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ORIGINAL RESEARCH ARTICLE

Analysis of the Distribution Patterns of Dengue Hemorrhagic Fever (DHF) Using a Geographic Information System (GIS) Approach: A Case Study in Benowo Sub-District, Surabaya City

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ABSTRACT

Dengue hemorrhagic fever (DHF) remains endemic in Benowo Sub-district, Surabaya, where the annual number of cases fluctuated from 43 in 2022 to 26 in 2023 and 44 in 2024. This study aimed to describe the spatial distribution pattern of DHF cases and its relationship with population density in Benowo Sub-district during 2022–2024 using a Geographic Information System (GIS) approach. A descriptive study with a spatial approach was conducted from January to June 2026. All 113 DHF cases recorded at the Sememi Public Health Centre in 2022–2024 were included (total sampling). Case data were obtained from the health centre, population density data from Statistics Indonesia (BPS) of Surabaya City, and the coordinates of patients' residences were collected through field observation using a smartphone GPS application. Data were analyzed descriptively and spatially by plotting case points and overlaying them on population density polygons to produce thematic maps. Cases were unevenly distributed: Sememi Urban Village accounted for 58.4% of cases and Kandangan for 37.2%, whereas Romokalisari (2.7%) and Tambak Osowilangun (1.8%) recorded few cases. Case points appeared clustered in 2022 and randomly dispersed in 2023 and 2024. The two urban villages with very high and high population density (Sememi and Kandangan) consistently recorded the most cases, while the low-density villages recorded the fewest. DHF cases in Benowo Sub-district were concentrated in densely populated urban villages. GIS-based mapping can support area-targeted dengue control, prioritizing intensified mosquito breeding-site eradication (PSN 3M Plus) in Sememi and Kandangan.

Introduction

Dengue hemorrhagic fever (DHF) is an environment-based infectious disease that remains a public health problem in Indonesia because of its high morbidity and mortality. The disease is caused by the dengue virus, which has four serotypes, and is transmitted through the bites of infected female *Aedes aegypti* and *Aedes albopictus* mosquitoes [1]. Globally, more than 6.5 million dengue cases and over 7,300 dengue-related deaths were reported to the World Health Organization in 2023 [2]. In Indonesia, 257,271 dengue cases and 1,461 deaths were recorded in 2024, a substantial increase compared with the previous year [3]. Surabaya City is an endemic area in which the incidence rate increased from 6.7 to 7.9 per 100,000 population, and Benowo Sub-district experienced a rise in cases from 26 in 2023 to 44 in 2024 [4].

The increase in DHF cases is driven by interacting climatic, environmental, and demographic factors that support the life cycle of the vector. Rainfall and temperature are key climatic determinants:

the optimum temperature for *Ae. aegypti* development ranges from 25 °C to 30 °C, and high rainfall creates standing water that serves as breeding sites [5], [6]. Population density is positively correlated with DHF incidence, because the flight range of *Ae. aegypti* (approximately 50–100 m) facilitates transmission between people living in densely populated areas [7]. The larva-free index (*Angka Bebas Jentik*, ABJ), with a national target of ≥ 95%, is used as an indicator of the success of the mosquito breeding-site eradication programme [8], [9], and children have been reported to be at higher risk of DHF [10], [11].

Geographic Information Systems (GIS) allow disease cases to be mapped at their exact locations and overlaid with environmental and demographic layers, so that high-risk areas can be identified and control resources can be targeted [12], [13], [14], [15]. Although many studies have identified risk factors for DHF, evidence on how the spatial distribution of cases changes from year to year at the urban-village level, and how it corresponds to differences in population density between neighbouring villages, remains limited, particularly in peri-urban sub-districts such as Benowo, which comprises densely populated residential villages alongside sparsely populated industrial, fish-pond, and open-land areas. Such fine-scale, multi-year spatial information is needed by local health centres to prioritize vector control.

Therefore, this study aimed to analyze the distribution patterns of DHF cases in Benowo Sub-district, Surabaya, during 2022–2024 using a GIS approach and to describe their relationship with population density at the urban-village level. The results are expected to provide spatially based evidence to support more targeted and effective DHF control programmes and to strengthen environment-based early warning in endemic areas.

Materials and Methods

Study Design and Setting: This descriptive study used a spatial approach based on a Geographic Information System (GIS). The study was conducted in Benowo Sub-district, Surabaya City, which consists of four urban villages (*kelurahan*): Sememi, Kandangan, Romokalisari, and Tambak Osowilangun, all within the working area of the Sememi Public Health Centre. Data collection and analysis were carried out from January to June 2026.

Population and Sample: The population comprised all DHF cases in Benowo Sub-district recorded at the Sememi Public Health Centre from 2022 to 2024, totalling 113 cases. All cases were included in the analysis using total sampling.

Data Sources and Collection: Secondary data on DHF cases (year and residential address) were obtained from the surveillance records of the Sememi Public Health Centre. Population density data (people/km²) for each urban village in 2022–2024 were obtained from Statistics Indonesia (*Badan Pusat Statistik*, BPS) of Surabaya City. Primary spatial data were collected by visiting the residence of each case and recording its geographic coordinates using a GPS Map application on a smartphone.

Data Analysis: Data were analyzed descriptively and spatially. Descriptive analysis summarized the number and proportion of cases by urban village and year. Spatial analysis was carried out in two stages using GIS software. First, an elementary analysis of disease distribution was performed by plotting each case as a point at the patient's residence to produce annual case distribution maps (scale 1:41,000). Second, an overlay analysis combined the case points with urban-village polygons classified by population density (low, medium, high, and very high) to produce thematic maps. The distribution pattern of case points in each year was described as clustered or random based on interpretation of the thematic maps.

Research Ethics: This study received ethical approval from the Health Research Ethics Committee of Poltekkes Kemenkes Surabaya on 20 February 2026 (No. 4079-KEPK). Patient identities were kept confidential, and coordinates were used only for mapping at the aggregated scale presented.

Results

Distribution of DHF Cases and Spread Patterns, 2022–2024

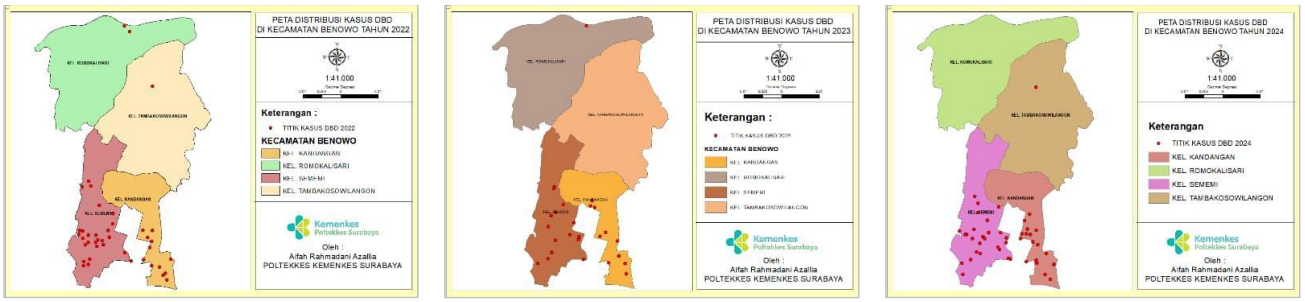
A total of 113 DHF cases were recorded in Benowo Sub-district during 2022–2024, with 43 cases in 2022, 26 in 2023, and 44 in 2024 (Table 1). Cases were unevenly distributed across urban villages. Sememi Urban Village recorded the highest number of cases (66 cases; 58.4%), followed by Kandangan (42 cases; 37.2%), whereas Romokalisari (3 cases; 2.7%) and Tambak Osowilangun (2 cases; 1.8%) recorded the fewest. Romokalisari recorded no cases in 2024, and Tambak Osowilangun recorded no cases in 2023.

Table 1. Distribution of DHF Cases and Population Density by Urban Village in Benowo Sub-district, 2022–2024

Urban Village	DHF Cases (n)			Total, n (%)	Population Density (people/km²)			Density Category
	2022	2023	2024		2022	2023	2024	
Sememi	25	15	26	66 (58.4)	9,652	9,163	9,410	Very high
Kandangan	15	10	17	42 (37.2)	6,897	6,783	6,921	High
Romokalisari	2	1	0	3 (2.7)	421	386	394	Low
Tambak Osowilangun	1	0	1	2 (1.8)	458	298	292	Low
Benowo Sub-district	**43**	**26**	**44**	**113 (100.0)**	–	–	–	

Case data: Sememi Public Health Centre; population density: Statistics Indonesia (BPS) of Surabaya City. Density categories follow the classes used in the thematic maps.

The annual case distribution maps are presented in Figure 1. Case locations (red dots) were concentrated in the southern part of the sub-district, which comprises Sememi and Kandangan, while the northern urban villages of Romokalisari and Tambak Osowilangun contained only a few scattered points. In 2022, case points formed clusters in Sememi and Kandangan, whereas in 2023 and 2024 the points were more randomly dispersed, although they remained largely within the same two villages.

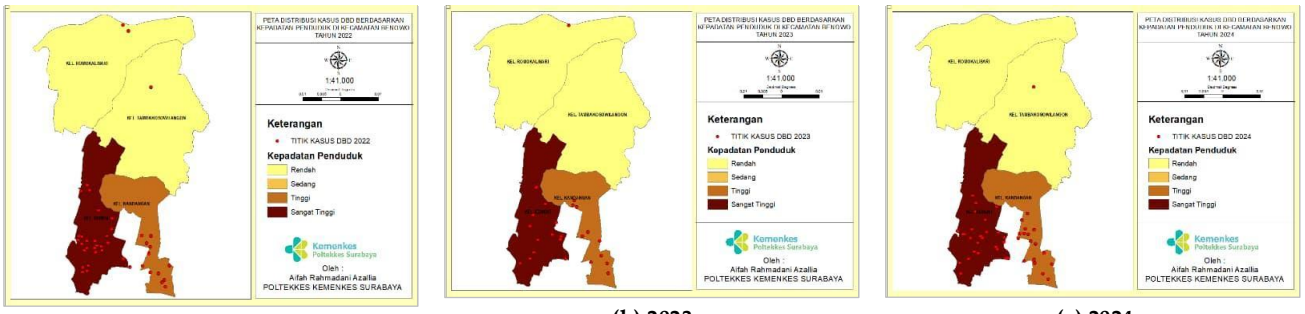


(a) 2022 **(b) 2023** **(c) 2024**

Figure 1. Distribution of DHF cases in Benowo Sub-district in (a) 2022, (b) 2023, and (c) 2024. Red dots indicate case locations. Map legends are in Indonesian: *Titik kasus DBD* = DHF case point; *Kel.* = urban village.

Distribution of DHF Cases by Population Density

Sememi had a very high population density throughout the study period (9,163–9,652 people/km²), and Kandangan had a high density (6,783–6,921 people/km²). In contrast, Romokalisari (386–421 people/km²) and Tambak Osowilangun (292–458 people/km²) had low population densities; the lowest density was recorded in Tambak Osowilangun in 2024 (Table 1). The overlay maps (Figure 2) show that the urban villages with very high and high population density consistently contained most of the case points in every year, while the low-density villages contained very few.



(a) 2022 **(b) 2023** **(c) 2024**

Figure 2. Distribution of DHF cases by population density in Benowo Sub-district in (a) 2022, (b) 2023, and (c) 2024. Legend (*Kepadatan Penduduk*): *Rendah* = low, Sedang = medium, Tinggi = high, Sangat Tinggi = very high.

Discussion

This study found that DHF incidence in Benowo Sub-district fluctuated during 2022–2024 and that cases were concentrated in the two most densely populated urban villages, Sememi and Kandangan, which together accounted for 95.6% of all cases. The spatial pattern of cases changed from clustered in 2022 to random in 2023 and 2024. Sememi consistently recorded the highest number of cases, with 25 cases in 2022, 15 in 2023, and 26 in 2024, whereas Romokalisari and Tambak Osowilangun recorded few or no cases in each year.

A clustered pattern of DHF cases indicates the presence of vector habitats and the potential for local transmission in that area. The random pattern observed in 2023 and 2024 is consistent with the findings in the working area of the Sei Panas Public Health Centre, Batam, where DHF cases were randomly distributed [12]. In contrast, spatial analysis in Tanjungpinang Timur Sub-district revealed a clustered distribution of DHF cases [13], and a study in Seruyan Regency found that cases in 2023 occurred in clusters, reflecting the potential for cluster-based transmission [14]. These differences suggest that distribution patterns may shift over time and between settings, depending on local vector density, human mobility, and the timeliness of control measures. Information on transmission patterns can therefore be used to develop spatially targeted control strategies for public health programmes [15].

The concentration of cases in Sememi and Kandangan corresponds to their very high and high population densities. The greater the number of people living in an area, the greater the opportunity for transmission, and urban villages with high population densities tend to have higher DHF incidence [16], [17]. High population density increases contact between humans and infected *Ae. aegypti* mosquitoes, thereby facilitating the spread of the dengue virus from person to person [18], [19]. Spatial mapping in Seruyan Regency similarly showed that higher population density was associated with higher DHF incidence [14], and a study in West Java found a positive correlation between population density and DHF incidence, with Bandung City having both the highest population density and the highest number of cases in the province [7]. Dense settlements also place houses close together, which falls within the limited flight range of *Ae. aegypti* and enables the vector to move easily between households [20], [21]. Unregulated population growth can further trigger outbreaks in a particular area [22].

High population density is often accompanied by limited land and poor environmental sanitation, which can provide breeding sites for mosquitoes [23], [24]. Accordingly, control measures should be differentiated by area. In Sememi and Kandangan, efforts should focus on reducing vector density and protecting residents through intensified mosquito breeding-site eradication using the 3M Plus approach (draining, closing, and recycling water containers, plus additional protective measures), together with physical, chemical, and biological control [6], [25]. In Romokalisari and Tambak Osowilangun, efforts can focus on eliminating breeding sites around fish ponds and open land through regular larval inspections, the use of larvivorous fish, and the planting of mosquito-repellent plants.

These programmes should be supported by communication, information, and education for the community on DHF prevention and control [26], [27].

This study has several limitations. First, distribution patterns were classified by visual interpretation of the thematic maps; formal spatial statistics such as average nearest neighbour analysis, Moran's I, or kernel density estimation were not applied. Second, the relationship with population density was described at the urban-village level without statistical testing or calculation of incidence rates per population, so it reflects an ecological association rather than individual-level risk. Third, the use of health centre surveillance data may underestimate the true number of cases. Finally, other determinants such as rainfall, temperature, the larva-free index, and patient age were not included in the spatial analysis and should be incorporated in future studies.

Conclusions

The incidence of DHF in Benowo Sub-district fluctuated during 2022–2024, with an increase in 2024. Case distribution was clustered in 2022 and random in 2023 and 2024. Cases were concentrated in Sememi (very high population density) and Kandangan (high population density), whereas Romokalisari and Tambak Osowilangun (low population density) recorded few cases. The GIS approach effectively visualized the spatial distribution of cases and its correspondence with population density, and the resulting maps can be used by the Sememi Public Health Centre and the Surabaya City Health Office to plan area-based DHF control. Communities, particularly in densely populated urban villages, are encouraged to implement mosquito breeding-site eradication (PSN) through the 3M Plus strategy consistently.

Declarations

Author Contributions: Conceptualization, A.R.A., P.H., and D.N.; methodology, A.R.A. and P.H.; data collection and mapping, A.R.A.; formal analysis, A.R.A.; writing—original draft preparation, A.R.A.; writing—review and editing, P.H. and D.N.; supervision, P.H. and D.N. All authors have read and agreed to the published version of the manuscript.

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Ethics Approval: The study was approved by the Health Research Ethics Committee of Poltekkes Kemenkes Surabaya on 20 February 2026 (No. 4079-KEPK).

Informed Consent Statement: Informed consent was obtained from all patients or their family members whose residences were visited for coordinate collection.

Data Availability Statement: The aggregated data presented in this study are available on reasonable request from the corresponding author. Individual case locations are not publicly available to protect patient confidentiality.

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Declaration of Generative AI and AI-Assisted Technologies: During the preparation of this manuscript, AI-assisted tools were used only to improve language, grammar, and readability and to support copyediting. These tools were not used to generate data, perform analyses, or interpret the results. The authors reviewed and edited all content as needed and take full responsibility for the content of the publication.

Conflicts of Interest: The authors declare no conflict of interest.

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