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Mapping Dengue Vulnerability in West Java, Indonesia, 2019-2023

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ABSTRACT

Dengue fever has long been a pressing public health problem in West Java, Indonesia, with reported cases rising sharply from 23 per 100,000 population in 2018 to more than 72 per 100,000 in 2022, driven by rapid urbanization, high population density, and climate variability that collectively favor Aedes mosquito transmission. This study aimed to map dengue vulnerability across 27 districts and cities in West Java over a five-year period from 2019 to 2023. An ecological descriptive approach was employed using secondary data on dengue incidence, population density, and climate variables sourced from the West Java Provincial Health Office, Statistics Indonesia, and four BMKG meteorological stations. Climate data were spatially interpolated using the inverse distance weighting method in QGIS, and a dengue vulnerability index was constructed through binary scoring dan overlaying of each variable, yielding a composite score ranging from 6 to 12, which was subsequently classified into low (7–8), moderate (9–10), and high (11–12) vulnerability categories. Spatial vulnerability patterns fluctuated throughout the study period, with 20 of 27 districts and cities (74%) predominantly falling within the low-to-moderate range. However, certain urban centers emerged as persistently high-risk areas, with Bogor City classified as highly vulnerable in four of the five study years (2019, 2020, 2021, and 2023), and Cirebon City flagged as highly vulnerable for two consecutive years (2021–2022). These findings underscore the urgent need for spatially targeted dengue prevention strategies, including strengthened surveillance, vector control, risk communication, and preparedness, particularly in identified high-vulnerability urban areas.
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Keywords: Dengue; vulnerability mapping; geographic information system; climate variability; West Java

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INTRODUCTION

Dengue is an Aedes-borne viral disease caused by dengue virus, which consists of four main serotypes: DENV-1, DENV-2, DENV-3, and DENV-4. The disease is transmitted primarily by Aedes aegypti and Aedes albopictus mosquitoes and remains highly endemic in tropical and subtropical regions. Its clinical manifestations may overlap with other febrile illnesses, making surveillance, early detection, and accurate risk mapping important for public health action (1).

The global burden of dengue has increased substantially. Reported cases increased from approximately 505,430 cases in 2000 to more than 14.6 million cases in 2024, which was the highest recorded annual burden. Dengue is now endemic in more than 100 countries (2). In Southeast Asia, dengue transmission is hyperendemic, with the co-circulation of multiple serotypes increasing the risk of severe disease and recurrent outbreaks. Indonesia continues to report a high dengue burden, with dengue cases and deaths distributed across many provinces, including West Java (1).

West Java is one of Indonesia's provinces with a persistently high dengue burden. Reported dengue cases increased from 25,282 cases in 2019 to 61,423 cases in 2024, indicating a more than two-fold increase over six years. In 2024, the highest number of dengue cases in West Java was reported in Bandung City, Depok City, Bekasi City, West Bandung Regency, and Bandung Regency (3).

The transmission of dengue is shaped by the interaction between vector ecology, population density, urban mobility, and climate variability. High population density may increase human-vector contact and accelerate dengue transmission in urban settlements. West Java is one of the most densely populated provinces in Indonesia, with a population density of 1,370 people per km2 in 2025 (4). Previous research also reported an association between population density and dengue incidence in West Java (5).

Climate variability is another important determinant of dengue transmission. Rainfall can create additional breeding sites for Aedes mosquitoes, while temperature and humidity influence mosquito survival, biting frequency, viral replication, and the extrinsic incubation period. Several studies have shown that rainfall, temperature, humidity, and wind speed may be associated with dengue occurrence, although the magnitude and direction of these associations may vary across settings and time lags (6–10).

Dengue transmission also has a strong spatial dimension. Spatial epidemiology and geographic information systems can help identify areas where epidemiological burden, demographic pressure, and environmental suitability overlap (11,12). Overlay and scoring methods are commonly used to combine multiple indicators into a composite vulnerability map that can support public health prioritization (13).

Several studies in Indonesia have used geographic information systems to map dengue risk or vulnerability. Yuliana et al. applied overlay and scoring methods to map dengue vulnerability in Padang City, while Purnama et al. used spatial analysis to describe tuberculosis distribution in Java (13,14).

However, most existing studies were cross-sectional, limited to a single administrative level, or did not integrate multiple environmental parameters simultaneously over a multi-year period (15). Longitudinal vulnerability mapping at the district and city level in West Java that integrates dengue incidence, population density, and climate variability over the 2019–2023 period remains limited.

This methodological gap is important because a single-year map may not capture the temporal fluctuation of vulnerability driven by interannual climate variability and changing epidemiological patterns. A multi-year vulnerability map can help district health offices and primary health centers identify areas that consistently or recurrently classify as high-vulnerability, thereby supporting more targeted and sustained priority areas for vector control, surveillance strengthening, and risk communication. Therefore, this study aimed to map dengue vulnerability in West Java Province from 2019 to 2023.

METHOD

This study used an ecological descriptive design with a quantitative geographic information system approach. The unit of analysis was the district/city administrative area in West Java Province. The study period covered 2019 to 2023. The composite dengue vulnerability index was developed using epidemiological, demographic, and climate parameters, namely dengue incidence rate, population density, rainfall, wind speed, air temperature, and humidity.

Dengue data were obtained from the West Java Provincial Health Office. Population density data were obtained from West Java in Figures published by Statistics Indonesia. Climate data, including rainfall, wind speed, air temperature, and humidity, were obtained from Meteorology, Climatology, and Geophysics Agency stations in Dramaga, Citeko, Bandung, and Kertajati/Jatiwangi. The climate data from these stations were interpolated using the inverse distance weighting method to estimate climate values in areas without direct station measurements. The centroid of each station was defined as a point layer, with the assumption that each point layer (interpolation surface) exerted the greatest influence on nearby areas and progressively less influence on areas located farther away (14). Spatial processing and map production were conducted using QGIS.

Spatial vulnerability analysis was performed using scoring, weighting, and overlay techniques. Overlay analysis is a method performed by integrating multiple map variables to produce a new map (16). The six selected variables (dengue incidence rate, population density, rainfall, air temperature, humidity, and wind speed) were chosen based on their established association with dengue transmission reported in the literature (6–10) and their availability as district-level secondary data. Each variable was classified into two categories using literature-based cut-off values: dengue incidence rate was dichotomized at 10 cases per 100,000 population, consistent with national endemic thresholds (17); population density was dichotomized at 8,500 people per km²(18), rainfall was categorized at 3,000 mm per year (19); air temperature at 26°C (8), representing the lower boundary of the optimal range for

Aedes mosquito development (25–30°C); humidity at 70%(20); and wind speed at 1 knot (21). All variables were assigned equal weight (score 1 or 2), reflecting the absence of validated weighting coefficients specific to West Java and the exploratory nature of this study.

Dengue incidence was included as an index component representing accumulated epidemiological burden rather than an independent outcome, consistent with composite vulnerability frameworks used in previous dengue mapping studies (13). The final vulnerability index was calculated as the sum of all six scores, yielding a range of 6 to 12, which was reclassified into three vulnerability categories: low (6–8), moderate (9–10), and high (11–12). As an internal consistency check, the year-specific vulnerability classifications were compared with observed high-dengue areas reported by the West Java Provincial Health Office to assess whether high-vulnerability districts corresponded to areas with elevated incidence (16).

Table 1. Operationalization of variables for the dengue vulnerability index

Parameter	Unit/indicator	Data source	Direction of risk	Score/weight
Dengue incidence rate	Cases per 100,000 population (17)	West Java Provincial Health Office	a. Low (IR < 10) b. High (IR ≥ 10)	Low = 1 High = 2
Population density	People per km2 (18)	Statistics Indonesia/BPS	a. Low (≤ 8500 people/km^2) b. High (> 8500 people/km^2)	Low = 1 High = 2
Rainfall	mm/year (19)	BMKG stations	a. Low (< 3000 mm/year) b. High (>3000 mm/year)	Low = 1 High = 2
Air temperature	Degrees Celsius (8)	BMKG stations	a. Low (≤ 26 ℃) b. High (>26 ℃)	Low = 1 High = 2
Humidity	Percent (20)	BMKG stations	a. Low (≤70 %) b. High (> 70%)	Low = 1 High = 2
Wind speed	Knot (21)	BMKG stations	a. Low (<1 knot) b. High (≥1 knot)	Low = 2 High = 1
Final index	Sum of weighted scores (22)	QGIS overlay output	Higher index indicates higher vulnerability	Low: 7-8 Moderate: 9-10 High: 11-12

Because this study used aggregate secondary data at the district/city level, the findings should be interpreted as ecological vulnerability patterns rather than individual-level risk estimates. The analysis did not use personal identifiers. The limited number of climate stations may introduce spatial uncertainty in the interpolated climate surfaces, especially in areas with heterogeneous topography. Therefore, the generated maps should be used as programmatic screening tools and not as precise predictions for household-level risk.

This study received ethical approval from the Health Research Ethics Committee of the Faculty of Health Sciences at UIN Syarif Hidayatullah Jakarta (Un.01/F.10/KP.01.1/KE.SP/03.08.020/2024). The research used secondary data from the West Java Provincial Health Office, Statistics Indonesia of West Java Province, and Meteorology, Climatology, and Geophysics Agency of West Java Province, without involving human or animal subjects.

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RESULTS

Figure 1 shows that dengue vulnerability in West Java fluctuated during 2019–2023. In 2019, 18 of 27 districts and cities (67%) were classified as low-vulnerability areas, 8 (30%) as moderate vulnerability, and 1 (4%) part of Bogor City as high vulnerability. Moderate vulnerability was observed in several urban and peri-urban areas, including Bekasi City, Depok City, Cimahi City, Bandung City, Cirebon City, Banjar City, and parts of Bogor Regency, Sumedang, Indramayu, Tasikmalaya, and Ciamis.

In 2020, moderate vulnerability areas expanded to 11 districts and cities (41%), while parts of Bogor City remained in the high-vulnerability category and the proportion of low-vulnerability areas declined to 15 (55%). In 2021, high vulnerability was identified in two areas (Bogor City and Cirebon City) that representing 7% of all administrative units. In 2022, Cirebon City remained the sole high-vulnerability area, while the distribution of low and moderate vulnerability areas was broadly similar to the preceding year. In 2023, high vulnerability was again identified in Bogor City. Overall, across the five-year period, 20 of 27 districts and cities (74%) were predominantly classified as low or moderate vulnerability, while high vulnerability appeared repeatedly in selected urban areas. Bogor City recorded high vulnerability in four of the five study years (2019, 2020, 2021, and 2023), and Cirebon City in two consecutive years (2021–2022). The consistent high vulnerability in these two cities suggests a persistent convergence of epidemiological burden, population density, and climate conditions that warrants prioritized programmatic attention.

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Lack of numerical summaries.
Limited analytical depth.

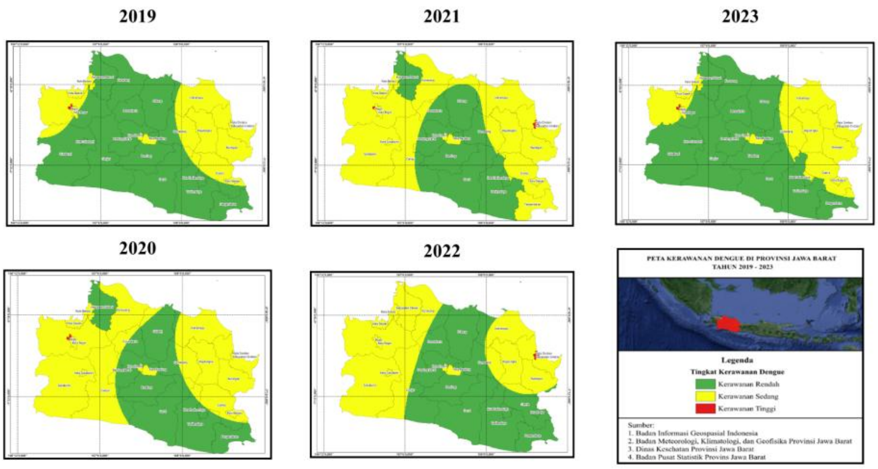

Figure 1. Dengue vulnerability map in West Java Province, 2019-2023

Table 2. Summary of high-vulnerability areas identified from the dengue vulnerability map

Year	High-vulnerability area identified in the manuscript	Interpretive note
2019	Part of Bogor City	High vulnerability was localized
2020	Part of Bogor City	High vulnerability persisted
2021	Bogor City and Cirebon City	High vulnerability expanded to two urban areas
2022	Cirebon City	High vulnerability persisted in Cirebon City
2023	Bogor City	High vulnerability reappeared in Bogor City

DISCUSSION

The main finding of this study was that high dengue vulnerability in West Java was not evenly distributed across all districts and cities. Instead, high vulnerability recurred in selected urban areas, particularly Bogor City and Cirebon City. Bogor City was identified as a high-vulnerability area in several studies. This condition may be related to its dense population and strategic geographic position, which support urban growth, economic activity, trade, and tourism (23). High population density may increase the frequency of human-vector contact and facilitate dengue spread in urban settings. This finding is consistent with Komaling et al., who reported a positive relationship between population density and dengue occurrence (24). Urban settlements may also contain many artificial water containers, such as used tires, buckets, and other water-holding objects, which can serve as Aedes breeding sites (25).

Rainfall may further contribute to dengue vulnerability in Bogor City. Bogor is widely known as a rainy city, and in 2022, the average number of rainy days reached approximately 20 days per month. (26) Frequent rainfall can increase the availability of vector breeding habitats, particularly when environmental management and larval source reduction are not conducted consistently. This interpretation is supported by previous studies in Tangerang Selatan and Bogor Regency, which reported an association between rainfall and dengue occurrence. (27,28)

Cirebon City was identified as a high-vulnerability area in 2021 and 2022. The vulnerability in this city may be influenced by the combined effects of rainfall and temperature, both of which exceeded the index thresholds in these years based on interpolated BMKG station data. Rainfall in the Cirebon area recorded by the nearest station exceeded 3,000 mm per year, and average air temperature surpassed 26°C, placing it in the high-score category for both variables. These observed climate values are consistent with conditions that support Aedes mosquito breeding and vector development. Rainfall can increase the availability of stagnant water as breeding sites, while temperature within the 25–30°C range accelerates larval development and shortens the extrinsic incubation period. A systematic review and meta-analysis reported that moderate to high rainfall at certain time lags was associated with increased dengue risk. (7)

Air temperature also plays an important role in the development and survival of Aedes mosquitoes. Optimal development commonly occurs within the 25–30°C range, while temperatures below or above this range may reduce mosquito survival and inhibit egg and larval development. (7) In 2021 and 2022, interpolated temperature values in Cirebon City remained within the range above 26°C, consistent with the high-score category in the vulnerability index and with conditions reported to support dengue vector development. This is consistent with studies reporting a positive association between temperature and dengue incidence. (9,29,30)

In addition to climate, the geographic position of Cirebon City may increase dengue vulnerability. Cirebon is located near the border between West Java and Central Java and functions as an important transit and connecting area. (31) The geographic position of Cirebon as a transit city may also contribute to its vulnerability. However, this study did not collect or analyze mobility data, and this interpretation is inferential. The potential role of human mobility warrants further investigation in future studies using mobility data or network analysis. Research in other urban settings has shown that mobility patterns can shape local dengue clusters and support transmission in urban environments (32–34).

From a public health perspective, the findings suggest that dengue prevention in West Java should be spatially prioritized. District and city health offices can use vulnerability maps to identify areas that require earlier and more intensive larval source reduction, vector surveillance, risk communication, and community mobilization. Primary health centers in high-vulnerability areas should strengthen routine monitoring before and during rainy periods, improve rapid reporting of suspected dengue cases, and coordinate environmental management with local government and community organizations.

This study has several limitations. First, the ecological design does not allow causal inference at the individual level. Second, the vulnerability index depends on the selected variables, scoring approach, and weighting scheme. Third, interpolation of climate data from a limited number of stations may introduce spatial uncertainty. Fourth, the analysis did not include other relevant determinants such as vector density, larval indices, land use, waste management, water storage practices, and human mobility data. Future studies should incorporate finer spatial units, entomological indicators, time-lag analysis, and validation of vulnerability categories against observed dengue incidence.

CONCLUSIONS AND RECOMMENDATIONS

This study aimed to map dengue vulnerability in West Java Province from 2019 to 2023 using a composite index integrating dengue incidence rate, population density, rainfall, air temperature, humidity, and wind speed. The findings show that most districts and cities (74%) were classified as low or moderate dengue vulnerability areas during the study period. However, high vulnerability was identified repeatedly in Bogor City (2019, 2020, 2021, and 2023) and in Cirebon City (2021 and 2022), indicating spatially concentrated and recurrent dengue risk in selected urban centers. These results confirm that dengue vulnerability in West Java is not uniformly distributed, but is concentrated in urban areas where the convergence of epidemiological burden, high population density, and unfavorable climate conditions creates conditions for persistent transmission. Based on these findings, dengue prevention should be prioritized in high-vulnerability areas through strengthened surveillance, routine larval source reduction, and climate-informed preparedness before and during peak rainfall seasons. Further research is recommended to validate the vulnerability index against observed dengue outcomes, incorporate entomological and land-use data, and extend the analysis to sub-district administrative units for more operationally targeted planning.

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