

# GIS-Based Spatial Risk Mapping of *Aedes aegypti* Larval Density and Dengue Transmission Risk in the Kassi-Kassi Community Health Center Area, Makassar City

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## ABSTRACT

Dengue Hemorrhagic Fever (DHF) remains a major public health concern in Makassar City, Indonesia. This study aimed to analyze the spatial distribution of *Aedes aegypti* larval density and its association with dengue transmission risk among children in the working area of the Kassi-Kassi Community Health Center. A quantitative cross-sectional design with a geographic information system approach was used. A total of households were selected using proportional simple random sampling. Data were collected through field observations, household surveys, and secondary data from health institutions. The results showed that temperature ranged from 25.3°C to 27.3°C, humidity from 70% to 89%, and rainfall from 45 mm to 463 mm. Larval density was classified into low-risk (0–4), medium-risk (5–9), and high-risk (10–15) categories, while larvae-positive houses ranged from 87.5% to 100%. Spatial analysis using showed that high-risk areas were concentrated in densely populated settlements with poor drainage and uncovered water storage containers. The association between larval density and dengue incidence was indicated by [insert correlation/index value; p-value]. This study was limited by its cross-sectional design, single study area, and incomplete ability to establish causal relationships. The findings support targeted dengue prevention through Mosquito Nest Eradication, 3M Plus education, and routine larval monitoring.

Keywords: *Aedes aegypti*; dengue hemorrhagic fever; spatial analysis; larval density; geographic information system.

## INTRODUCTION

Dengue Hemorrhagic Fever (DHF) is one of the infectious diseases with high morbidity and mortality rates, especially in tropical and subtropical regions. Dengue is a vector-borne disease transmitted by female *Aedes aegypti* mosquitoes and has become endemic in many parts of the world, including Indonesia<sup>12</sup>. The dengue virus belongs to the genus *Flavivirus* and consists of four serotypes that can cause a wide range of clinical manifestations<sup>3</sup>. In Indonesia, dengue cases remain a major public health problem, with thousands of cases reported annually, indicating the need for effective prevention and control strategies<sup>4</sup>.

The spread of dengue is influenced by multiple factors, including host, environmental, climatic, behavioral, and socio-demographic factors. Environmental conditions such as stagnant water, poor drainage, inadequate sanitation, and uncovered household water storage containers provide ideal breeding sites for *Aedes aegypti* larvae<sup>567</sup>. Community behavior related to water storage, container covering, and sanitation practices also contributes significantly to the presence of mosquito breeding sites<sup>5</sup>. Climatic factors such as rainfall, temperature, and humidity play an important role in increasing mosquito population density by creating suitable conditions for larval development and adult mosquito survival<sup>67</sup>.

Larval density is a key indicator in assessing the risk of dengue transmission in a particular area. In Indonesia, Angka Bebas Jentik (ABJ), or Larvae-Free Rate, is used as a national standard for larval surveillance to describe the percentage of houses without mosquito larvae<sup>8</sup>. A low ABJ indicates a higher risk of dengue transmission because it reflects the presence of larvae in household environments. In addition to ABJ, internationally recognized entomological indicators include the House Index (HI), Container Index (CI), and Breteau Index (BI), which are commonly used to measure larval infestation levels and dengue vector transmission risk<sup>8</sup>.

Children are an important subgroup in dengue prevention because they are vulnerable to dengue infection and may experience more severe clinical outcomes if prevention is not carried out properly. Children also spend much of their time in household and school environments, where exposure to *Aedes aegypti* breeding sites may occur. Therefore, identifying larval density and dengue transmission risk in areas where children live is important for strengthening targeted prevention programs.

Spatial analysis using Geographic Information Systems (GIS) has been widely applied in public health to analyze disease distribution and identify risk areas. GIS enables visualization of spatial patterns, analysis of relationships between environmental factors and disease incidence, and supports decision-making in disease prevention strategies<sup>9</sup>. This approach is particularly useful in dengue control because it helps identify areas with high transmission risk and prioritize intervention programs.

However, previous studies have mostly focused on dengue incidence, environmental sanitation, or larval density separately, while spatial-based studies that integrate *Aedes aegypti* larval density, environmental conditions, climatic factors, population density, and community water management behavior remain limited, particularly in the working area of the Kassi-Kassi Community Health Center<sup>679</sup>. This research gap makes it difficult to determine priority intervention areas based on local spatial risk patterns.

Therefore, this study aims to analyze the spatial distribution of *Aedes aegypti* larval density using a Geographic Information System (GIS) approach and to identify environmental, climatic, demographic, and behavioral factors associated with dengue transmission risk among children in the working area of the Kassi-Kassi Community Health Center, Makassar City.

## MATERIALS AND METHODS

This study used a quantitative method with a cross-sectional design combined with a spatial-based Geographic Information System (GIS) approach. This design enabled the analysis and mapping of the distribution of *Aedes aegypti* larval density and the identification of areas at risk of Dengue Hemorrhagic Fever (DHF) transmission in the working area of the Kassi-Kassi Community Health Center, Makassar City<sup>9</sup>.

The population of this study consisted of all households in the working area of the Kassi-Kassi Community Health Center that had water storage containers with the potential to become breeding sites for *Aedes aegypti* mosquitoes and were at risk of dengue transmission in children. The sampling frame included households located in sub-areas with recorded dengue cases in the Kassi-Kassi Community Health Center working area. The sample consisted of selected households that met the inclusion criteria, namely respondents who were willing to participate, resided in the study area, and had water containers inside or around their homes that could support mosquito breeding<sup>67</sup>.

The sample size was determined using the Slovin formula:

$$n = N / 1 + N(e^2)$$

where  $n$  represents the required sample size,  $N$  represents the total number of households in the sampling frame, and  $e$  represents the margin of error. The sampling technique used in this study was proportional simple random sampling. The number of samples in each sub-area was determined proportionally based on the number of dengue cases recorded in each sub-area. This approach was used to ensure that the selected households represented the spatial distribution of dengue-risk areas and to minimize sampling bias.

The variables analyzed included environmental factors, such as drainage conditions and water storage; climatic factors, including rainfall and air humidity; population density; and community behavior related to mosquito breeding control. Larval density was measured using entomological indices, namely the House Index (HI), Container Index (CI), and Breteau Index (BI)<sup>8</sup>. The House Index refers to the percentage of houses positive for mosquito larvae among all houses inspected. The Container Index refers to the percentage of water containers positive for mosquito larvae among all containers inspected. The Breteau Index refers to the number of larvae-positive containers per 100 houses inspected.

The interpretation of larval density was linked to the Indonesian Ministry of Health standard, namely Angka Bebas Jentik (ABJ), or Larvae-Free Rate. An ABJ value of 95% or higher indicates a safer condition, while an ABJ value below 95% indicates a higher risk of dengue transmission<sup>8</sup>. These indicators were used to classify larval density and to support the identification of dengue transmission risk areas.

Data collection was carried out in 2025 through field observations, household surveys, and documentation from relevant health institutions. Primary data were obtained through direct observation of household environmental conditions, water storage containers, and the presence of mosquito larvae. Secondary data included dengue case data, rainfall, air humidity, and population density obtained from health institutions and related agencies.

The instruments used in this study included household observation sheets, larval inspection forms, household survey questionnaires, documentation sheets, and geographic coordinate recording tools. The instruments were reviewed before data collection to ensure that they were appropriate for identifying environmental conditions, water storage practices, larval presence, and dengue prevention behavior. All collected data were checked for completeness and consistency before analysis.

Data analysis was performed descriptively and spatially using GIS. Descriptive analysis was used to describe climatic conditions, larval density categories, and the distribution of houses with larvae-positive containers. Spatial analysis was conducted through coordinate plotting, overlay analysis, and risk classification mapping to visualize the distribution of *Aedes aegypti* larval density and dengue transmission risk in the study area<sup>9</sup>. The relationship between larval density, larvae-positive containers, and dengue cases was examined through spatial overlay and risk area comparison. The results of the spatial analysis were used to identify priority areas for dengue prevention and vector control interventions.

This study considered ethical principles by obtaining respondent consent before household observation and survey activities. Respondents were informed about the purpose of the study, the voluntary nature of participation, and the confidentiality of the collected information.

**RESULTS**

**Table 1.** Monthly Climatic Conditions in Makassar City

Climate Variable	January	February	March	April	May	June	July	August	September	October	November	December
Average Temperature (°C)	25.3	25.4	25.7	26.2	26.2	26.1	25.8	26.3	27.2	27.3	26.6	25.7
Minimum Temperature (°C)	24.0	23.9	24.0	24.2	24.2	23.6	22.8	22.6	23.2	24.1	24.5	24.2
Maximum Temperature (°C)	27.1	27.3	27.8	28.6	29.3	29.0	29.2	30.3	31.2	30.5	28.9	27.6
Precipitation/Rainfall (mm)	463	355	294	296	234	176	122	57	64	168	259	443
Humidity (%)	89%	89%	88%	87%	84%	83%	80%	73%	71%	76%	85%	89%
Rainy Days (days)	21	19	20	20	17	15	10	6	7	14	20	21
Average Sunshine Hours (hours)	5.7	6.3	6.9	7.6	8.4	8.5	8.8	9.6	10.1	9.4	7.9	6.4

In Table 1 shows that the average air temperature in Makassar City was relatively stable throughout the year, ranging from 25.3°C to 27.3°C. Air humidity ranged from 70% to 89%, while monthly rainfall varied from 45 mm to 463 mm. The highest rainfall and humidity were recorded in January, while the lowest rainfall occurred in August. These climatic conditions indicate that the rainy season, particularly from December to May, may increase the availability of water-holding containers and support the breeding of *Aedes aegypti*. The dry season occurred from June to October, with lower rainfall and humidity.

**Table 2.** Distribution of *Aedes aegypti* Larval Density in the Kassi-Kassi Community Health Center Working Area in 2025

Category	Larva Density Interval
Low Risk	0 – 4
Medium Risk	5 – 9
High Risk	10 - 15

Based on Table 2, *Aedes aegypti* larval density was classified into three risk categories: low risk, medium risk, and high risk. The low-risk category represented areas with larval density scores of 0–4, the medium-risk category represented scores of 5–9, and the high-risk category represented scores of 10–15. These categories indicate different levels of dengue transmission risk. Areas classified as high risk require priority intervention because they indicate a higher presence of mosquito larvae and potential breeding sites. The interpretation of larval density should be linked to the Indonesian Ministry of Health larval surveillance standard, including Angka Bebas Jentik (ABJ) or Larvae-Free Rate, and WHO-recognized entomological indices such as the House Index (HI), Container Index (CI), and Breteau Index (BI) <sup>8</sup>.

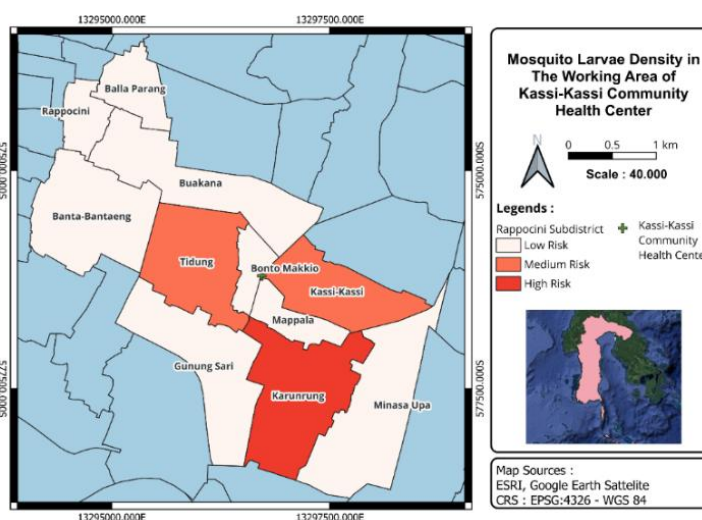


Figure 1. Spatial distribution of *Aedes aegypti* larval density in the working area of the Kassi-Kassi Community Health Center, Makassar City, 2025.

Figure 1. This GIS map presents the spatial classification of larval density into low-risk, medium-risk, and high-risk areas. The map shows the location of the Kassi-Kassi Community Health Center as the main health service reference point and displays administrative boundaries within the study area. High-risk larval density areas were mainly concentrated in residential zones with poor drainage, humid environmental conditions, and uncovered water storage containers.

**Table 3.** Distribution of Houses with *Aedes aegypti* Larvae-Positive Containers in the Kassi-Kassi Community Health Center Working Area in 2025

Category	Positive Larvae Interval
Low Risk	87,5 – 91,6
Medium Risk	91,7 – 95,8
High Risk	95,9 – 100

Based on Table 3, the percentage of houses with larvae-positive containers ranged from 87.5% to 100.0%. The low-risk category ranged from 87.5% to 91.6%, the medium-risk category ranged from 91.7% to 95.8%, and the high-risk category ranged from 95.9% to 100.0%. A higher percentage indicates that more household containers were positive for mosquito larvae, reflecting a greater risk of dengue transmission. These findings suggest that several households still had water containers that could serve as breeding sites for *Aedes aegypti*. This condition should be evaluated using ABJ and related entomological indices based on the Indonesian Ministry of Health standard <sup>8</sup>.

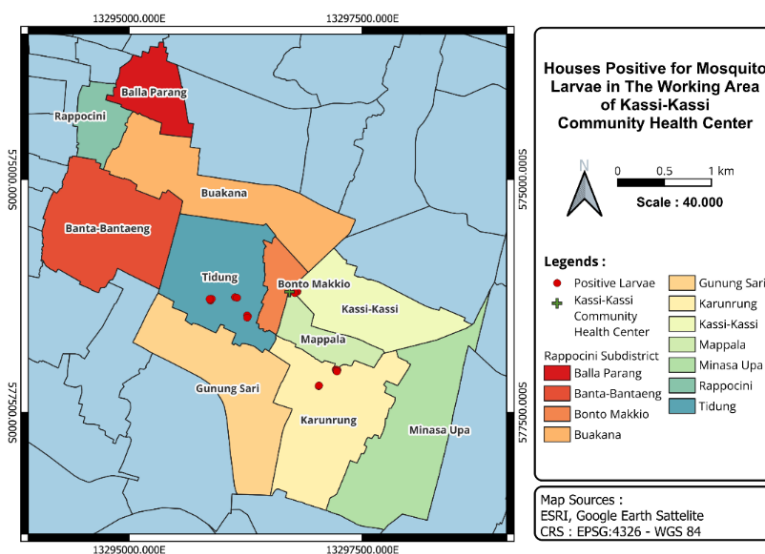


Figure 2. Spatial distribution of houses with *Aedes aegypti* larvae-positive containers in the working area of the Kassi-Kassi Community Health Center, Makassar City, 2025.

Figure 2. This GIS map shows the distribution of houses with larvae-positive containers across the study area. The map identifies areas with higher concentrations of larvae-positive containers, especially in densely populated settlements and locations where household water management practices were inadequate. These areas should be prioritized for Mosquito Nest Eradication, 3M Plus education, and routine larval monitoring.

Figure 3. This GIS map displays the distribution of Dengue Hemorrhagic Fever cases in relation to larval density and larvae-positive container distribution. Areas with higher dengue case distribution appeared to overlap with areas showing higher larval density and more larvae-positive containers. This spatial pattern indicates that larval density and container positivity may contribute to dengue transmission risk in the study area.

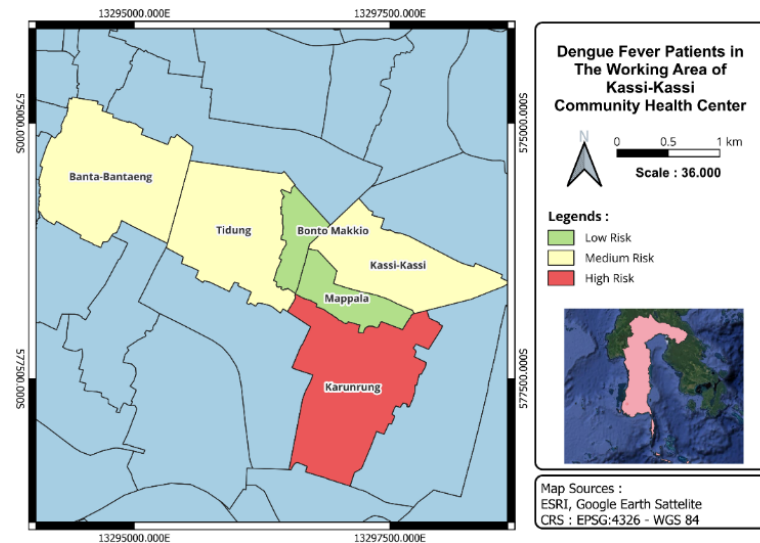


Figure 3. Results of Distribution of Houses with Mosquito Larvae-Positive Containers in the Kassi-Kassi Health Center Working Area

## DISCUSSION

### Influence of environmental and climatic factors

The findings of this study indicate that environmental and climatic conditions contributed to the spatial pattern of *Aedes aegypti* larval density in the Kassi-Kassi Community Health Center working area. The temperature range of 25.3°C–27.3°C, humidity of 70%–89%, and rainfall of 45–463 mm created favorable conditions for mosquito breeding. In the local context of Makassar City, high rainfall during the rainy season increases the number of water-holding containers around households, while high humidity supports larval survival and adult mosquito longevity. This explains why high-risk larval density areas tended to appear in residential areas with poor drainage, stagnant water, and uncovered water storage containers. Previous spatial research also found that rainfall and larval indices, including House Index, Container Index, Breteau Index, and Larvae-Free Rate, were significantly associated with DHF incidence<sup>10</sup>. Similar findings were reported in Manado City, where rainfall and rainy days were associated with increased DHF incidence<sup>11</sup>. Therefore, in the Kassi-Kassi area, climatic conditions should be understood not only as background factors, but also as triggers that interact with household environmental conditions and increase the availability of breeding habitats for *Aedes aegypti*<sup>101112</sup>.

### Role of community behavior and population density

Community behavior also helps explain the observed spatial pattern of larvae-positive containers. The presence of uncovered water storage containers, irregular cleaning of water reservoirs, and incomplete implementation of 3M Plus activities allow mosquito breeding sites to persist inside and around houses. In densely populated settlements, this problem becomes more important because houses are located close to one another, water containers are more numerous, and mosquito flight distance is sufficient to support local transmission between households. Thus, the clustering of larvae-positive containers in residential areas is likely caused by the combination of household water storage practices and high population density. Studies on dengue prevention behavior have shown that knowledge and attitudes do not always translate into consistent preventive practices, which may explain why larvae-positive containers remain common even when dengue prevention messages are already known by the community<sup>13</sup>. Spatial studies also show that population density can influence dengue distribution and spatial clustering because densely populated areas provide more hosts and more domestic breeding sites for *Aedes aegypti*<sup>1415</sup>. Environmental sanitation conditions, including water storage practices and poor drainage, are also consistently associated with increased larval density and dengue incidence in Indonesia<sup>16</sup>. Community-level interventions emphasizing 3M Plus behaviors have been shown to reduce breeding sites when implemented consistently<sup>17</sup>.

### Spatial analysis and dengue risk mapping

The use of Geographic Information Systems (GIS) in this study helped identify areas where larval density, larvae-positive containers, and DHF cases overlapped spatially. In the Kassi-Kassi Community Health Center area, high-risk zones were not randomly distributed, but appeared in residential environments characterized by dense housing, poor drainage, and inadequate water container management. This suggests that dengue

transmission risk in this setting is shaped by micro-environmental conditions at the household and neighborhood levels. Spatial mapping is useful because it allows health workers to move from general prevention campaigns to more targeted interventions in specific high-risk areas. Previous studies have shown that GIS can support dengue surveillance by visualizing risk patterns, detecting clusters, and guiding public health decision-making<sup>1819</sup>. However, in this study, the spatial output should be interpreted as GIS-based risk mapping rather than a validated predictive model, because model validation statistics were not presented in the manuscript.

### **Implications for dengue control strategies**

The findings support the need for integrated dengue control strategies involving environmental management, household behavior change, and routine larval monitoring. Mosquito Nest Eradication (PSN), 3M Plus education, and larva monitoring cadres or jumantik are feasible interventions for the Kassi-Kassi Community Health Center area because they can be implemented through existing primary health care activities, community health posts, schools, and neighborhood-based health cadres. In Makassar City, these strategies are especially relevant because dengue prevention depends heavily on community participation and routine monitoring at the household level. Community-based interventions are more sustainable than relying only on fogging because they directly target larval breeding sites before mosquitoes become adults<sup>20</sup>. Studies have also documented that high larval density indices, including elevated House Index and Breteau Index values, are significantly associated with increased dengue transmission risk in residential communities<sup>21</sup>. Fogging may still be useful during outbreaks, but it should not be the main long-term strategy because studies in Indonesia have reported widespread *Aedes aegypti* resistance to pyrethroid insecticides, which can reduce the effectiveness of chemical control<sup>22</sup>. Therefore, strengthening PSN, 3M Plus, and jumantik activities is more appropriate as a routine preventive strategy, while insecticide use should be limited, monitored, and supported by resistance management.

### **Children as a vulnerable subgroup**

Children are an important subgroup in dengue prevention because they spend much of their time in household and school environments where exposure to *Aedes aegypti* may occur. In addition, children may have limited ability to recognize early symptoms, avoid mosquito bites, or manage their own preventive behavior. Clinical evidence also shows that children are among the groups associated with severe dengue outcomes, making early prevention in the household environment important<sup>2324</sup>. Entomological surveys conducted in Makassar have similarly shown high larval infestation rates in urban residential areas, underscoring the need for household-level vector control strategies<sup>25</sup>. Therefore, identifying high-risk larval density areas in communities where children live can help prioritize school-based education, household larval monitoring, and early warning activities for families.

### **Study limitations**

This study has several limitations. First, the cross-sectional design limits the ability to establish a causal relationship between larval density, environmental conditions, and DHF incidence. Second, the study was conducted only in the working area of the Kassi-Kassi Community Health Center, so the findings may not be generalizable to all areas of Makassar City. Third, the high percentage of larvae-positive houses shown in Table 3 suggests possible sampling bias because the sample may have been concentrated in areas already known to have dengue cases or high-risk environmental conditions. Fourth, the study relied on spatial mapping and descriptive risk classification, while advanced spatial statistical outputs such as Moran's I, Getis-Ord  $G_i^*$ , or spatial regression were not fully reported. Future studies should include longitudinal data, larger sampling frames, and validated spatial statistical models to strengthen causal interpretation and improve dengue risk prediction.

## **CONCLUSION AND RECOMMENDATIONS**

This study concludes that the spatial approach based on Geographic Information System (GIS) is useful in identifying the distribution and risk patterns of *Aedes aegypti* larval density in the working area of the Kassi-Kassi Community Health Center, Makassar City. The findings indicate that larval density is influenced by environmental conditions such as poor drainage systems, uncovered water storage containers, high population density, and community behavior that has not optimally implemented mosquito breeding control practices. These factors contribute to the increased risk of Dengue Hemorrhagic Fever (DHF), particularly in densely populated areas and during the rainy season.

This study also confirms that the integration of environmental, climatic, and behavioral factors through spatial analysis can provide a more comprehensive understanding of dengue transmission patterns. The GIS-based risk classification used in this study helped identify priority intervention areas and can support more targeted dengue prevention efforts, especially among vulnerable populations such as children. However, this study was limited by its cross-sectional design, single study area, and descriptive spatial mapping approach, which cannot establish causal relationships or provide a formally validated predictive model.

Based on these findings, local governments and health authorities are recommended to strengthen community-based dengue control programs, such as Mosquito Nest Eradication (PSN), 3M Plus activities, and routine larval monitoring by jumentik cadres through continuous education and active community participation. Improving environmental sanitation and drainage systems is also essential to reduce mosquito breeding sites. Future research should use longitudinal data and more specific spatial analytical methods, such as spatial regression, Moran's I spatial autocorrelation, and Getis-Ord  $G_i^*$  hotspot analysis, to improve the accuracy of dengue risk assessment and support sustainable public health interventions.

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