ORIGINAL ARTICLE

Analysis of Vulnerability and Risk Mapping of Dengue Hemorrhagic Fever in Metro City, Lampung, Indonesia: A Geographic Information System (GIS) Approach

Sutarto Sutarto[1], Ratna Dewi Puspita Sari[2], Winda Trijayathi Utama[1], Reni Indriyani[3]

[1] Medical Education Study Program, Faculty of Medicine, Universitas Lampung, Indonesia. 35111
[2] Doctor Profession Study Program, Faculty of Medicine, Universitas Lampung, Indonesia.35111
[3] Department of Nutrition, Ministry of Health Poltekkes Tanjungkarang, Indonesia. 35362

ABSTRACT

Introduction: This study analyzes DHF vulnerability in Metro City, Lampung, Indonesia, highlighting case fluctuations, high Incidence Rate (IR), and Case Fatality Rate (CFR), emphasizing the need for intervention. This study aims to identify and map the spatial distribution of dengue hemorrhagic fever (DHF) vulnerability and risk areas in Metro City, Lampung Province, Indonesia, using a Geographic Information System (GIS) approach. The findings are expected to support evidence-based public health interventions, improve the precision of resource allocation, and strengthen disease prevention strategies in high-risk areas. **Methods:** Vulnerability mapping using Geographic Information System (GIS) showed variation in risk between villages, with some areas showing high case concentrations. **Results:** The results of this study indicate that Iring Mulyo and Yosomulyo are the most vulnerable areas in Metro City, based on the highest number of DHF cases. Vulnerability mapping also revealed significant spatial clustering in the eastern part of the city. Most DHF cases (83.1%) occurred among individuals aged 6–59 years, with a higher prevalence among females (54.8%). These findings suggest that population density, age, gender, and environmental factors strongly influence DHF distribution and should be considered in targeted vector control and prevention efforts. **Conclusion:** GIS-based vulnerability mapping is essential for identifying high-risk zones and guiding targeted dengue interventions. The findings support evidence-based decision-making to improve vector control, enhance public awareness, and strengthen preventive strategies tailored to the demographic and spatial risk profiles in Metro City.
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Corresponding Author:
Sutarto Sutarto, PhD
Email: sutarto@fk.unila.ac.id
Tel : +62812727065

INTRODUCTION

The disease, caused by the Dengue virus and transmitted through the Aedes Aegypti and Aedes Albopictus mosquitoes, can cause panic because of its rapid spread and the risk of death. Metro City is an endemic area for DHF or Dengue Fever (DHF) (1). The number of dengue cases in 2018 decreased to 59 cases; in 2019, it increased to 192 cases; in 2020, it decreased to 148 cases; in 2021, it decreased to 138 cases; and in 2022, it decreased to 88 cases. The Incidence Rate (IR) of dengue in 2018 was 35.7 per 100,000 population; in 2019, it was 114.7 per 100,000 population; in 2020, it fell to 87.3 per 100,000 population; in 2021, it fell to 80.2 per 100,000 population, and in 2022, it fell to 51.40 per 100,000 population. The development of the number of dengue cases in Metro City during 2018-2022 is that the incidence rate of dengue in 2022 has decreased from 2021, down by 50 cases. The Case Fatality Rate (CFR) indicates a disease's malignancy and assesses the treatment quality. Metro City's CFR decreased in 2021 from 80.2% to 51.40% in 2022. From this information, dengue disease in Metro City is still a public health problem in IR and CFR indicators, so it must be handled quickly and appropriately (2). Mapping dengue-prone areas is essential for prevention and control in Metro City. Using remote sensing data and GIS to create a regional vulnerability model supports disease eradication efforts. GIS offers advantages over manual mapping, including overlay analysis and scoring, which are key processes for effectively identifying high-risk regions (3).

One of the challenges in planning and developing an area is the existence of disasters, so it is necessary to integrate policies into disaster mitigation, including dengue fever outbreaks or pandemics (KLB). This non-natural disaster is a threat, so the Metro City Government, in the case of dengue hemorrhagic fever (DHF), needs to mitigate the existence of KLB or dengue disease outbreaks (4,5) It is crucial to assess the effectiveness of health service interventions to reduce dengue vulnerability and improve control and prevention in Metro City. This study uses data from the Metro City Health Office's dengue control programs, geographic data, and satellite imagery. The research aims to map areas prone to dengue in Metro City, Lampung Province, Indonesia, to guide targeted intervention efforts.

MATERIALS AND METHODS

This study, conducted from April to September 2024 in Metro City, Lampung Province, Indonesia, used a quantitative approach to analyze geospatial information systems (GIS) and assess the distribution and risk factors of Dengue Hemorrhagic Fever (DHF). The subjects included DHF patients from January to April 2024, residing in Metro City and nearby sub-districts. Primary data were collected through activity checkpoint sheets, observing patient residence coordinates and surrounding environmental risk factors.

A team of trained enumerators collected data through checkpoint sheets, determining ordinate points and observing risk factors. After gathering primary and secondary data, it was processed through examination, clearing, entry, and coding. GIS data analysis was interpreted qualitatively, providing recommendations for DHF prevention in Metro City.

Ethical approval for this study was obtained from the Ethics Committee of Universitas Lampung, Indonesia, with approval number 4074/UN26.18/PP.05.02.00/2024.

RESULTS

Metro City is a city in Lampung Province, Indonesia, about 52 km from Bandar Lampung City. It is geographically located at 105017'-105021' East Longitude and 506'-5010' South Latitude. Metro City has an area of around 73.16 km2 (6). According to the 2022 data from the Central Statistics Agency, Metro City has 5 sub-districts with a total population of 141,872. East Metro has the highest population (53,413), while South Metro has the lowest (3,255), indicating uneven population distribution. The city's population density in 2022 was 1,939.2 people per km².

Metro City has 249 health service facilities, including general and specialized hospitals, public health centers (main, auxiliary, and mobile), clinics, private doctor practices, traditional medicine, blood banks, transfusion units, and pharmaceutical facilities (wholesalers, pharmacies, drug stores, and medical device distributors). In 2000, there were 11 health centers, including treatment centers. By 2022, the Sumbersari Bantul Treatment Center was upgraded to a Type D Hospital, reflecting the city's growing healthcare infrastructure.

In 2022, the ratio of Health Centers to 20,000 residents was 1.30, meaning that, on average, 1 to 2 Health Center units served every 20,000 residents. This ratio has met the working area of the Health Center, with an average of 1 health Center unit serving 20,000 residents.

Dengue fever remains a significant concern in Metro City, with outbreaks driven by Aedes mosquitoes. Cases fluctuated from 59 in 2018 to 192 in 2019, then decreased to 88 in 2022. The Incidence Rate dropped significantly from 114.7 in 2019 to 51.4 in 2022, and the Case Fatality Rate improved. Dengue affected 22 villages, with East Metro having the highest cases. (7–9). This study analyzes the vulnerability map and demographic risk factors of DHF in Metro City and provides recommendations for its prevention and control (see distribution in Figure 1).

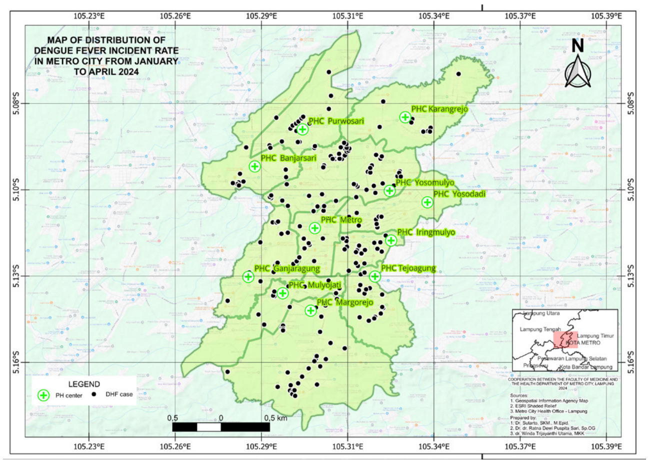

Figure 1: Dengue Hemorrhagic Fever (DHF) distribution in Metro City, Jan-April 2024

Figure 1 shows significant variation in the distribution of Dengue Hemorrhagic Fever (DHF) cases in Metro City from January to April 2024. Iring Mulyo Village had the highest number of cases (27 cases or 10.9%), followed by Yosomulyo (25 cases or 10.1%). In contrast, Mulyosari Village had the lowest (1 case or 0.4%). These differences suggest that factors such as population density, environmental conditions, and vector control effectiveness influence each village's vulnerability to dengue spread (10,11). Figure 1 shows 248 dengue cases, with high incidence in Iring Mulyo and Yosomulyo. Targeted interventions, spatial analysis and strategies like community empowerment, sanitation, and vector control are crucial for reducing dengue in vulnerable Metro City areas (12). Table I presents dengue incidence by age group, showing the number and percentage of cases. This analysis helps understand the distribution and risk proportion of dengue in Metro City (13).

Table I. Dengue patient distribution by age group. January–April 2025. Metro City

Age Groups at Risk	Frequency	Percent
Age 1-5 years (high risk)	22	8.9
Age over 60 years (Medium Risk)	20	8.1
Age 6-59 years (Low Risk)	206	83.1
Total	248	100.0

Table I shows that from January to April 2025, 206 DHF cases (83.1%) occurred in the 6–59 age group, with high mobility, outdoor activities, and environmental exposure increasing vulnerability. McCutcheon RA, Keefe RSE, McGuire PK. (2023) found similar results, highlighting the role of environmental factors. Meanwhile, the 1–5 age group had 22 cases (8.9%) (14). Yudhastuti R, D Lusno MF (2021) found that children are more susceptible to dengue due to underdeveloped immune systems and higher indoor activity, increasing exposure to Aedes aegypti breeding grounds like waterlogged areas (15). With moderate risk, the 60–100 age group recorded 20 cases (8.1%). Elderly individuals are vulnerable due to weaker immunity, requiring age-specific dengue prevention and control strategies (16).

Table II shows the distribution of dengue cases by gender, providing frequency and percentage data. This analysis offers an overview of the demographic composition of dengue cases, highlighting gender proportions in the studied population. Table II shows that of 248 dengue cases in Table City (January–April 2025), 136 were females (54.8%) and 112 males (45.2%). Studies like Thi-Quynh Nguyen, Thi-Hien Cao, (2023) suggest women's higher exposure to Aedes aegypti habitats due to domestic roles (17). Socio-economic factors and gender roles increase women's dengue vulnerability, supporting targeted interventions (18,19).

Although data show a relatively balanced number of male and female dengue cases, further analysis is needed to understand the influencing factors. Tristiana RD, Pratiwi IN, Wulansari D, Yusuf A, Sulistyono RE. (2023), and Shafiq S. (2019) emphasized gender-based approaches in prevention, the value of gender-specific data for effective health communication strategies (20,21).

Figure 2 shows high-risk dengue clusters in Metro City, particularly in Purwosari, Purwoasri, East Hadimulyo, and West Hadimulyo. Population density, environment,

Table II. Distribution of Dengue Patients by Age Group for January to April 2025

Gender	Frequency	Percent
Man	112	45.2
Woman	136	54.8
Total	248	100.0

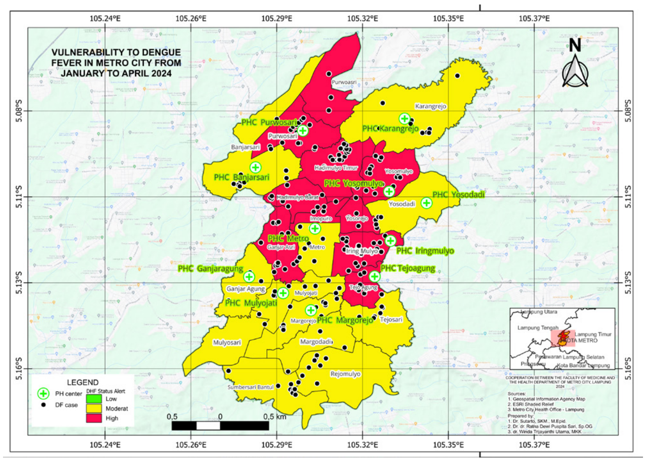

Figure 2: Metro City Dengue Vulnerability Map in 2024

and climate change highlight the need for targeted interventions via risk mapping (22). Spatial analysis helps identify high-risk areas needing urgent intervention. It supports efficient resource allocation, such as fogging and community education, enabling targeted, effective dengue prevention tailored to each region's needs in Metro City (23,24).

The results of this study indicate that Iring Mulyo and Yosomulyo are the most vulnerable areas in Metro City, based on the highest number of DHF cases. Vulnerability mapping revealed significant spatial clustering, particularly in the eastern part of the city. The demographic analysis showed that the majority of DHF cases (83.1%) occurred among individuals aged 6–59 years, who are highly mobile and thus more exposed to mosquito habitats. In terms of gender, females accounted for 54.8% of cases, likely due to their increased exposure to indoor breeding sites associated with domestic roles. These findings suggest that population density, environmental conditions, age, and gender are key determinants of dengue distribution and should be prioritized in the development of targeted prevention and vector control strategies.

DISCUSSION

DHF vulnerability in Metro City varies by village and is driven by urbanization and density, highlighting the need for targeted dengue prevention efforts (25,26). This relationship underscores the need for comprehensive planning and management strategies that incorporate human geography to mitigate health risks in urban settings. The demographic breakdown in Metro City shows a population density of 1,939.2 people/km², which exceeds the threshold where increased dengue transmission risk is anticipated (27). High population density and poor sanitation promote dengue spread, with waste and stagnant water serving as key mosquito breeding sites (28,29). From January to April 2025, most dengue cases occurred in East Metro District, especially Iring Mulyo and Yosomulyo, influenced by local sociodemographic and environmental factors (30).

High community interaction in risk areas can increase dengue spread, requiring focused vector control. Table 1 shows 83.1% of cases in ages 6–59, emphasizing the need for tailored prevention targeting adults' mobility, outdoor activity, and lifestyle. Young children aged 1–5, a high-risk group, made up 8.9% of cases, reflecting their greater vulnerability due to weaker immunity (31). The domestic environment, with stagnant water, fosters mosquito breeding. Community awareness and cleanliness programs are vital to reducing dengue transmission risks at the household level.

Dengue incidence is low among the elderly (60–100 years), possibly due to reduced exposure from lifestyle factors (32). Although the elderly face lower exposure, health conditions heighten severity risks, requiring monitoring. Table II shows higher dengue prevalence in females (54.8%) due to increased household mosquito exposure from domestic roles (33,34). Understanding these gender dynamics is crucial for designing effective public health interventions that account for differential exposure risks based on societal roles.

Figure 2's vulnerability map shows dengue clusters, highlighting the importance of spatial analysis in targeting resources and improving public health efforts (35). GIS improves dengue risk assessments and enables targeted community interventions. Combating dengue in Metro City requires community engagement, environmental management, health education, and collaboration between authorities and locals for effective prevention (36). Furthermore, using data from prior years to forecast potential outbreaks will provide additional foresight into resource allocation (37). Historical data concerning incidence patterns can guide preventive strategies and contingency planning measures during peak transmission periods, allowing rapid response operations to curb outbreak intensity. An analysis of dengue in Metro City highlights the need for targeted interventions, considering demographics, environment, and health access, to reduce transmission and protect vulnerable groups.

In addition to demographic and environmental determinants, behavioral and socio-cultural aspects also play a crucial role in dengue transmission dynamics. Community-level practices such as improper waste disposal, limited knowledge about mosquito breeding sites, and irregular participation in fogging or clean-up programs contribute to persistent risk in vulnerable areas (32). Therefore, strengthening community-based interventions with culturally sensitive health promotion can bridge the gap between risk awareness and preventive action. Integrating school-based education, community empowerment, and mobile health technologies may increase the reach and sustainability of dengue control efforts (36) . Future strategies should also consider integrating predictive modeling using multi-year GIS data to anticipate outbreak patterns, enabling faster, more efficient responses (37). Ultimately, dengue control in urban settings like Metro City requires not only technical interventions but also adaptive, inclusive, and participatory approaches involving all stakeholders.

CONCLUSION

This study successfully identified and mapped the spatial distribution of Dengue Hemorrhagic Fever (DHF) vulnerability and risk areas in Metro City, Lampung Province, Indonesia, using a Geographic Information System (GIS) approach. Spatial analysis revealed high-risk clusters, particularly in Iring Mulyo and Yosomulyo, highlighting the importance of focusing interventions in these areas. The analysis also demonstrated that age (6–59 years), female gender, and high population density are significant factors associated with DHF incidence. These findings confirm the effectiveness of GIS as a decision-support tool for targeting disease prevention efforts. Consequently, this study provides evidence-based recommendations to improve public health strategies through community empowerment, improved sanitation, and targeted vector control, tailored to the specific vulnerabilities identified in the study.

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