10 (Rainfall)+20 (Temperature)+10 (Land Cover) =40
Total Score=10(Rainfall)+20(Temperature)+10 (Land Cover) =40

After calculating the total score for each location, the next step is to create a risk map. This map can use a color scale to represent the risk levels (e.g., green for low risk, yellow for medium risk, and red for high risk). The weight values for each class of parameters are shown in Tables 2, 3, and 4.

Table 2. Weighting in the Dry Month 2018

Parameter	Interval	Score
	$x \leq 175$	5
Rainfall (x) (mm/month)	$175 \leq x \leq 191$	10
	$191 \leq x \leq 203$	15
	$y \leq 33$	20
Temperature (y) (celsius)	$33 \leq y \leq 34$	7
	$34 \leq y \leq 37$	3
Land Cover	Residential area	10
	Mid Vegetation	5
	Heavy Vegetation	15

Table 3. Weighting in the Wet Month 2018

Parameter	Interval	Score
	$x \leq 1057$	10
Rainfall (x) (mm/month)	$1057 \leq x \leq 1071$	10
	$1071 \leq x \leq 1091$	10
	$y \leq 31$	15
Temperature (y) (celsius)	$31 \leq y \leq 33$	10
	$33 \leq y \leq 35$	5
Land Cover	$600 \leq z \leq 800$	15
	$800 \leq z \leq 1000$	10
	$1000 \leq z \leq 1200$	5

Table 4. Weighting in 2018

Parameter	Interval	Score
Rainfall (x) (mm/month)	$x \leq 2880$	7
	$2880 \leq x \leq 2895$	8
	$2895 \leq x \leq 2905$	15

Temperature (y) (celsius)	$y \leq 31$	15
	$31 \leq y \leq 33$	10
	$33 \leq y \leq 36$	5
Elevation (z) (meters)	$600 \leq z \leq 800$	15
	$800 \leq z \leq 1000$	10
	$1000 \leq z \leq 1200$	5
Land Cover	Residential area	10
	Mid Vegetation	5
	Heavy Vegetation	15

The results of weighting for each class of research parameters in Tables 2, 3, and 4 are the best results used in this study based on experimental simulations that have been done before. However, this weight value needs to be applied to other areas, given the differences in geographical, demographic, and climate locations in the study area. The results of the study are divided into three hazard classifications shown in Figure 3, with the total range of scores shown in Table 5.

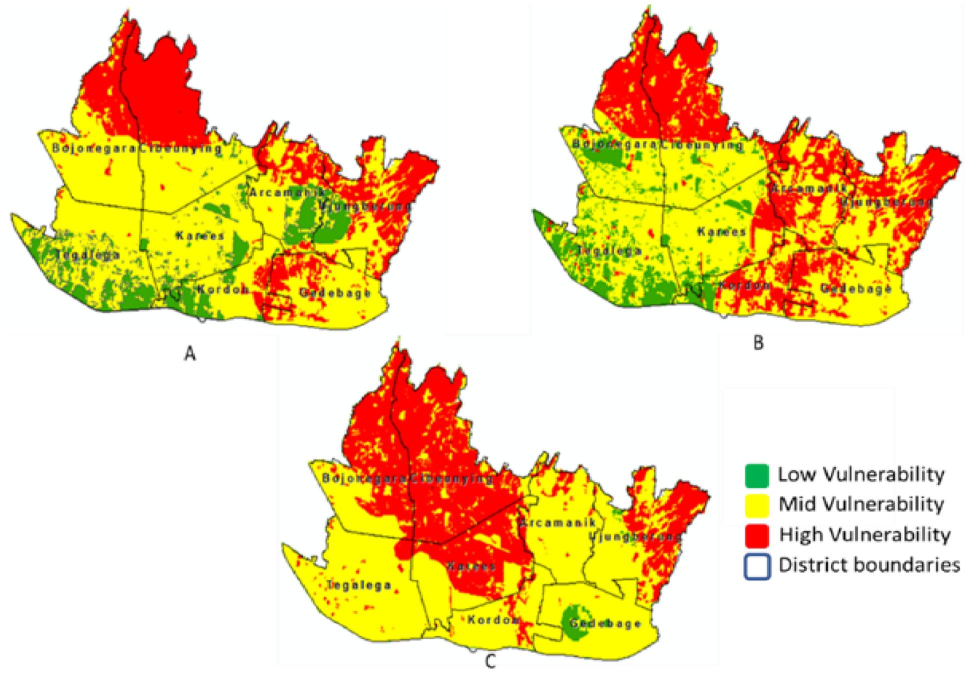

Figure 3. Classification of dengue fever Areas:
(A) Dry Season 2018; (B) Wet Season 2018; (C) Average Season 2018
(B)

Table 5. Classification of Areas of Vulnerability Dengue Fever

Classification	Score
Low Vulnerability	0 – 20
Middle Vulnerability	20 – 40
High Vulnerability	40 – 60

3. RESULTS AND DISCUSSION

The year 2018 has the most complete and accurate data on dengue cases, environmental parameters (such as rainfall, temperature, and land use), and socio-economic data needed for risk mapping. Data from 2018 provide a recent enough picture for analysis and mapping, but far enough back in time to allow reflection on interventions that have been implemented since then. Selecting a relatively recent year allows for analysis of changes in disease patterns over time, as well as the effectiveness of control measures that have been implemented.

Vulnerability classification in dengue mapping refers to the grouping or assessment of the level of vulnerability of an area to the spread of dengue fever based on certain risk factors. This classification helps to identify areas that are vulnerable to the disease so that appropriate prevention or mitigation interventions can be carried out.

Mapping of dengue fever-prone areas is the result of data processing using the average temperature, average rainfall, elevation in 2018, and land cover in Bandung City (Figure 4). Also, to see the correlation of temperature and rainfall on the vulnerability of dengue fever areas, using the parameter data on the average temperature of the wet and dry months of 2018, the average rainfall of the wet and dry months of 2018, and the elevation and land cover indicated in Figures 5 and 6, Next, the area of each hazard area is shown in Table 6.

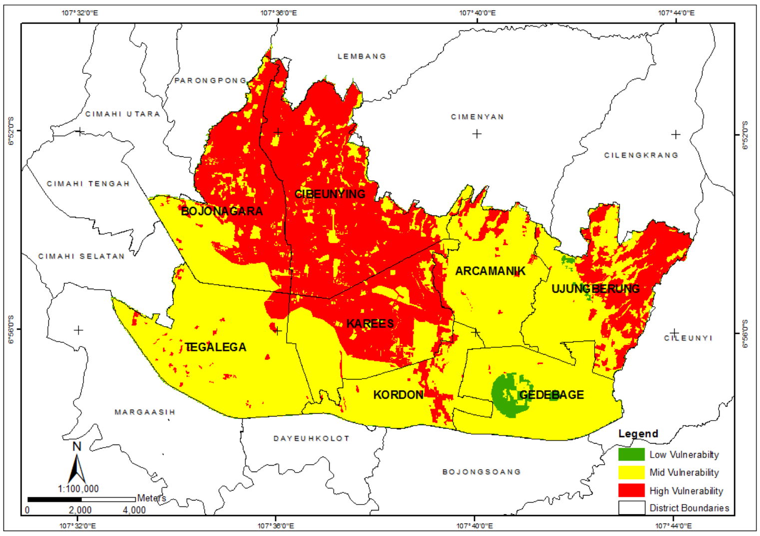

Figure 4. Map of areas prone to dengue fever in 2018

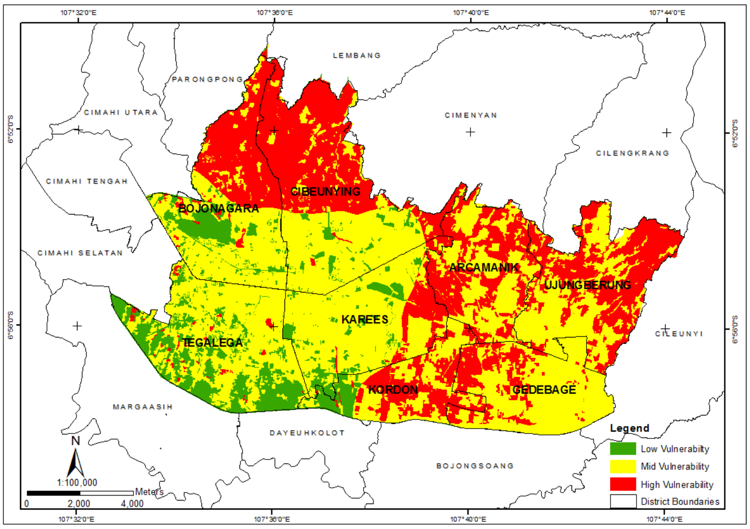

Figure 5. Map of the area prone to dengue fever in the wet months in 2018

Table 6. Wide Vulnerability Area of Dengue Fever Disease in Bandung

Category Vulnerability	Wet Season 2018		Dry Season 2018		Average Season 2018	
	Area (Km²)	Percentage	Area (Km²)	Percentage	Area (Km²)	Percentage
Low	53.2	31.7%	64.1	38.2%	11.4	6.8%
Middle	83.4	49.7%	93.1	55.5%	87.3	52.1%
High	31.1	18.6%	10.5	6.3%	69	41.1%

The classification results show that there are differences in hazard areas from the process by using temperature and rainfall data in 2018 (Wet Month and Dry Month). The area of dengue fever susceptibility experiences a significant difference in high vulnerability in wet and dry months, with a percentage difference of around 12%. Figure 7 shows the results of a study that was overlaid with 2018 dengue fever cases in Bandung.

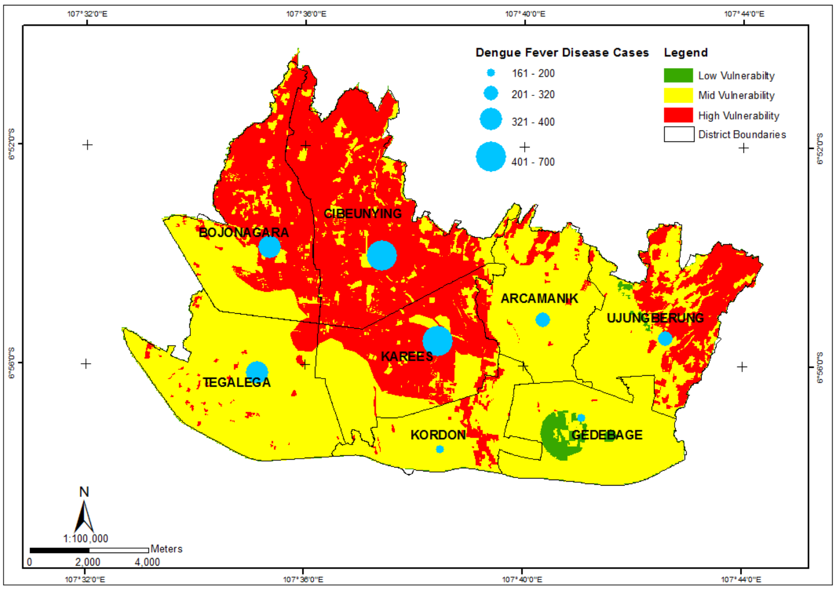

Figure 7. Cases of dengue fever in Bandung City, 2018

Based on the total score or index calculated, classify the level of vulnerability for each area. For example, an area with a low score may have a low risk, while an area with a high score may have a high risk of dengue.

3.1 Correlation of Dengue Fever Cases with Rainfall

Rainfall is one of several climate parameters that can influence the development of the dengue vector in Bandung (Figure 8). The case of dengue fever increases when rainfall intensity decreases. This phenomenon occurs because there were previous months of high rainfall, which caused many places to be inundated with water and was a good breed for mosquitoes Aedes aegypti and Aedes albopictus. Correlation values between cases of dengue fever and rainfall are shown in Figure 9.

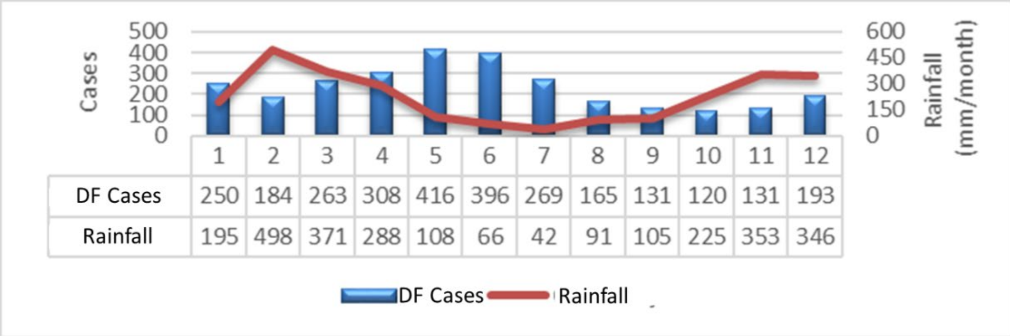

Figure 8. Chart of Dengue Fever Disease Cases: Rainfall in Bandung 2018

The coefficient of determination (r^2) is close to 1, meaning that cases of dengue and rainfall have a fairly high correlation. The linear line formed also shows the negative tendency direction, meaning that during high rainfall, the incidence of low dengue fever cases increases.

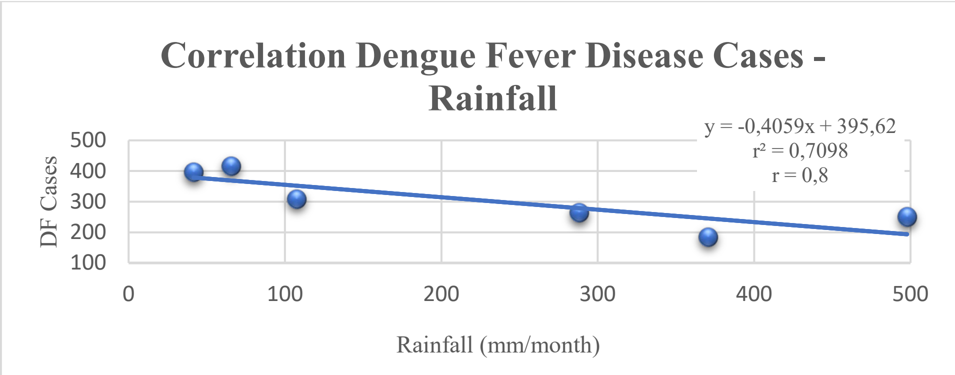

Figure 9. Correlation Dengue Fever Disease cases: Rainfall in Bandung 2018

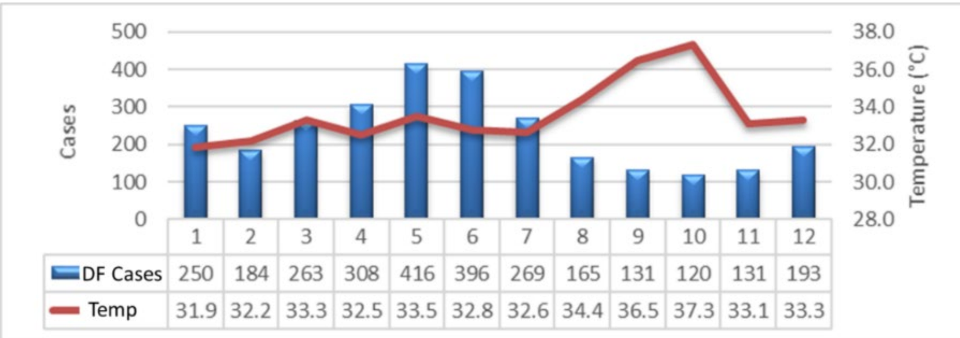

Figure 10**.** Chart of Dengue Fever Disease Cases-Temperature in Bandung 2018

3.2 Correlation of Dengue Fever Cases with Temperature

Figure 10 shows a decrease in cases of dengue fever when the temperature reaches more than 34° C. The phenomenon is caused by the Aedes aegypti and Aedes albopictus mosquitoes, whose development will be disrupted at high temperatures. The correlation value between dengue cases and the temperature is shown in Figure 11.

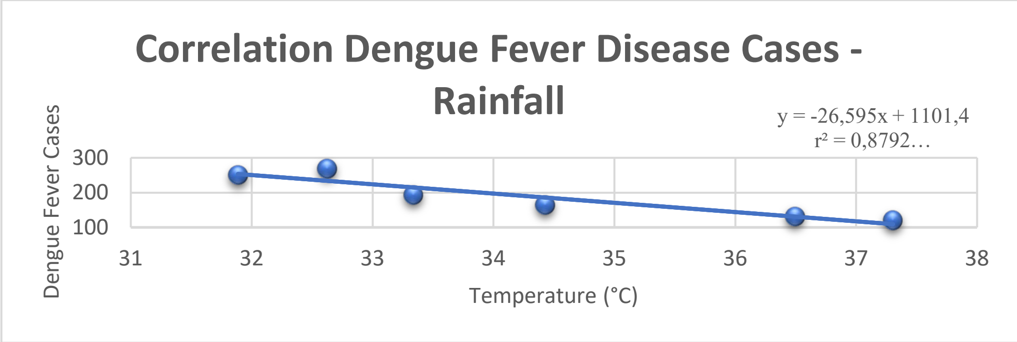

Figure 11. Correlation Dengue Fever Disease Cases-Rainfall in Bandung 2018

The coefficient of determination (r^2) indicates a value close to 1, meaning that it is a fairly high correlation between the incidence of dengue and temperature. The linear lines formed also have a negative direction, meaning that at high temperatures, the incidence of low dengue fever increases.

3.3 Relationship Between Dengue Fever Case with Elevation and Land Cover

Figure 12 shows the area of dengue fever in the city of Bandung that dominates many highland areas, such as Cibeunying, Bojonagara, and Ujungberung area which has elevations above 720 meters which at this height are often found in land cover with dense and moderate vegetation. Land cover is one of the important factors for the development of Aedes Aegypti and Aedes Albopictus mosquitoes, the results of the study show that high vulnerability occurs in areas with dense vegetation because in those areas it is suspected there is a natural breeding place for habitat for the growth of the dengue vector. Although dense vegetation at certain altitudes supports mosquito breeding, areas with other land cover such as dense housing, vacant land with stagnant water, or areas with accumulation of used goods that can become mosquito egg-laying places, can also increase the risk of dengue transmission.

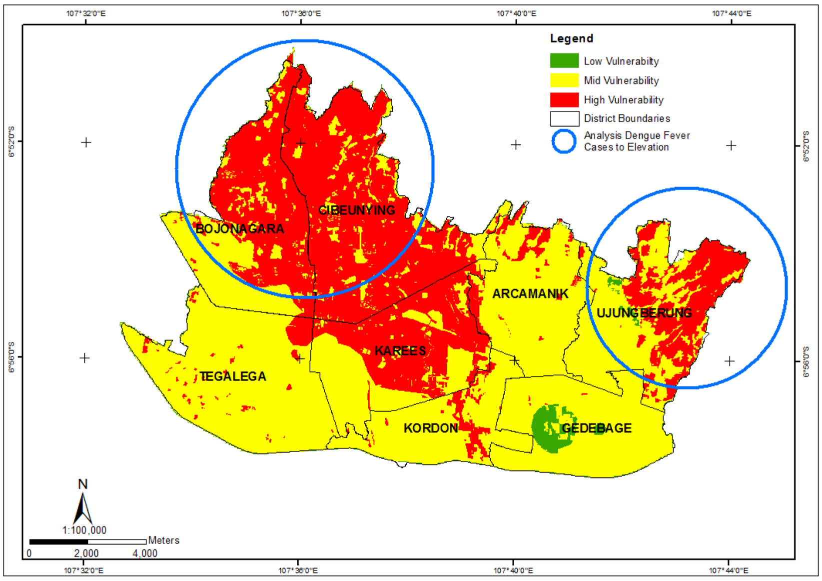

Figure 12. Elevation of Altitude in Hazardous Areas

4. CONCLUSION

1. Dengue distribution maps can help identify high-risk areas or hotspots of dengue cases. This allows local governments to focus more intensive prevention interventions in these areas.
2. The results of the study show that the city of Bandung is dominated by areas of moderate and high fever severity. The percentage of the area of vulnerability is 41.1%, the area of vulnerability is 52.1%, and the area of vulnerability is 6.8%.
3. There is a change in the level of the area of dengue fever during processing using data on average rainfall and temperature in the wet months (January, February, and March) and the dry months (July, August, and September). During the wet month, the percentage of hazardous areas is high (18.6%), areas of moderate vulnerability are 49.7%, and areas of low vulnerability are 31.7%. As for the dry month, the percentage of hazardous areas is 6.3%, areas of moderate vulnerability are 55.5%, and areas of low vulnerability are 38.2%.
4. Cases of dengue fever in the city of Bandung are found in many sub-cities that have elevations above 720 metres, such as the sub-districts of Bojonagara, Cibeunying, and Karees.
5. Results of dengue fever cases in Bandung increase if the average temperature is between 30-34° C, while dengue cases will decrease if the average temperature in Bandung is above 34° C.
6. Based on the pattern of dengue fever transmission, it is necessary to pay special attention to certain months that may have high rainfall or optimal temperatures for Aedes aegypti mosquito breeding. This includes increased monitoring and prevention during the rainy season or when temperatures are high.
7. By conducting further research in this area, it is hoped that we can further improve our understanding of the factors influencing dengue fever as well as the effectiveness of prevention strategies that can be implemented to reduce the burden of this disease globally.

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