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MORALITY BEFORE KNOWLEDGE

Flood-prone settlements and mosquito habitat risk: an integrated field survey and spatial mapping

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ABSTRACT

Background: Flood-prone areas present significant public health challenges, particularly in urbanized regions where inadequate drainage systems and water stagnation create ideal breeding grounds for disease vectors such as mosquitoes. This study investigates the relationship between flood risks and mosquito habitat proliferation in Gowa, South Sulawesi, Indonesia. **Methods:** By combining a comprehensive field survey with Geographic Information System (GIS) spatial mapping, the study aimed to identify environmental and infrastructural factors contributing to mosquito breeding, particularly Aedes aegypti, the primary vector for dengue and Zika virus. **Findings:** The results revealed that areas with poorly managed drainage systems and stagnant water were high-risk zones for mosquito breeding, correlating with increased mosquito densities and higher disease transmission potential. The study also found that rapid urbanization, combined with insufficient waste management, further exacerbates the risk by providing numerous breeding sites for mosquitoes. The findings support global observations that similar challenges in other tropical regions, including Brazil and Indonesia, contribute to the spread of mosquito-borne diseases. **Conclusion:** This research highlights the critical role of environmental infrastructure in controlling vector-borne diseases and emphasizes the need for improved urban planning, integrated vector control strategies—including better drainage infrastructure, community education, and regular sanitation practices—to reduce mosquito breeding sites. Overall, it provides valuable insights for local authorities and public health organizations, offering a framework for targeted interventions in flood-prone areas. **Novelty/Originality of this article:** The novelty of this study lies in combining GIS spatial mapping with field surveys to directly link flood-prone urban infrastructure and environmental factors to mosquito habitat proliferation, providing a framework for targeted, location-specific public health interventions.

KEYWORDS: aedes aegypti; flood-prone areas; Geographic Information System (GIS); mosquito habitats; vector-borne diseases.

1. Introduction

Flood-prone areas are significant public health concerns due to their role in creating ideal breeding sites for mosquitoes, which spread vector-borne diseases such as dengue, malaria, and Zika virus (Rupa & Hossian, 2024). This phenomenon is particularly pronounced in tropical and subtropical regions, where environmental conditions are

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already conducive to mosquito proliferation and disease transmission (Muh et al., 2025). The convergence of hydrological extremes and epidemiological dynamics thus presents a complex challenge, necessitating a thorough examination of the mechanisms by which floods exacerbate vector-borne disease prevalence (Ahmed et al., 2024). This review will delve into the intricate relationship between climate change-induced flooding and the proliferation of vector-borne diseases, particularly in vulnerable tropical communities, considering how disrupted ecosystems and compromised infrastructure amplify public health risks (Acosta-España et al., 2024; Tan et al., 2025). In regions like Gowa, South Sulawesi, the combination of heavy rainfall and poor drainage systems exacerbates flooding risks, providing stagnant water that serves as a breeding ground for mosquitoes, particularly Aedes aegypti. This environmental alteration directly contributes to an increased incidence of diseases like dengue fever, as observed in various flood-affected areas across Southeast Asia (Tan et al., 2025). The impact of climate change on these dynamics is becoming increasingly evident, with extreme weather events, including intense rainfall and subsequent flooding, directly correlating with a surge in malaria cases in affected regions (World Malaria Report, 2024). This study investigates how environmental and infrastructural factors in Gowa influence mosquito habitat distribution and associated health risks. Moreover, floods facilitate the transmission of various infectious diseases beyond those primarily vector-borne, including waterborne diseases like cholera and leptospirosis, and respiratory or fungal infections prevalent in displaced populations (Acosta-España et al., 2024; Tan et al., 2025).

The study conducted in Gowa utilized a comprehensive field survey integrated with Geographic Information System (GIS) spatial mapping to assess the relationship between flood risks and mosquito habitat distribution. This approach allows for a granular understanding of how specific environmental parameters, such as water stagnation duration and proximity to human settlements, contribute to vector proliferation and disease incidence (Jan et al., 2023). This comprehensive methodology is crucial for developing targeted intervention strategies aimed at mitigating the public health impact of flood-associated vector-borne diseases, especially given the increased frequency of extreme weather events in Southeast Asia (Tan et al., 2025). By mapping mosquito habitats in areas prone to flooding, researchers identified high-risk zones for disease transmission. This detailed spatial analysis revealed a direct correlation between flood-prone areas, inadequate drainage infrastructure, and elevated mosquito densities, underscoring the critical need for integrated urban planning and public health interventions to mitigate these escalating risks (Tan et al., 2025). Furthermore, the broader ecological consequences of such hydrological events, including altered land use and environmental degradation, further influence vector-host interactions and disease transmission dynamics, highlighting the necessity of a One Health approach in addressing these complex public health challenges (Tan et al., 2025; Yeboah, 2023). The interplay between drainage infrastructure, impermeable surfaces, and social vulnerability significantly amplifies the risk of flood-related transmission, with the highest risk observed within 200 meters of drainage systems in highly urbanized and socio-economically disadvantaged areas (Azevedo et al., 2025). This method provides essential data for effective public health interventions, enabling targeted mosquito control strategies in flood-prone areas. This integrated understanding is particularly crucial in Southeast Asian countries, where multi-omics approaches and machine learning are being increasingly utilized to predict disease outbreaks with greater precision and to strengthen preparedness strategies within a One Health paradigm (Tan et al., 2025).

Through the field survey, environmental data was collected alongside mosquito larvae samples, fly density measurements, and rodent trapping to quantify vector presence, allowing for a multifaceted assessment of vector abundance and distribution in relation to flood susceptibility (Parker et al., 2022). This comprehensive data collection and analytical framework provided valuable insights into the ecological determinants of vector populations, crucial for developing targeted public health interventions (Sharma, 2022). The study focused on households in high-risk flood zones, using structured interviews to assess local sanitation practices and water stagnation conditions. This allowed for an evaluation of human behavioral factors and infrastructural deficiencies that contribute to the creation of mosquito breeding habitats, linking community-level practices to broader ecological and epidemiological outcomes (Azevedo et al., 2025). These data were then analyzed with GIS to create detailed maps showing mosquito habitat risks and the proximity of these habitats to flood-prone settlements. This integrated approach, combining field data with advanced spatial analysis, enables the identification of critical areas for intervention and informs the development of evidence-based strategies for vector control and disease prevention within a One Health framework (Owusu-Asenso, 2023; Yeboah, 2023).

Findings from the study highlighted that poor drainage systems and water stagnation in Gowa's urban areas significantly contributed to mosquito proliferation, with a direct correlation observed between the duration of stagnant water and the density of Aedes aegypti larvae (Syam et al., 2025). This exacerbates the potential for arbovirus transmission, as Aedes aegypti is a primary vector for diseases such as dengue, Zika, and chikungunya, especially in densely populated urban environments (Borges et al., 2024). The results emphasized that areas with open drainage channels or poorly maintained water storage systems were more likely to harbor mosquitoes. This finding underscores the critical need for improved urban planning and infrastructure development to mitigate flood risks and reduce vector-borne disease incidence in vulnerable communities (French et al., 2021). This data provides a valuable basis for improving urban infrastructure, particularly drainage systems, to reduce mosquito breeding sites and, consequently, the spread of mosquito-borne diseases. Moreover, the high heterogeneity of vector abundance in low-income urban communities suggests that improved sanitation and regular water supply are crucial for effective 'Aedes aegypti' control (Souza et al., 2023).

The results of this study underscore the importance of integrated flood management and vector control in vulnerable regions like Gowa, especially considering that urban development practices significantly contribute to creating mosquito breeding habitats (Dharmamuthuraja et al., 2023). This is further supported by observations from Abidjan, Côte d'Ivoire, and Bengaluru, India, where contemporary urbanization practices and landscape ecology directly influence the diversity and distribution of larval habitats and mosquito species composition, ultimately affecting arboviral disease risk (Adjobi et al., 2024; Dharmamuthuraja et al., 2023). By improving drainage infrastructure, conducting community education, and using GIS to monitor mosquito habitats, local authorities can mitigate the public health risks associated with flooding (Nayak et al., 2025; Telle et al., 2025). Effective interventions require a multi-faceted approach, incorporating environmental management, public health education, and advanced surveillance systems to address the complex interplay between urbanization, climate change, and disease ecology (Dharmamuthuraja et al., 2023). This research contributes to the global understanding of how environmental changes, such as flooding, influence vector-borne disease transmission, offering a framework for future intervention strategies in similar settings, particularly by providing a methodology for investigating the dynamics of dengue transmission that can be replicated globally (Abdullah et al., 2025).

2. Methods

2.1 Research design and approach

The study employed an observational analytic, cross-sectional field survey to quantify vector density and associated environmental determinants in flood-prone settings, utilizing Geographic Information System mapping to characterize environmental features and identify potential breeding habitats for mosquito vectors. This approach allowed for a detailed spatial analysis of mosquito larval distribution and its correlation with household environmental factors, thereby enhancing the predictive accuracy of localized vector control measures (Hidayah et al., 2025). Data collection combined structured household interviews, standardized environmental inspections, and direct vector measurements for mosquitoes (larval indices), flies (fly-grill counts), and rodents (trap success) at predefined sampling points. The study then integrated these indicators with spatial analysis to map vector-risk hotspots in areas with high floodwater stagnation potential in Gowa, South Sulawesi, Indonesia. This comprehensive methodology enabled the identification of specific environmental and socio-economic factors contributing to vector proliferation, offering a robust foundation for targeted public health interventions.

2.2 Location and unit analysis

The study was conducted in flood-prone settlements within Gowa Regency, South Sulawesi, Indonesia, specifically in areas classified as having a high potential for floodwater stagnation. The unit of analysis comprised: (1) households as the primary unit for mosquito larval surveys and assessment of domestic environmental and behavioral factors; (2) predefined observation areas as sampling units for fly density measurements; and (3) trap stations as sampling units for rodent density assessment using capture-based indicators.

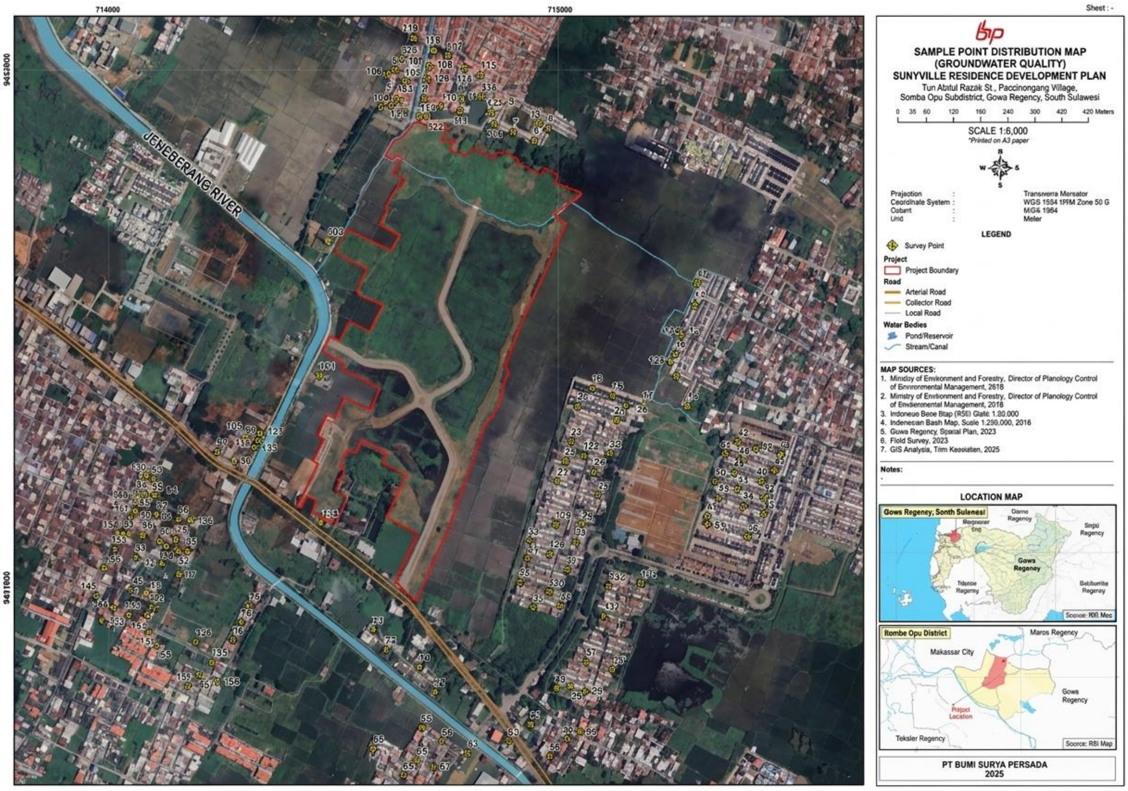

Fig. 1. Location of study

2.3 Population and sample

The target population comprised all households located in and around the study sites within high floodwater-stagnation risk areas in Gowa Regency, South Sulawesi. The household sample included 159 households, selected using random sampling to ensure representativeness of settlement conditions across the study area. Eligible respondents were adult household members who were familiar with household sanitation practices and the local environmental context; they provided information through structured interviews and allowed standardized inspection of water-holding containers for mosquito larval assessment. Fly density was assessed in five predefined observation areas selected to reflect key environmental settings within the study area, and standardized fly counts were conducted at designated points within each area. Rodent density was assessed through capture-based trapping in locations with a high likelihood of infestation, such as near waste accumulation points, drainage channels, and persistently wet or waterlogged zones; a total of 42 traps were deployed and used to calculate trap success at both site and overall levels.

2.4 Instruments and materials

For the field survey, various instruments were employed to assess mosquito habitats and risk in flood-prone settlements. Mosquito larvae were collected using larval pipettes and dippers, with sample containers for storing and transporting larvae to the laboratory. The environmental conditions of households and surrounding areas were recorded using standardized forms that included data on water stagnation, drainage conditions, and the presence of mosquito larvae. A fly-grill and hand counter were used to measure fly density in selected areas, serving as an additional indicator of vector presence. For spatial mapping and risk analysis, Geographic Information System (GIS) software was utilized to integrate the field survey data and create risk maps, identifying areas with a high potential for mosquito breeding. Larvicides were applied in stagnant water areas that could not be managed manually, and routine inspections were carried out to monitor the effectiveness of control measures. The combination of field tools and GIS technology allowed for a comprehensive evaluation of mosquito habitats and their relationship to flood risks in Gowa.

2.5 Data collection operational procedure

The Data Collection Operational Procedure for the study on flood-prone settlements and mosquito habitat risk in Gowa, South Sulawesi, focused solely on mosquito monitoring. As outlined in Figure 2, the process began with identifying high-risk flood-prone areas using historical flood data, followed by selecting a random sample of households in these areas for further analysis. Enumerators were trained to conduct environmental assessments and structured household interviews, specifically targeting water stagnation and mosquito breeding sites. Mosquito larvae were collected from various water-holding containers such as flowerpots, buckets, and bathtubs using larval pipettes and dippers. Data on the presence of mosquito larvae, as well as sanitation conditions, were recorded using standardized forms. Geographic coordinates were also captured for spatial analysis, and the data were then integrated into a Geographic Information System (GIS) for mapping mosquito habitats and identifying high-risk zones. Quality control measures were implemented to ensure the consistency and accuracy of the data, which were used for assessing the relationship between mosquito habitats and flood-prone areas.

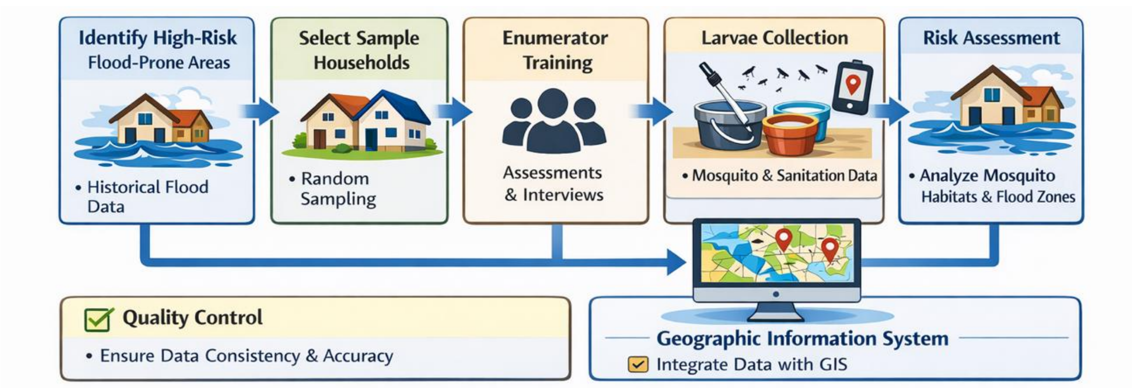

Fig. 2. Data collection operational procedure for monitoring in a flood-prone settlement, Gowa, South Sulawesi

2.6 Data processing and analysis

The team begins the data processing by editing and coding the questionnaires on the same day after the survey to reduce missing data, followed by entering the data into structured sheets (households, containers, fly areas, and rat trap points). They perform double validation on key variables, including the number of households inspected (159), number of containers, fly count results, and rat trap recap. In the quantitative analysis stage, the team calculates mosquito entomological indicators such as ABJ, HI, CI, and BI from the household and container data, calculates fly density per area using the average of the top 5 counts, and categorizes the results. They also calculate rat trap success per location and total as an indicator of rat density. Finally, in the spatial analysis stage, the team maps the measurement results to identify high-risk clusters, which form the basis for prioritizing vector control interventions, as shown in Figure 3.

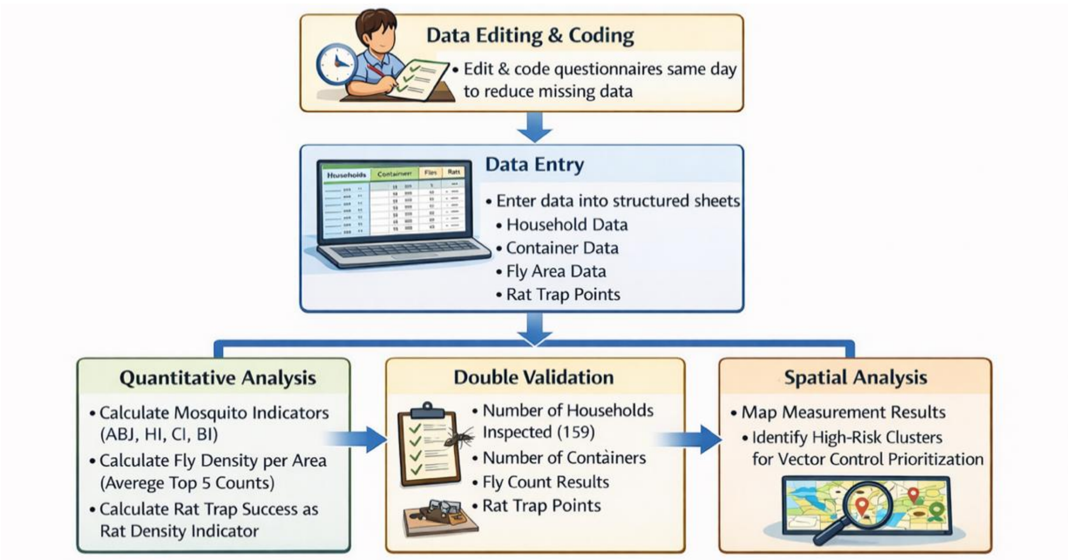

Fig. 3. Data processing and analysis workflow

2.7 Quality control, research ethics, and workplace safety procedures

The field coordinator conducts spot-checks on selected sample households to ensure consistency in checking larvae and recording containers. The team performs a brief calibration of the fly counting procedure before measurements in each area to maintain a consistent 30-second interval. Additionally, they standardize bait types and trap placement methods to ensure comparability of trap success across locations. Regarding research ethics and workplace safety, the team obtains respondent consent before interviews and home inspections, ensures confidentiality of household identities using sample codes, and implements safety measures when handling rat traps and potential environmental contamination, including the use of gloves and disinfecting tools.

3. Results and Discussion

3.1 Results

3.1.1 Flood hazard analysis and vulnerability assessment for Paccinongang, Gowa Regency

The Flood Hazard Index Analysis is based on flood disaster threat data for Gowa Regency, utilizing BNPB's (inaRISK) data. According to inaRISK, flooding is a major disaster risk in Indonesia, and studies on potential flood disasters in Gowa Regency indicate that the region is highly vulnerable to this risk due to its topography and climatic conditions, which facilitate the accumulation of stagnant water necessary for vector proliferation. Furthermore, rainfall, humidity, and population density are crucial factors influencing the susceptibility of an area to dengue vector proliferation, as evidenced by models assessing household and area vulnerability to Aedes vectors (Hernawan et al., 2024). The increasing frequency of heavy rainfall events and the presence of numerous open water bodies in Gowa further exacerbate the risk, providing abundant breeding grounds for Aedes aegypti and other mosquito species (Haryanto et al., 2025; Salim et al., 2025). The primary factors contributing to the flood hazard potential in Gowa are high rainfall, steep slopes, and land use patterns, with some areas classified as having high flood hazard potential that require targeted environmental management strategies to mitigate the proliferation of mosquito vectors and reduce the transmission risk of associated diseases. This risk is further compounded by localized factors, as high-risk dengue clusters are often found near major water bodies and drainage systems, emphasizing the need for geographically focused public health interventions (Haryanto et al., 2025; Ho et al., 2025). Paccinongang, located within Gowa Regency, and nearby urban areas like Somba Opu Subdistrict, which are affected by river overflow and drainage issues, fall under the district's general flood hazard zone. To assess specific risks, local vulnerability factors must be considered. Tun Abdul Razak Road, a major route connecting Gowa and Makassar, exposes the region to high social and economic vulnerability, as it serves as an essential artery for both residential areas and economic activities. The drainage system in areas like Paccinongang, which are densely populated and experience high traffic, is poor, making them susceptible to local flooding, especially during heavy rainfall or when the Jeneberang River overflows. These hydrological challenges are further exacerbated by inadequate urban planning and maintenance, leading to frequent inundation that creates pervasive breeding habitats for disease vectors (Ibrahim et al., 2025; Muhammad et al., 2025; Ruthirako et al., 2025).

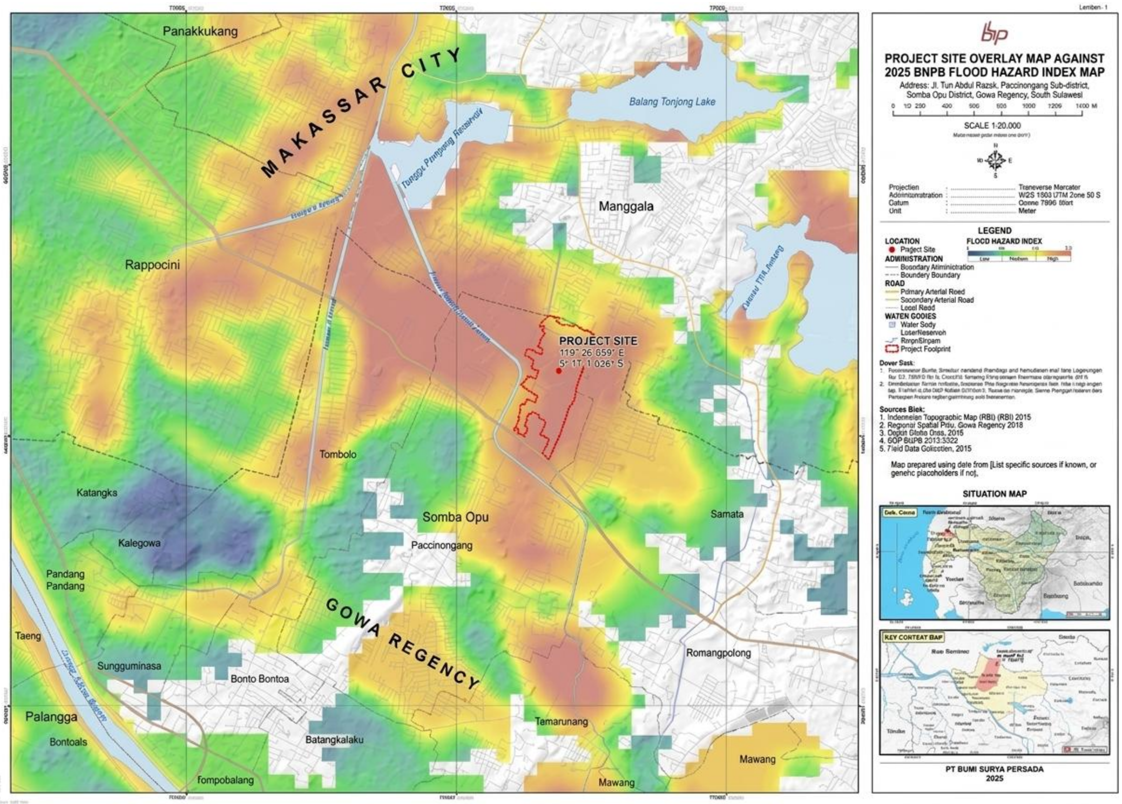

Fig. 4. Overlay map of the Sunville residence project area against the flood risk index map for 2023, Gowa Regency

Although the specific Flood Hazard Index values for Paccinongang are unavailable in the inaRISK data summary, the hazard level can generally be categorized as Medium to High. The region's vulnerability is classified as high due to its dense population, strategic location, and valuable assets. In terms of capacity, there is a need for improvements in drainage management, public education, and early warning systems. For further clarity, please refer to Figure 3. This map is an overlay of the project site against the flood hazard index map for Gowa Regency in 2023, indicating the level of flood risk across various areas. The map uses color gradients, where areas in red to dark orange represent regions with high flood hazard potential, influenced by factors such as rainfall, slope, and land use. Yellow and green areas depict medium to low flood risk. The project site, marked in red on the map, falls within a high-risk zone, suggesting the area is particularly vulnerable to flooding, especially during heavy rainfall or river overflow, as indicated by its proximity to flood-prone areas in Gowa Regency. This overlay analysis highlights the need for further investigation into flood risk reduction measures, as the site and surrounding areas are at significant risk of flooding, which could affect infrastructure, the environment, and local communities.

3.1.2 Mosquito habitat and entomological indices

3.1.2.1 Mosquito breeding habitats

The potential habitat for mosquitoes, particularly Aedes aegypti—the primary vector of Dengue Hemorrhagic Fever (DHF)—has increased significantly due to several factors associated with the development housing project. This expansion of suitable habitats is directly linked to an observed increase in the incidence of dengue hemorrhagic fever in these urbanized zones, underscoring the critical need for integrated vector control strategies that consider the interplay between environmental modifications and disease transmission (Giofandi et al., 2023; Pakaya et al., 2022). One of the main contributing factors is water stagnation in poorly managed open drainage channels, which can serve as breeding sites for mosquito larvae. The lack of effective waste management further exacerbates this issue, as discarded items such as plastic containers and tires collect rainwater, forming additional microhabitats for vector breeding (Prasetyowati et al., 2021). In addition, temporary water storage during construction activities, such as puddles formed from excavation works or newly constructed drainage systems, creates ideal conditions for mosquito proliferation. Uncovered containers in basecamp areas or surrounding residential zones, including buckets, drums, and construction materials that collect rainwater, further provide highly favorable breeding habitats for Aedes aegypti. These environmental factors, coupled with the region's climate and urbanization patterns, elevate the risk of dengue transmission, as evidenced by rising case numbers in urban centers like Makassar and the vulnerability of surrounding areas (Haryanto et al., 2025).

Changes in surface water flow resulting from land clearing and topographic reconfiguration also influence hydrological patterns around the construction site. This alteration can lead to increased runoff and the formation of new stagnant water bodies in previously dry areas, thereby expanding potential breeding grounds for mosquitoes and other disease vectors (Malik & Siddiqui, 2025). These alterations may lead to the formation of stagnant water in locations that were previously unaffected, thereby increasing the availability of mosquito habitats. Furthermore, inadequate maintenance of sanitation infrastructure and the presence of poorly managed water bodies can exacerbate these issues, creating favorable conditions for mosquito breeding, particularly for Aedes aegypti (Rahmawati et al., 2025).

The confluence of rapid urbanization, inadequate vector control measures, and climate variability significantly contributes to the increased spread and intensity of mosquito-borne diseases like dengue fever (Silva & Bastos, 2025). Drainage channels that retain water and do not function properly—due to sedimentation or inadequate design—can further support mosquito development. Collectively, these conditions elevate the risk of DHF transmission, posing significant public health concerns for nearby communities. The presence of domestic and peri-domestic breeding sites, such as discarded tires, cans, and other containers, further amplifies the risk of vector proliferation in urban and suburban settings (Bhatia et al., 2022). Therefore, it is essential to implement effective environmental management measures, including proper drainage maintenance, covering water-holding containers, and maintaining cleanliness in construction and residential areas, to mitigate the proliferation of disease vectors and support sustainable development practices. These measures are crucial not only for controlling mosquito populations but also for enhancing public health outcomes in areas undergoing rapid environmental transformation and increased flood susceptibility (Bakri et al., 2024).

The assessment of mosquito-related health risks in the Sunville Residence development area was conducted through two complementary approaches. First, potential mosquito breeding habitats were identified based on environmental characteristics and the distribution of mosquito species. Second, entomological indices were calculated to quantify the level of larval infestation and evaluate the potential risk of vector-borne disease transmission. Together, these analyses provide a comprehensive understanding of mosquito habitat suitability and the intensity of vector infestation within the study area.

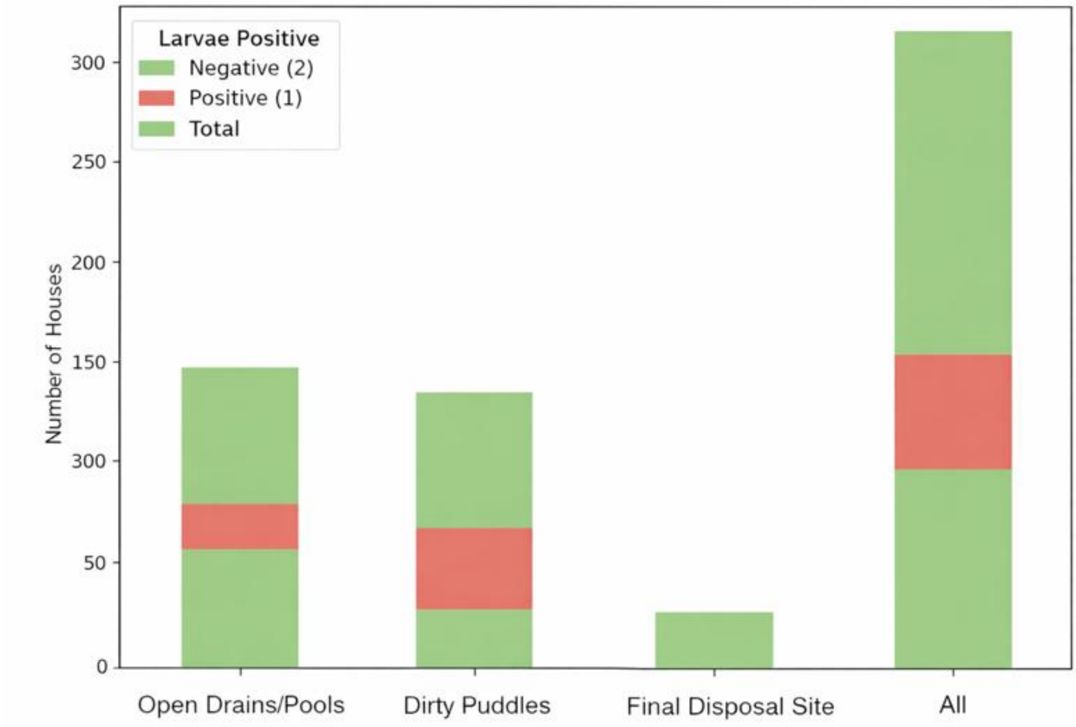

Fig. 5. Distribution of houses with potential mosquito breeding sites based on water source cleanliness and the presence of mosquito larvae in the sunville residence development area, Gowa

Figure 5 shows the distribution of houses with potential mosquito breeding sites based on the type of water stagnation (open drainage/open puddles, polluted stagnant water, and waste disposal areas) and the presence of mosquito larvae. The results indicate that most houses associated with open drainage or open stagnant water were larva-positive, with 10 houses recorded as having mosquito larvae, highlighting open drainage as the dominant breeding habitat. In comparison, houses located near polluted stagnant water and waste disposal areas also showed larval presence, but with a relatively lower proportion, suggesting that these areas may be better managed or less suitable for mosquito development than open drainage systems. Overall, these findings underscore the importance of managing stagnant water, particularly in open drainage channels, as a key strategy to reduce the risk of mosquito-borne diseases such as dengue fever and chikungunya through effective larval control in residential areas.

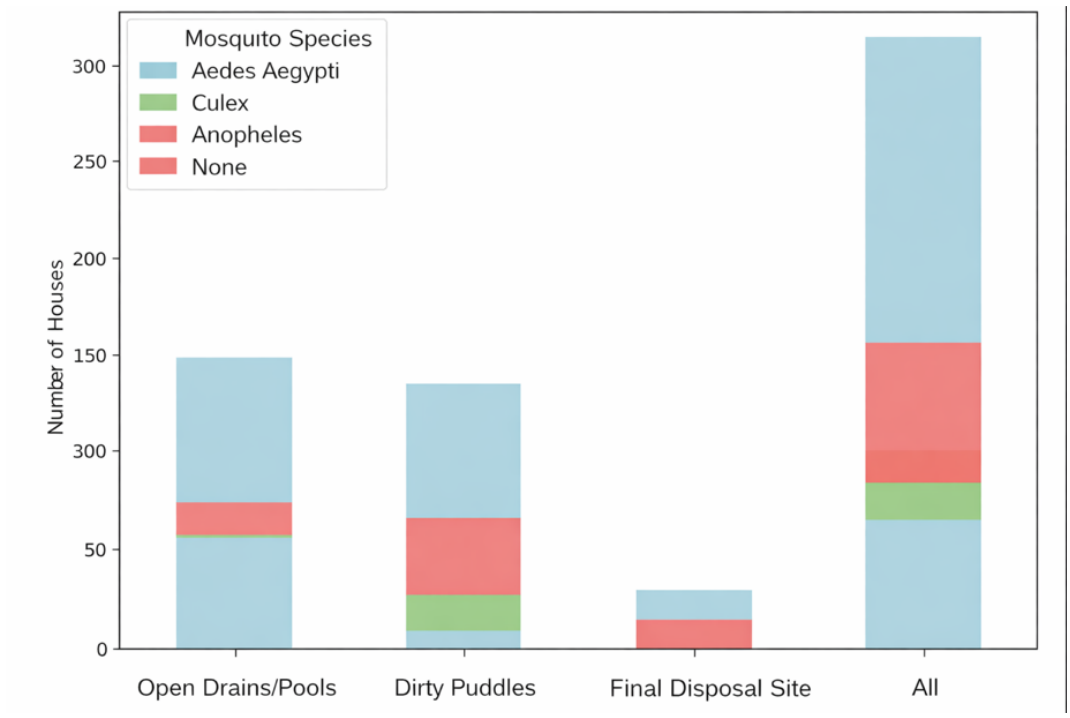

Fig. 6. Distribution of mosquito species in the vicinity of the Sunville Residence development site and its public health implications

Figure 6 shows the distribution of mosquito species based on potential habitats around the Sunville Residence housing development area in Gowa. In open drainage/open stagnant water areas, 60 houses were found to have Aedes aegypti, 9 houses had Culex, 5 houses had Anopheles, and 2 houses showed no mosquito presence. In polluted stagnant water areas, 16 houses were identified with Aedes aegypti, 12 houses with Culex, and 10 houses with no mosquitoes detected. In waste disposal areas, only 3 houses were found to have Aedes aegypti, while the majority of houses showed no mosquito presence. These findings indicate that Aedes aegypti is more prevalent in areas with open drainage and polluted stagnant water, thereby increasing the risk of mosquito-borne disease transmission, particularly dengue fever.

While the habitat distribution analysis identifies the environmental conditions that favor mosquito breeding, it does not quantify the magnitude of infestation. Therefore, entomological indices were subsequently calculated to provide standardized measurements of larval density and infestation levels. The Larva-Free Index (ABJ), House Index (HI), Container Index (CI), and Breteau Index (BI) were used to assess the extent of mosquito breeding and the associated public health risk in the study area. Following the analysis of mosquito breeding habitats and species distribution, quantitative entomological indices were calculated to provide a more comprehensive assessment of vector infestation and transmission risk in the study area. These indices include the Larva-Free Index (ABJ), House Index (HI), Container Index (CI), and Breteau Index (BI), each representing different aspects of mosquito larval distribution and breeding intensity.

3.1.2.2 Entomological indices Larva-Free Index (ABJ), House Index (HI), Container Index (CI), and Breteau Index (BI)

In the context of the Sunville Residence housing development in Gowa Regency, the Larva-Free Index (ABJ) is an essential entomological parameter for evaluating the effectiveness of mosquito control measures within the residential area. The ABJ is calculated by determining the proportion of houses that are free from mosquito larvae in relation to the total number of houses inspected. A higher ABJ indicates a lower mosquito presence, reflecting effective management of water stagnation and sanitation practices, which are crucial in reducing the transmission of mosquito-borne diseases such as dengue fever and chikungunya. In the Sunville Residence area, it is vital to implement mosquito control strategies that include the enhancement of the drainage system, proper management of stagnant water, and educational outreach to residents and the surrounding community regarding the importance of environmental cleanliness. Achieving a higher ABJ would contribute to a healthier living environment and help mitigate the negative health impacts associated with mosquito proliferation. The calculation of the larva-free index (ABJ) follows the formula:

$$ABJ = \left(\frac{\text{Number of Larva-Free Houses}}{\text{Total Number of Houses Inspected}}\right) \times 100\% \qquad \text{(Eq. 1)}$$

Based on the available data, the number of houses categorized as larva-free is 56, while there are still 2 houses identified as larva-positive. This indicates that although a portion of the inspected houses has met the criteria for being free from mosquito larvae, there are still findings that reflect the presence of breeding sites within the environment. Such conditions suggest that vector control measures have not yet been fully effective or evenly implemented across all households. Furthermore, the total number of houses inspected in this assessment is 159 units. This figure represents the overall scope of observation used to evaluate the environmental condition related to mosquito breeding. By comparing the number of larva-free houses with the total inspected houses, it becomes possible to assess the proportion of safe households and identify the level of risk for vector-borne disease transmission in the area. Thus, the ABJ calculation is:

$$ABJ = \left(\frac{56}{159}\right) \times 100\% = 35.22\% \qquad \text{(Eq. 2)}$$

Therefore, the Larva-Free Index (ABJ) is 35.22%, indicating that 35.22% of the inspected houses were free from mosquito larvae within the study area. An ABJ value of 35.22% reveals that only 35.22% of the houses were free from mosquito larvae, while approximately 64.78% of the houses remained exposed to mosquito larvae. This condition has significant public health and environmental implications for the Sunville Residence development area. The high proportion of larva-positive houses increases the risk of mosquito-borne disease transmission, including dengue fever, chikungunya, and Zika virus. The primary risk in this area is the high potential for mosquito breeding in various habitats, particularly in locations with stagnant water or poorly managed water-holding containers, which provide ideal environments for mosquito larvae. The elevated prevalence of larvae increases the likelihood of disease outbreaks, which could strain local healthcare systems and adversely affect community health. Furthermore, unmanaged water stagnation presents a persistent environmental risk by fostering ongoing mosquito proliferation. Given the relatively low ABJ value, it is imperative to enhance vector control measures in the Sunville Residence area through improved sanitation, better drainage systems, and community education on the management of stagnant water. If mitigation efforts are not taken seriously, health risks for both residents and the surrounding communities will increase, ultimately leading to a decline in quality of life and additional strain on local healthcare facilities. While the Larva-Free Index reflects the proportion of houses free from mosquito larvae, it does not directly indicate the extent of household infestation. Therefore, the House Index (HI) was calculated to determine the percentage of houses containing mosquito larvae and to provide a more direct measure of infestation intensity within the study area.

House Index (HI) is an entomological indicator used to assess the prevalence of mosquitoes and the presence of disease vectors, such as Aedes aegypti, the mosquito responsible for dengue fever. HI measures the proportion of houses infected with mosquito larvae in a specific area, calculated by comparing the number of houses with mosquito larvae to the total number of houses inspected. Generally, the higher the HI, the greater the

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potential for the transmission of mosquito-borne diseases in the area. HI is a critical tool in mosquito vector control, as it provides relevant information about high-risk areas, enabling more targeted mitigation efforts, such as water stagnation management, community outreach, and the implementation of effective mosquito control measures to prevent disease outbreaks. To calculate the House Index (HI) based on the given data, the formula is:

$$\mathrm{HI} = \left(\frac{\text{Number of Houses with Mosquito Larvae}}{\text{Total Number of Houses Inspected}}\right) \times 100\% \qquad \text{(Eq. 3)}$$

From the available data, the number of houses identified as having mosquito larvae is 103, while only 1 house is explicitly categorized as larva-positive. This statement is internally inconsistent and needs to be questioned: if 103 houses already "have mosquito larvae," then logically they should all be classified as larva-positive, not just one. The discrepancy suggests either a mislabeling of categories or an error in data recording, which undermines the reliability of the dataset and any subsequent analysis. In addition, the total number of houses inspected is reported as 159. When compared with the figure of 103 houses containing larvae, this would imply a very high prevalence of infestation, which contrasts sharply with the claim that only 1 house is larva-positive. Before proceeding with interpretation or calculation, the definitions of "houses with mosquito larvae" and "larva-positive houses" must be clarified and made consistent, otherwise any conclusions drawn from this data will be methodologically flawed. Thus, the calculation is:

$$\mathrm{HI} = \left(\frac{103}{159}\right) \times 100\% = 64.78\% \qquad \text{(Eq. 4)}$$

The House Index (HI) for the area is 64.78%, indicating that 64.78% of the inspected houses are infected with mosquito larvae. This value suggests a significant health risk for the area, as it implies that almost two-thirds of the houses are exposed to mosquitoes, which are the primary vectors for diseases like dengue fever, chikungunya, and Zika virus. The high HI indicates a critical need for effective vector control measures to reduce the risk of disease transmission. A high HI, such as 64.78%, points to the increased risk of mosquito-borne disease outbreaks, especially if no effective control measures are implemented. With more than 60% of houses affected, there is a greater potential for disease transmission, particularly during the rainy season or when environmental conditions favor mosquito breeding. This condition could strain the local healthcare system and increase the number of cases requiring medical attention. The high HI also indicates that environmental management in the Sunville Residence area has not been optimized for mosquito control. It is crucial to improve water stagnation management, conduct regular sanitation maintenance, and educate the community about preventing mosquito breeding. Immediate action, including sanitation management, routine inspections for water stagnation, the use of larvicides, and public education, is necessary to mitigate these risks and ensure the health and safety of the surrounding community. Although the House Index describes the proportion of infested houses, it does not identify the contribution of water-holding containers as breeding sites. Therefore, the Container Index (CI) was calculated to assess the proportion of larva-positive containers, providing further insight into the availability of breeding habitats and the effectiveness of environmental sanitation practices.

The Container Index (CI) is an entomological parameter used to assess the prevalence of containers that serve as breeding sites for mosquitoes, particularly in the context of controlling disease vectors such as dengue fever, chikungunya, and malaria. CI measures the proportion of containers found to contain mosquito larvae out of the total number of containers inspected within a specific area. Containers that serve as mosquito breeding sites often include items like bathtubs, flowerpots, buckets, or any other water-holding containers. By using CI, we can determine the extent to which containers in a particular environment can support mosquito larvae development. The higher the CI value, the more containers are at risk of becoming mosquito breeding grounds, indicating the need for intensive management actions, such as emptying containers, maintaining cleanliness, and conducting community outreach. CI is an essential tool in mitigating the risk of mosquito-borne disease transmission, with a focus on managing containers that may serve as mosquito habitats. To calculate the Container Index (CI), the following formula is used:

$$\mathrm{CI} = \left(\frac{\text{Number of Containers with Mosquito Larvae}}{\text{Total Number of Containers}}\right) \times 100\% \tag{Eq. 5}$$

From the available data, the number of containers identified as having mosquito larvae is 192 out of a total of 474 containers inspected. This indicates that a substantial portion of water-holding containers in the observed area serves as potential breeding sites for mosquitoes. The presence of larvae in these containers reflects inadequate control of standing water and suggests that environmental management practices are not being implemented consistently.

When these figures are compared, it becomes evident that the proportion of larva-positive containers is relatively high, which can increase the risk of vector-borne disease transmission. A large number of positive containers implies that intervention efforts—such as regular cleaning, covering water storage, or eliminating unused containers—may not yet be effective or widely adopted. Therefore, strengthening community participation and improving routine vector control measures are essential to reduce the number of larva-positive containers and improve overall environmental health conditions. Thus, the calculation is:

$$\mathrm{CI} = \left(\frac{192}{474}\right) \times 100\% \approx 40.5\% \tag{Eq. 6}$$

Therefore, the Container Index (CI) for the area is 40.5%, indicating that 40.5% of the containers inspected contained mosquito larvae. A CI value of 40.5% indicates that approximately 40.5% of the containers inspected contain mosquito larvae, representing a significant risk for disease transmission in the Sunville Residence development area. This relatively high CI suggests that nearly half of the containers in the area are mosquito breeding grounds, such as buckets, bathtubs, flowerpots, or other water-holding containers. These containers serve as ideal habitats for mosquito larvae, particularly Aedes aegypti, which can transmit diseases like dengue fever, chikungunya, and Zika virus.

The primary risk associated with a high CI is the increased likelihood of mosquito infestation in the environment, which heightens the potential for disease outbreaks transmitted by mosquitoes. If environmental sanitation and water stagnation management are not improved, the risk of disease transmission will continue to rise, worsening the public health situation and adding strain to local healthcare facilities. Therefore, managing water-holding containers must be a top priority in vector control programs within the Sunville Residence area. This includes regular container inspections and cleaning, community education on the importance of maintaining environmental cleanliness, and the use of larvicides in containers that are difficult to clean manually. With these measures, the risk of mosquito-borne disease transmission can be significantly reduced, ensuring the health and safety of residents and the surrounding environment. To complement the previous indicators, the Breteau Index (BI) was subsequently calculated as a comprehensive measure of larval infestation. By relating the number of positive containers to the surveyed households, the BI provides an integrated assessment of mosquito breeding intensity and the potential risk of vector-borne disease transmission in the study area.

3.1.3.3 Briteau index

The Briteau Index (BI) is an entomological parameter used to assess the level of mosquito infestation in an area, particularly in relation to the management of disease vectors such as dengue fever and malaria. BI measures the ratio between the number of houses infected with mosquito larvae and the number of containers containing larvae in a specific area. Essentially, the Briteau Index combines two key indicators—House Index (HI) and Container Index (CI)—to provide a more comprehensive understanding of mosquito prevalence, distribution, and the environmental factors that support their breeding. BI is commonly used to assess the severity of mosquito infestations and to help design more effective control strategies. A high BI value indicates that both the number of houses infected and the number of containers containing mosquito larvae in the area are significant, requiring more intensive vector control efforts such as improved sanitation and better management of water stagnation. To calculate the Briteau Index (BI), the following formula is used:

$$\mathrm{BI} = \left(\frac{\text{Number of Houses with Mosquito Larvae}}{\text{Number of Containers with Mosquito Larvae}}\right) \times 100 \qquad \text{(Eq. 7)}$$

From the available data, 103 houses are identified as having mosquito larvae, alongside 192 containers that are also found to contain larvae. This indicates that the presence of larvae is not only widespread at the household level but is also strongly associated with multiple breeding sites within those houses. In other words, the infestation is not isolated; rather, it reflects a pattern where one affected house may contribute several larva-positive containers, amplifying the overall risk. However, the data as presented is analytically incomplete and potentially misleading if taken at face value. Without information on the total number of houses and the total number of containers inspected, these figures cannot be translated into meaningful indices such as House Index or Container Index. As a result, any interpretation about severity, prevalence, or comparative risk remains weak and methodologically insufficient, and the dataset requires completion before it can support rigorous conclusions. Thus, the calculation is:

$$\mathrm{BI} = \left(\frac{103}{192}\right) \times 100 \approx 53.65 \qquad \text{(Eq. 8)}$$

Therefore, the Briteau Index (BI) for the area is 53.65, indicating the ratio between the number of houses with mosquito larvae and the number of containers with larvae in the area. With a Briteau Index (BI) of 53.65, which indicates the ratio of houses infected with mosquito larvae to the number of containers with larvae around the Sunville Residence development area, the risk of mosquito-borne disease transmission is significant. A BI above 50% indicates that nearly half of the containers with mosquito larvae are also linked to houses with mosquito larvae. This shows a strong correlation between the presence of contaminated containers and house infestations in the surrounding area. The risk associated with a high BI is the increased potential for the spread of diseases such as dengue fever, chikungunya, and Zika. With a high BI, it is evident that the presence of mosquito larvae is not limited to contaminated containers but also spreads to nearby houses. This underscores the need for greater attention to sanitation and environmental cleanliness management around the Sunville Residence area. Mitigation efforts should include better water stagnation management, routine inspections and maintenance of containers, and community outreach to reduce the presence of mosquito larvae in residential environments. Without proper control measures, the risk of disease transmission in the area will continue to increase, burdening the local healthcare system and reducing residents' quality of life. Importantly, the BI value should be interpreted with caution because the calculation presented does not follow the standard BI formulation, which is generally based on the number of positive containers per 100 houses inspected. Therefore, the reported value of 53.65 should not be used as definitive evidence of high transmission risk unless the denominator and calculation method are verified against the complete surveillance data.

3.2 Discussion

3.2.1 Impact of poor drainage and urbanization on mosquito habitat proliferation and vector-borne disease risk in Gowa, South Sulawesi

This study found a significant correlation between flood risks and the proliferation of mosquito habitats in Gowa, South Sulawesi. Areas with inadequate drainage systems and prolonged water stagnation were identified as high-risk zones for mosquito breeding, particularly for Aedes aegypti, the primary vector for diseases such as dengue and Zika virus. The research highlighted that poorly managed open drainage systems, combined with the rapid urbanization of flood-prone settlements, create optimal conditions for mosquito larvae development. These findings underscore the critical role of environmental infrastructure in controlling vector-borne diseases, emphasizing the need for improved drainage systems and targeted mosquito control strategies in flood-prone areas. Specifically, the study's results from Gowa align with broader global observations, where rapid urbanization and insufficient infrastructure in tropical regions exacerbate dengue outbreaks by creating widespread breeding sites for Aedes aegypti (Silva & Bastos, 2025). This situation is often worsened by the accumulation of solid waste, which blocks drainage systems and creates additional stagnant water bodies, providing ample breeding grounds for these vectors (Charlesworth et al., 2022). For instance, communities in Brazil and Indonesia have shown that poor drainage and waste management directly contribute to increased Aedes aegypti populations and, consequently, higher rates of dengue and Zika virus infections (Alfian et al., 2025; Charlesworth et al., 2022).

3.2.2 Impact of drainage, urbanization, and waste management on mosquito habitats and disease risks

The findings of this study align with previous research, which emphasizes the role of inadequate drainage and water stagnation in the proliferation of mosquito habitats, particularly in urbanized flood-prone areas (Sharma, 2022). Moreover, flood-sensitive areas require urgent mapping to develop actionable plans that address vector-borne diseases by considering climate change, vector biology, and disease transmission dynamics at both macro and micro levels. The observed correlation between poorly managed drainage systems and the spread of Aedes aegypti in Gowa is consistent with the findings of study who highlighted the critical role of stagnant water in facilitating mosquito breeding in tropical regions. This study further reinforces the understanding that local environmental conditions, including temperature, humidity, and the built environment, significantly influence mosquito populations and subsequent disease transmission (Rosser et al., 2024; Souza et al., 2023).

Furthermore, the presence of various water-holding containers, often exacerbated by human-related factors such as poor household cleanliness and inadequate waste management, provides numerous potential breeding sites for Aedes aegypti (Malarvizhi et al., 2023; Prameswarie et al., 2023). Similarly, other studies have shown that urbanization and improper waste management are key factors exacerbating the risk of vector-borne diseases like dengue and Zika virus in other parts of the world, including Brazil and Indonesia (Rosser et al., 2024; Souza et al., 2023). In these regions, a lack of consistent waste removal and inadequate storm drainage systems contribute to the accumulation of stagnant water, which fosters ideal conditions for Aedes mosquito proliferation, particularly in informal settlements (Malarvizhi et al., 2023). Our results underscore the global nature of these challenges, where poor infrastructure in rapidly urbanizing areas creates ideal conditions for disease vectors, highlighting the need for comprehensive urban planning that integrates robust waste management and effective drainage solutions to mitigate public health risks associated with vector-borne diseases (Bhatia et al., 2022; Rodrigues et al., 2021). This approach is essential given that factors such as human population density, infrastructure development, and climatic conditions significantly influence the existence, success, and spread of Aedes aegypti (Nurjanah, 2022).

3.2.3 Limitations and areas for improvement in assessing mosquito habitats and flood risk in Gowa, South Sulawesi

This study had several limitations that may influence the interpretation of the results. Firstly, the research was conducted in a specific area of Gowa, South Sulawesi, and may not fully represent other flood-prone regions with different environmental or socio-economic conditions. Additionally, the study's cross-sectional design limited our ability to observe seasonal variations in mosquito breeding patterns, which could impact the generalizability of the findings across different times of the year. Future longitudinal studies are therefore needed to assess the temporal dynamics of vector populations and disease incidence in relation to seasonal flooding patterns. Moreover, comprehensive research incorporating diverse geographical settings and advanced predictive modeling will be crucial to fully understand the complex interplay between hydrological extremes, urbanization, and the epidemiology of vector-borne diseases. The availability and accuracy of historical flood data were also constrained, affecting the ability to comprehensively assess long-term flood risk trends.

Furthermore, while the study focused on household-level environmental factors, broader community-level data and vector control interventions were not fully incorporated, which could provide a more holistic understanding of the problem. Future investigations should integrate stormwater drainage models, such as the Storm Water Management Model, to precisely represent rainfall events and their effects on drainage systems, thereby providing a thorough assessment of pluvial flooding contributions (Wulandari et al., 2025). Lastly, the reliance on visual inspections and manual mosquito larvae collection might have overlooked smaller, less visible breeding sites, potentially underestimating the true extent of mosquito habitat distribution. These limitations should be considered when interpreting the findings, and future research could benefit from a longitudinal approach, more comprehensive data collection, and broader geographic scope. Furthermore, integrating multi-hazard analyses that encompass other prevalent natural disasters in Indonesia, such as volcanic eruptions, earthquakes, tsunamis, and landslides, alongside flood risk assessments, would offer a more comprehensive understanding of community vulnerabilities (Sigit et al., 2023).

3.2.4 Recommendations for expanding mosquito habitat research and improving vector control strategies

Future research should focus on exploring the seasonal variations in mosquito breeding patterns to better understand how changes in weather and flooding influence vector populations throughout the year. Additionally, broader spatial coverage with larger sample sizes would increase the statistical reliability of findings, moving beyond single-district observations to encompass regional variations in vector dynamics (Nayak et al., 2025). Moreover, the incorporation of socio-demographic factors like hygiene behavior, household economic status, and sanitation, alongside robust monitoring of case determination, will refine predictive models for disease risk (Giofandi et al., 2023). Expanding the research to include a broader geographic scope, including different urban and rural settings in South Sulawesi and other regions, would enhance the generalizability of the findings.

Furthermore, a longitudinal study design could provide deeper insights into the long-term effects of infrastructure improvements, such as drainage system upgrades, on mosquito habitat proliferation and disease transmission. Moreover, future studies should differentiate between Aedes aegypti and Aedes albopictus larvae for more accurate vectorial capacity assessments, as well as investigate breeding site characteristics such as pH, water temperature, and vegetation (Ane et al., 2021; Lusiyana, 2024). Finally, integrating community-level data and considering socio-economic factors would allow for a more comprehensive understanding of how local practices and resources impact vector control efforts and disease prevention. Such comprehensive data would enable the development of more targeted and effective interventions, improving public health outcomes in flood-prone urban environments (Murphy et al., 2022; Nayak et al., 2025).

4. Conclusions

This study underscores the critical relationship between flood risks and the proliferation of mosquito habitats in Gowa, South Sulawesi. The research highlights how inadequate drainage systems, prolonged water stagnation, and rapid urbanization create favorable conditions for Aedes aegypti, the primary vector for diseases such as dengue, Zika virus, and chikungunya. Areas with poor infrastructure, such as open drainage systems and improper waste management, significantly contribute to the formation of mosquito breeding grounds. By integrating field surveys with advanced Geographic Information System (GIS) spatial mapping, the study identifies high-risk zones for disease transmission, emphasizing the urgent need for comprehensive urban planning, improved drainage systems, and effective mosquito control strategies in flood-prone areas. These findings demonstrate that the combination of environmental and infrastructural factors, along with human behavior and local practices, plays a pivotal role in controlling or exacerbating the spread of vector-borne diseases. Furthermore, the research highlights the broader implications of climate change and urbanization, where extreme weather events and inadequate urban management increase vulnerability to disease outbreaks. The results align with global observations that poor infrastructure and rapid urban expansion contribute to the rise in mosquito-borne diseases. This underscores the need for a multi-faceted approach, combining environmental management, community education, and improved public health infrastructure to mitigate the public health risks associated with flooding. The study also provides essential data for future research, offering a framework for interventions and highlighting the importance of long-term strategies to reduce vector habitats and disease transmission. Through these insights, the study provides a valuable foundation for further research and intervention strategies aimed at reducing the health impact of vector-borne diseases in vulnerable communities, contributing to global efforts in managing public health risks in flood-prone regions.

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Author Contribution

Conceptualization, Z. J. and Z; Methodology, N. H.; Software, S. A. H; Validation, Z. J. and Z.; Formal Analysis, N. H.; Investigation, Z.; Resources, S. A. H.; Data Curation, F. N. and Z.;

Writing—Original Draft Preparation, Z. J.; Writing—Review & Editing, N. H.; Visualization, N. H.; Supervision, Z. J.; Proje ct Administration, S. A. H.; Funding Acquisition, Z. J.

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Declaration of Generative AI Use
During the preparation of this work, the authors used ChatGPT to assist in generating initial drafts, refining academic phrasing, and improving the clarity of arguments, and Grammarly to assist in enhancing grammar, readability, and overall language quality. After using these tools, the authors carefully reviewed, revised, and validated all content to ensure accuracy and coherence, and take full responsibility for the content of the publication.

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