

Multidimensional Drivers of Dengue Transmission in Kalimantan: Climate, Spatial, Entomological, Behavioral, and Socioeconomic Factors - A Systematic Literature Review

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ABSTRACT

Dengue fever (DF) remains a significant public health problem in Kalimantan. Its transmission is influenced by the interaction of multiple factors, including climate, spatial conditions, entomological aspects, behavioral factors, and socioeconomic conditions. However, scientific evidence regarding these factors in Kalimantan remains limited and has not been comprehensively synthesized. This study aims to examine the climatic, spatial, entomological, behavioral, and socioeconomic drivers of dengue transmission in Kalimantan to inform future control strategies. This study employed a systematic literature review design following the PRISMA 2020 guidelines. A total of 7,410 articles published between 2016 and 2025 were identified from several databases, of which 7 articles met the inclusion criteria and were included in the final analysis. Data were analyzed using narrative synthesis by grouping key findings. The results show that DF incidence in Kalimantan is spatially heterogeneous and forms risk clusters associated with population density and settlement structure. Climatic factors, particularly temperature, humidity, and rainfall, influence seasonal patterns of DF, but do not fully explain variations in risk across regions. Evidence related to entomological and behavioral dimensions remains limited, despite their important role in modifying transmission risk. Socioeconomic factors are generally assessed using proxy indicators. DF in Kalimantan is a multidimensional phenomenon that requires an integrative and predictive research approach to support effective control strategies.

Keywords: dengue fever; Kalimantan; spatial; entomology; behavior;

INTRODUCTION

Dengue fever remains a serious public health challenge in Indonesia and continues to pose a significant burden in tropical regions. In recent years, Kalimantan has emerged as one of the regions in Indonesia where dengue transmission continues to occur in a variety of ecological and socio-environmental settings, with peak incidence typically occurring during the rainy season from January to May.¹ To date, dengue fever continues to show fluctuations in incidence rates and an upward trend in various endemic areas, especially in regions with environmental conditions that support vector development². Although climatic factors such as temperature, rainfall, and humidity are widely recognized as important drivers of dengue

transmission, a growing body of evidence suggests that climate-based explanations alone are insufficient to account for the striking spatial heterogeneity in dengue risk observed in Kalimantan.³

Kalimantan represents a unique epidemiological context in Indonesia. Unlike densely populated urban areas such as Java, Kalimantan is characterized by vast forest landscapes, rapid land use change, growing urban settlements, and heterogeneous levels of infrastructure development. The increase in dengue fever incidence is influenced by a combination of environmental conditions, community behavior, and the presence of vectors that support disease transmission.^{2,3} These

features shape vector ecology, breeding site availability, and human-vector interactions in ways that differ from the classic urban dengue setting. As a result, dengue transmission in Kalimantan occurs not only in urban centers but also in suburban and rural areas, resulting in complex spatial patterns of risk that cannot be adequately captured by climate-based models alone.

Climatic conditions play an important role in dengue transmission. Based on several studies, the main climatic factors contributing to the spread of dengue include temperature, humidity, rainfall, and wind speed. Higher temperatures can accelerate the maturation process of mosquitoes and increase their capacity for disease transmission.¹ Studies show that both minimum and maximum temperatures significantly affect the incidence of dengue fever.⁴

Rainfall creates breeding grounds for mosquitoes by providing standing water. The relationship between rainfall and dengue fever incidence has been observed in several studies.⁵ High relative humidity is another critical factor, as it affects the survival and reproduction of mosquitoes. Studies show that relative humidity is significantly associated with dengue fever incidence.^{6,7} Wind speed also greatly affects mosquito flight behavior, spatial vector distribution, and the chance of contact between mosquitoes and humans, thereby increasing the likelihood of dengue transmission, while excessively strong winds can inhibit mosquito flight activity.⁸

Climate change, including changes in temperature, rainfall, and humidity, as well as extreme weather events, has a significant impact on the mosquito life cycle and the rate of dengue transmission.⁹ Studies show that abnormally wet months significantly increase mosquito populations. The transmission of dengue fever is greatly influenced by various environmental factors that affect the breeding and survival of *Aedes* mosquitoes, and *Aedes* mosquitoes require stagnant water for breeding. These factors collectively accelerate the growth of mosquito populations, expand their geographical range, and increase the potential for dengue fever outbreaks.

In addition to climate and environmental factors, entomological factors play a critical role in shaping the dynamics of dengue transmission in Kalimantan, which is generally measured through larval density indicators such as the Larval Index (LI), House Index (HI), Container

Index (CI), and Breteau Index (BI).¹⁰ High vector density has been shown to be closely related to an increase in dengue fever cases. Therefore, vector control is one of the main strategies in dengue fever prevention efforts in endemic areas. Vector factors are the most significant direct determinants of dengue fever incidence. The presence of larvae, low ABJ values, and high *Aedes* mosquito density have been shown to be significantly associated with an increase in dengue incidence.¹¹ In addition, low AHI and high *Aedes* mosquito density were found to be significantly associated with an increase in dengue fever cases, especially in areas that spatially showed high case clusters.¹² However, many dengue fever studies conducted in Kalimantan still rely on aggregate case data and meteorological variables, while direct entomological indicators remain underrepresented. This limitation reduces the ability of existing research to explain the biological pathways linking environmental conditions to dengue fever incidence and to provide input for locally appropriate vector control strategies.

Another equally important factor is socioeconomic factors, because behavioral and social dimensions also mediate the risk of dengue fever in Kalimantan. Community knowledge, attitudes, and practices related to water storage, waste management, and participation in vector control programs directly influence the persistence of breeding sites and the effectiveness of dengue fever prevention efforts.¹³

In Kalimantan, where the socio-cultural context and access to infrastructure vary significantly between districts, behavioral heterogeneity can substantially alter dengue transmission patterns.¹⁴ However, behavioral factors are often analyzed separately from spatial and entomological analyses, resulting in fragmented evidence that fails to capture the multidimensional nature of dengue risk.

Although several studies from Malaysian Borneo provide useful comparative insights particularly regarding vector ecology in rural and suburban environments evidence specific to Indonesian Kalimantan remains limited and uneven in scope. Many studies focus on a single dimension, typically climate or spatial distribution, without systematically integrating entomological and behavioral indicators. As a result, there is a lack of comprehensive synthesis reflecting the unique ecological and social context of Kalimantan in Indonesia. A systematic synthesis

of available evidence is essential to move beyond climate-centered perspectives and toward a holistic understanding of dengue transmission in Kalimantan, while carefully utilizing evidence from neighboring regions in Borneo for contextual comparison.

This review aims to analyze how dengue transmission varies across different regions in Kalimantan, evaluate the extent to which entomological evidence has been integrated into dengue research, and assess the role of community knowledge, attitudes, and practices in shaping dengue risk. Evidence from other parts of Borneo, including Malaysian Borneo, is selectively used to provide contextual comparisons and highlight similar ecological features and methodological gaps. By identifying key limitations in the current evidence base, this review aims to inform future research directions and support the development of more effective, spatially explicit, and context-sensitive dengue prevention and control strategies tailored to Kalimantan.

METHOD

Study Design

This study employed a systematic literature review (SLR) design conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure a transparent, systematic, and reproducible process in synthesizing existing evidence on dengue fever in Kalimantan/Borneo, with a particular focus on climatic, environmental, socioeconomic, vector-related, spatial, and predictive aspects on dengue fever in Kalimantan. PRISMA was used in this study because it allows for the search of terms related to the review and also provides important considerations necessary in reporting the review for publication.¹⁵

Search Strategy

To ensure a wide coverage of peer-reviewed literature, a comprehensive literature search was conducted using several international scientific databases, such as Scopus, ScienceDirect (Elsevier), Emerald Insight, and Pubmed. The search strategy was designed to capture studies related to dengue transmission by integrating key concepts of climate, spatial factors, vectors, and socioeconomic aspects. The search approach integrated free-text phrases associated with dengue, climate, and spatial analysis with regulated vocabulary. The following

keyword combinations were included in the primary search string: *dengue* AND (*climate* OR *rainfall* OR *temperature* OR *humidity*) AND (*socioeconomic* OR *vector* OR *mosquito* OR *breeding site* OR *spatial* OR *prediction*) AND (*Kalimantan* OR *Borneo*). Search terms were applied to titles, abstracts, and keywords. Reference lists of eligible articles were also screened to identify additional relevant studies. To increase transparency and ensure comprehensive coverage, the reference lists of eligible articles were also manually screened to identify additional relevant studies that may not have been covered by the database search.

Study Selection and Data Extraction

Studies that meet the established criteria are original research articles that have been peer-reviewed and published between 2016 and 2025 that examine dengue fever in Kalimantan or the wider Borneo region in relation to climatic, environmental, socioeconomic, vector, spatial, or predictive factors. Review articles, non-empirical studies, conference abstracts without full text, studies conducted outside the study area, and non-English publications were excluded.

Study selection was conducted in three stages: removal of duplicates, screening of titles and abstracts, and assessment of full texts for eligibility. Information such as author affiliation, year of publication, location, design, key variables, analytical methods, and main results were entered into a standardized form used for data extraction. The extracted data were synthesized narratively and summarized in tabular form. During the extraction process, key variables such as study location, study design, main variables (spatial, entomological, behavioral, and socioeconomic factors), and main findings were systematically coded using a standard framework. Disagreements in data interpretation were resolved through discussion and re-examination of the original articles until consensus was reached.

Analysis Data

A narrative and thematic synthesis approach was used to analyze data in this systematic literature review. AW was the principal investigator of the analysis, and he conducted the extraction of data, thematic grouping, and synthesis of results from the included studies. The studies that were included focused on spatial patterns, climatic and environmental factors, entomological indicators, and behavioral elements related to dengue transmission. TJ, M,

and N supervised the analytical process and the interpretation of the results. They also provided methodological guidance and critical input to ensure the synthesized evidence was coherent, consistent, and robust.

RESULT

The study selection process was conducted in accordance with PRISMA guidelines. A total of 7,410 records were identified from four main databases (Scopus, ScienceDirect, PubMed, and Emerald Insight). After removing duplicate records ($n = 54$) and filtering out irrelevant records through automated screening and other means ($n = 6,580$), 776

records remained for title and abstract screening. Of these, 586 records were excluded because they did not meet the inclusion criteria.

A total of 190 reports were retrieved to obtain the full text, but 134 reports could not be obtained. Furthermore, 56 articles were assessed for eligibility, and 51 articles were excluded because they were not original research, were not located in Kalimantan/Borneo, did not involve human subjects, or had low methodological quality. Finally, 7 studies met all criteria and were included in the final synthesis, which highlighted the limited number of high-quality studies specifically addressing dengue in Kalimantan/Borneo.

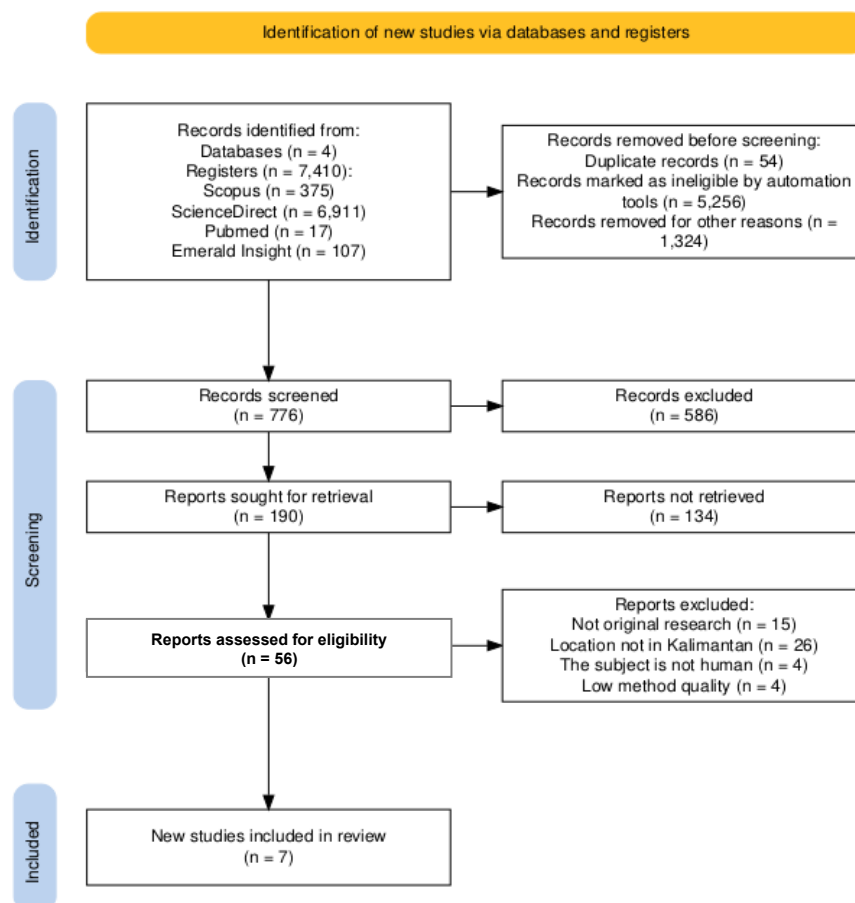


Figure 1. Systematic Review Flow ¹⁶

Based on the study selection flowchart using the PRISMA approach, the initial identification process yielded a total of 7,410 articles obtained from four main databases, namely Scopus (375 articles), ScienceDirect (6,911 articles), PubMed (17 articles), and

Emerald Insight (107 articles). In the initial stage, data cleaning was carried out before screening, resulting in the removal of 54 duplicate articles, 5,256 articles automatically eliminated by the screening tool, and 1,324 articles removed for other reasons, leaving 776 articles to enter the

screening stage. During the title and abstract screening stage, 586 articles were excluded because they were not relevant to the research focus. Subsequently, 190 articles were identified for full-text retrieval, but 134 articles could not be obtained and therefore could not be analyzed further. At the eligibility assessment stage, several articles were again eliminated because they did not meet the research inclusion criteria, namely not original research (15 articles), the

research location was not in Kalimantan (26 articles), the research subjects were not human (4 articles), and the quality of the research methods was low (4 articles). After going through all these rigorous selection stages, 7 articles were finally declared to meet the criteria and were included in the systematic review, which was then analyzed to identify multidimensional factors that influence the transmission of dengue fever in the Kalimantan region.

Table 1. Summary of reviewed articles

Author (Years)	Location	Variabel	Method	Main Result
Husnina et al. (2019)	Kalimantan (Indonesia)	Minimum temperature, humidity, forest cover, population density	Spatiotemporal Bayesian (ZIP regression)	Dengue risk increases with minimum temperature and decreases with humidity; hotspots in North and East Kalimantan. ¹
Risva et al. (2018)	Berau, Kalimantan Timur	Rainfall, drainage, water bodies, population density	GIS spatial vulnerability mapping	The vulnerability to dengue fever fluctuates and is influenced by climatic, environmental, and human factors. ¹⁷
Ridha et al. (2025)	Banjarmasin, South Kalimantan, Indonesia	Dengue fever incidence; temperature, humidity, rainfall	Retrospective ecological study; seasonal decomposition; path analysis; GIS	Climate variables significantly influence seasonal patterns and trends in dengue fever incidence, with temperature being the dominant factor, while rainfall and humidity contribute directly and indirectly. ¹⁸
Murphy et al. (2020)	Sabah, Borneo (Malaysia)	Spatial cases, Aedes vector	Spatio-temporal analysis & entomology	High dengue incidence in rural areas; Aedes albopictus dominant. ¹⁹
Jayaraj et al. (2019)	Tawau, Sabah, Malaysia (Borneo)	Dengue fever incidents; maximum, minimum, and average temperatures; relative humidity; rainfall	Time-series ecological studies; Spearman correlation; Poisson regression; SARIMA; SARIMA with external regressors	Variations in climatic factors, particularly temperature and humidity, are consistently associated with the dynamics of dengue transmission, and predictive models that incorporate delayed climate variables show significant performance and are key to predicting short-term dengue outbreaks in Kalimantan. ¹¹

Author (Years)	Location	Variabel	Method	Main Result
Norjanah & Ridha (2024)	Hulu Sungai Selatan, South Kalimantan, Indonesia	Dengue incidents; population density	Spatial ecology study; Moran's I; LISA	Dengue incidents show spatial autocorrelation and are associated with population density, especially in residential activity centers. ²⁰
Ridha et al. (2023)	Samarinda, East Kalimantan, Indonesia	Knowledge, attitude, behavior (KAB); implementation of G1R1J	Quasi-experimental with control; pre post test; t-test	Cadre-based interventions significantly improved community knowledge and behavior in dengue control, although changes in attitudes were relatively limited. ²¹

Based on a synthesis of study results summarized in the table, dengue fever (DF) in Kalimantan and the Borneo region is influenced by a combination of interacting climatic, spatial, vector, behavioral, and socioeconomic factors. Research findings indicate that variations in temperature, humidity, and rainfall contribute to the seasonal patterns of DHF, while population density and settlement structure form spatial risk clusters. In addition, vector characteristics and community behavior in DHF control also modify the risk of transmission. The diversity of approaches and results between these studies confirms that the dynamics of DHF in Kalimantan are multidimensional and cannot be explained by a single factor.

1. Climate Dimension of Dengue

Climate factors play an important role in shaping the dynamics of dengue transmission in Kalimantan and the wider Borneo region. Several studies have shown that temperature, rainfall, and humidity affect mosquito breeding, survival, and virus transmission. For example, Husnina et al. found that the risk of dengue fever increases with rising minimum temperatures, while higher humidity tends to reduce the risk of transmission, highlighting the complex relationship between climate variables and the distribution of dengue fever.¹ Similarly, Ridha et al. reported that temperature significantly affects the seasonal pattern of dengue fever incidence in Banjarmasin, with rainfall and humidity contributing both directly and indirectly to transmission dynamics.²¹ These findings indicate that climatic conditions influence the seasonal variability of dengue fever cases by altering the rate of mosquito

development and the length of the transmission cycle.

Additional evidence from the Borneo region also supports the strong influence of climate variability on dengue outbreaks. Time series analysis conducted by Jayaraj et al. shows that fluctuations in temperature and humidity are consistently associated with changes in dengue incidence, while predictive models that incorporate lagged climate variables can effectively predict short-term dengue outbreaks⁽¹¹⁾. Furthermore, environmental studies show that rainfall and water accumulation create ideal breeding grounds for *Aedes* mosquitoes, increasing the risk of transmission in areas with poor drainage or dense settlements.¹⁷ These findings highlight that climatic conditions not only influence vector ecology but also interact with environmental and human factors, making climate an important determinant in understanding dengue transmission patterns in Kalimantan and surrounding areas.

2. Spasial Dimension of Dengue

Based on the studies reviewed, the transmission of dengue fever (DF) in Kalimantan and Borneo shows strong spatial heterogeneity. The risk of DF is not evenly distributed, but rather forms clusters or hotspots in certain areas. In her research, Husnina identified dengue fever risk hotspots in North Kalimantan and East Kalimantan, which are influenced by a combination of climate factors and population density.¹ This finding is reinforced by Norjanah & Ridha, who showed the existence of spatial autocorrelation of dengue fever cases.²⁰ Especially in areas with high concentrations of residential activity.²² This indicates that spatial

structure, settlement patterns, and population distribution play an important role in shaping dengue transmission patterns.²³ Because densely populated areas, especially at district intersections and urban-rural fringes, are often hotspots for dengue fever transmission.^{24,25}

In addition, a study in the Malaysian Borneo region by Murphy mentions that dengue fever cases are not only concentrated in urban areas, but are also significant in rural and peri-urban areas.²⁶ This finding challenges the classic paradigm that dengue fever is solely an urban disease, and emphasizes the importance of a spatial approach that considers variations in geographical and ecological contexts.^{22,27} This is possible because dengue fever cases tend to be clustered and not evenly distributed, especially in areas with high population density and intense residential activity.²⁸ This condition is relevant to the characteristics of Kalimantan, which has a combination of urban, peri-urban, and rural areas, so that the risk of dengue fever is not only limited to city centers, but also arises in areas with limited infrastructure access.²⁹

3. Entomological Dimension of Dengue

The entomological dimension of dengue fever research in Kalimantan is still relatively limited, but available evidence points to the important role of vectors in determining the risk of transmission. Murphy reported the dominance of *Aedes albopictus* in rural areas of Borneo, demonstrating the vector's ability to adapt to non-urban environments.¹⁹ These findings are relevant to the conditions in Kalimantan, which has a vast landscape, forest areas, and scattered rural settlements. The presence and density of *Aedes aegypti* mosquitoes are very important in the transmission of dengue fever, so it is important to assess the risk^{30,31}, namely by analyzing and calculating its existence through its habitat or breeding grounds.

Various studies show that dengue control becomes more effective when community-based and spatial approaches are applied in a targeted manner. This is because community-based interventions can significantly reduce entomological indices and emphasize the importance of community involvement in vector control.³² This confirms that household breeding sites are the main contributors to vector density, making eco-bio-social approaches more accurate in controlling dengue.³³

From a spatial perspective, it shows that dengue transmission is highly localized, with certain houses or areas acting as the main

sources of transmission, so interventions focused on clusters and high-risk locations have proven to be more efficient than general approaches.^{34,35}

Although some studies include environmental and climatic factors as proxies for vector dynamics, direct entomological indicators such as larval density or larval index are still rarely analyzed explicitly.³⁶ This limitation indicates that the biological mechanisms of dengue transmission have not been fully elucidated, making the integration of entomological surveillance with spatial and climate analysis an important requirement in research because Monitoring mosquito populations and infection rates can provide early warnings for dengue outbreaks.^{30,37}

4. Behavioral Dimension of Dengue

The behavioral dimension of society plays an important role in dengue fever control, especially through prevention practices and environmental management. A study conducted by Ridha shows that cadre-based interventions significantly improve community knowledge and behavior in dengue fever control, although changes in attitude are relatively limited.²¹ These findings indicate that increased knowledge is not always directly followed by changes in attitude, so behavioral interventions need to be carried out continuously and contextually.

Various other studies show that public knowledge about dengue is not always followed by effective prevention practices, so education alone is not sufficient for dengue control.³⁸ Prevention practices are greatly influenced by the local social context, so behavioral interventions need to be adapted to local conditions.⁽³⁹⁾ In addition, community empowerment and active participation have been shown to reduce vector density in a sustainable manner, while high dependence on the government indicates the need to strengthen community responsibility and independence in dengue control.^{40,41}

However, the behavioral dimension is still rarely integrated with spatial or climate analysis in DBD studies in Kalimantan. As a result, the role of community behavior as a factor mediating the relationship between the environment, vectors, and DBD risk has not been comprehensively described. In fact, with proper education, the number of mosquito breeding sites can be reduced, which will be related to the presence of mosquitoes themselves.^{42,43}

5. Socioeconomic Dimension of Dengue

Socioeconomic factors in the reviewed studies were generally analyzed indirectly through proxy indicators, such as population density, land cover change, and residential environmental characteristics. Husnina and Risva showed that areas with demographic pressure and rapid environmental change tended to have a higher risk of dengue fever.^{1,17} This indicates that socioeconomic conditions affect the risk of dengue fever through structural pathways, such as environmental quality, infrastructure, and housing patterns^{44,45}, because socioeconomic variables were important in explaining some parts of the phenomenon.

The interaction between environmental factors (e.g., temperature, precipitation) and socioeconomic conditions (e.g., housing quality, access to services) is crucial in understanding dengue outbreaks.^{46,47} Improving infrastructure and reducing socioeconomic disparities can mitigate dengue risk.²³ However, direct socioeconomic indicators, such as income level, education, or housing conditions, are still very limited in dengue studies in Kalimantan. This limitation hinders understanding of social vulnerability to dengue and limits the formulation of social justice-based interventions. Moreover, the somewhat scattered population density in Kalimantan, both in urban and rural areas, is very important to study in depth, because demographic density has an important impact on the spread of vector-borne diseases²⁸, and can also be used to identify areas at risk.²⁹

6. Synthesis Across Dimensions

Overall, the characteristics of DHF in Kalimantan indicate that the transmission of this disease is the result of multidimensional interactions between spatial, entomological, behavioral, and socioeconomic factors. Although the spatial and climatic dimensions have been extensively studied, the integration of entomological, behavioral, and socioeconomic dimensions remains limited. These findings emphasize the need for a more comprehensive and integrative research approach to support the development of more effective and contextual DHF control strategies in Kalimantan.

7. Limitation

This systematic review has several limitations that should be considered when interpreting the findings. First, the number of studies included in the final analysis was relatively limited, with only seven articles meeting

the eligibility criteria after the screening process, indicating that research on dengue transmission in Kalimantan especially studies that integrate climate, spatial, entomological, behavioral, and socioeconomic dimensions is still relatively rare. Second, this review relies primarily on studies indexed in major international databases, which may introduce publication bias, as relevant studies published in local or non-indexed sources may not be included. Finally, Kalimantan's geographic heterogeneity, characterized by diverse ecological landscapes and settlement patterns, ranging from urban to rural and forest areas, may influence the dynamics of dengue transmission differently in different locations. As the included studies were conducted in specific areas, the findings may not be fully representative of the entire region and should therefore be interpreted with caution.

CONCLUSION

Based on a systematic synthesis of the reviewed studies, it can be concluded that the dynamics of dengue fever (DF) in Kalimantan are influenced by multidimensional interactions between climatic, spatial, entomological, behavioral, and socioeconomic factors. Climatic factors, particularly temperature, humidity, and rainfall, play an important role in shaping seasonal patterns and trends in DHF incidence, but do not fully explain the variation in risk between regions. A spatial approach shows that DHF incidence is heterogeneous and forms specific clusters related to population density and settlement structure. Meanwhile, evidence regarding entomological and behavioral dimensions is still limited, although existing studies show that vector characteristics and community practices in environmental control play an important role in modifying the risk of transmission. Overall, DHF research in Kalimantan is still dominated by climatic and spatial approaches, with limited integration of entomological, behavioral, and socioeconomic indicators, so that the understanding of DHF risk is not yet fully comprehensive.

Future dengue fever research in Kalimantan needs to integrate spatial analysis with entomological, behavioral, and socioeconomic indicators to improve the accuracy of risk mapping. The development of spatial-based predictive models supported by vector surveillance and community participation is important to strengthen early warning systems and more effective dengue fever control.

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