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Socio-environmental determinants of mosquito density and dengue risk in a high-density urban neighbourhood of Klang, Malaysia

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Abstract

Dengue fever remains a persistent public health challenge in rapidly urbanising areas of Malaysia, particularly in Klang, Selangor, where neighbourhood-scale environmental conditions and sociodemographic vulnerabilities interact to influence disease transmission. This study examines the socio-environmental determinants of mosquito density and dengue risk in selected endemic residential areas of Klang through an integrated neighbourhood-scale approach combining household surveys, environmental assessments, ovitrap surveillance, and secondary dengue surveillance records. A cross-sectional study was conducted involving 106 respondents across five endemic residential localities between January and March 2025. Descriptive and inferential statistical analyses, including Pearson's chi-square tests, were performed using SPSS to examine associations between socio-environmental variables and mosquito density. The findings revealed consistently higher ovitrap positivity rates in outdoor environments across all residential zones, indicating the dominant role of neighbourhood-level environmental exposure in sustaining mosquito breeding. Significant associations were identified between mosquito density and community knowledge of dengue prevention ($\chi^2 = 4.905$, $p = 0.027$), the presence of community dengue programmes ($\chi^2 = 7.880$, $p = 0.005$), and neighbourhood breeding-site inspections ($\chi^2 = 10.367$, $p = 0.001$). In contrast, conventional institutional control measures such as fogging, environmental surveys, and health inspections showed no significant association with reduced mosquito density ($p > 0.05$). High population density and socioeconomic vulnerability further intensified dengue risk within dense terrace-housing environments. This study demonstrates that dengue transmission in Klang is driven more strongly by neighbourhood-scale environmental conditions and collective community action than by isolated household practices or episodic institutional interventions. The study contributes a socio-environmental neighbourhood framework that highlights the importance of sustained community participation, targeted outdoor environmental management, and spatially informed vector-control strategies for improving dengue prevention in rapidly urbanising settings.

Keywords: Dengue fever, environmental risk, mosquito density, sociodemographic factors, urban health

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Introduction

Dengue fever remains one of the most critical vector-borne public health challenges in tropical and rapidly urbanising countries, with Southeast Asia accounting for a substantial proportion of global dengue cases. In Malaysia, dengue incidence has remained persistently high despite decades of vector-control programmes, with more than 120,000 reported cases recorded nationwide in recent years (Abu Bakar et al., 2022). Selangor consistently contributes the highest proportion of dengue cases in the country due to its dense urban population, rapid land-use change, and highly connected residential environments. Klang district, in particular, continues to experience recurrent dengue outbreaks and remains one of the major urban hotspots in Selangor (Mohamad & CommHlth, 2025). The disease is primarily transmitted by Aedes mosquitoes, which thrive in densely populated urban environments where human activities, environmental conditions, and settlement patterns interact to create favorable breeding habitats. Despite continuous vector control programmes and public health interventions, dengue continues to be endemic in many Malaysian cities, indicating that existing strategies may not sufficiently address the underlying environmental and sociodemographic drivers of transmission (Abd. Rahim et al., 2024; Adnan et al., 2021).

Urbanization has been widely recognized as a key factor shaping dengue dynamics. Rapid population growth, high residential density, inadequate waste management, and extensive use of artificial water containers contribute to the proliferation of mosquito breeding sites (Nasirian, 2024). In highly urbanised residential areas such as Klang, poorly maintained drainage systems, unmanaged solid waste, discarded containers, and shaded outdoor communal spaces frequently accumulate stagnant water, creating ideal breeding habitats for Aedes mosquitoes. Climatic conditions further intensify these risks. Rainfall increases the availability of temporary and permanent water-holding containers that serve as oviposition sites, while high temperatures accelerate larval development, shorten mosquito reproductive cycles, and enhance dengue viral replication within the mosquito vector. High humidity levels improve adult mosquito survival and prolong mosquito activity, thereby increasing the likelihood of human–mosquito contact and sustained transmission within dense urban neighbourhoods (Liu et al., 2023; Muhammad et al., 2022).

However, environmental factors alone do not fully explain dengue persistence. Sociodemographic characteristics, including socioeconomic status, education level, household structure, and community participation, play an equally important role in determining exposure and vulnerability to dengue infection (Ottay et al., 2025). Low-income and densely populated communities often experience greater environmental exposure due to inadequate housing conditions, limited access to environmental maintenance, and reduced capacity to sustain preventive measures. Weak neighbourhood participation in collective dengue-control activities may further contribute to persistent mosquito breeding habitats, even in areas receiving routine institutional interventions such as fogging and inspections. In contrast, stronger community engagement and coordinated neighbourhood action can improve source reduction practices and reduce mosquito density at the local scale.

Recent studies increasingly emphasize that dengue transmission should be understood as a socio-environmental and spatially embedded urban health issue rather than solely a climatic or entomological problem. Nevertheless, many existing studies in Malaysia focus primarily on climatic variables or reported dengue incidence without integrating neighbourhood-scale environmental assessments, community practices, and mosquito density indicators within the same analytical framework. In particular, limited studies have examined how outdoor environmental

conditions and collective community participation interact to shape mosquito density in dense residential neighbourhoods such as Klang.

Klang district in Selangor represents a critical urban hotspot for dengue fever (Hassan et al., 2012). Unlike broader district-level analyses, this study adopts a neighbourhood-scale integrated socio-environmental approach that combines household surveys, environmental risk assessment, ovitrap surveillance, and secondary dengue surveillance data to examine the determinants of mosquito density and dengue risk in selected endemic residential areas of Klang. Mosquito density, measured through ovitrap positivity rates, was used as a key indicator to assess spatial variation in vector proliferation across residential zones. By integrating environmental exposure, sociodemographic vulnerability, and community participation within a single analytical framework, the study aims to provide empirical evidence to support more targeted, spatially informed, and community-oriented dengue prevention strategies in rapidly urbanising settings.

Literature review

Dengue fever transmission is shaped by a complex interaction between environmental conditions and sociodemographic characteristics, particularly in rapidly urbanizing regions. Previous studies consistently demonstrate that dengue is not merely a climatic or biological phenomenon, but a spatially embedded public health issue influenced by human settlement patterns, social vulnerability, and environmental management practices (Nakase et al., 2023). Understanding these dynamics is crucial for developing effective prevention strategies that address both environmental and social factors contributing to dengue outbreaks in urban areas like Klang.

Environmental factors and dengue transmission

Environmental conditions play a fundamental role in determining the distribution and abundance of Aedes mosquitoes. Climatic variables such as temperature, rainfall, and humidity directly affect mosquito breeding cycles, survival rates, and viral replication (Permatasari & Masjud, 2024). Warmer temperatures accelerate larval development and shorten viral incubation periods, while rainfall creates temporary and permanent water collections that serve as breeding sites. (Gizaw et al., 2024). In tropical settings, where favourable conditions persist throughout the year, mosquito populations can be sustained continuously, increasing the risk of endemic transmission (Liu et al., 2023). Additionally, urbanization exacerbates these environmental factors by creating more artificial breeding habitats, thereby enhancing the potential for dengue outbreaks (Alias et al., 2025). Consequently, understanding the interplay between these environmental conditions and urbanization is vital for formulating effective dengue control strategies in Klang and similar regions.

Urban environments further intensify these risks through land-use changes and built-up density. Artificial containers, construction sites, poorly maintained drainage systems, and household water storage practices provide ideal breeding habitats for Aedes mosquitoes. Studies conducted in Southeast Asia, including Malaysia, have shown that dengue incidence is significantly higher in densely built residential areas where environmental sanitation is inadequate (Agolah, 2022; Jamil et al., 2021). These findings highlight the importance of environmental management and spatial planning in dengue prevention, particularly in urban neighbourhoods experiencing rapid development.

Sociodemographic determinants of dengue prevalence

Sociodemographic factors strongly influence exposure, vulnerability, and adaptive capacity to dengue fever. High population density increases human–mosquito contact, facilitating viral transmission within confined residential spaces (Nakase et al., 2023). Socioeconomic status has also been identified as a critical determinant, as lower-income communities often experience limited access to effective vector control measures, substandard housing conditions, and reduced health awareness (Alqassim, 2024).

Education and community knowledge play a pivotal role in shaping preventive behavior. Communities with higher levels of awareness are more likely to engage in practices such as eliminating stagnant water, participating in communal cleaning activities, and cooperating with health authorities (Yulfi et al., 2025). Conversely, limited education and weak community engagement are frequently associated with persistent breeding sites and delayed outbreak response (Stefopoulou et al., 2018). These patterns suggest that dengue control is closely linked to social organization and collective action at the neighbourhood level.

Interaction between environmental and sociodemographic factors

Recent literature increasingly emphasizes the need for integrated approaches that consider both environmental and sociodemographic dimensions of dengue transmission. Environmental risks are often amplified in socially vulnerable communities, where population density, housing conditions, and limited resources intersect with favorable mosquito breeding environments (Scavo et al., 2025). Integrated socio-environmental models have demonstrated improved capacity to identify high-risk urban zones compared to approaches that focus on single variables. (Dufitimana et al., 2025)

In Malaysia, studies conducted in the Klang Valley indicate that dengue hotspots frequently emerge in areas characterized by dense housing, outdoor environmental risk factors, and limited community participation in vector control programmes (Agolah, 2022). These findings underscore the importance of adopting locality-specific strategies that combine environmental management with social interventions, including community engagement and targeted health education.

Research gaps and study relevance

Despite growing recognition of the socio-environmental nature of dengue transmission, gaps remain in neighbourhood-scale studies that integrate environmental risk assessment, mosquito density surveillance, and sociodemographic analysis. Many existing studies rely heavily on climatic data or reported case numbers, with limited incorporation of household-level conditions and community practices.

This study addresses these gaps by adopting an integrated approach to examine environmental and sociodemographic determinants of dengue prevalence in selected endemic residential areas of Klang. By linking mosquito density indicators with population characteristics and environmental risk factors, the study contributes to a more spatially informed understanding of dengue transmission and supports evidence-based urban health planning.

Method and study area

Study design

This study employed a cross-sectional research design to examine the relationship between environmental and sociodemographic factors and dengue fever prevalence in selected endemic urban residential areas of Klang, Selangor. A quantitative approach was adopted to capture household-level characteristics, environmental risk conditions, mosquito density indicators, and reported dengue incidence within a defined study period. This design enables the identification of associations between variables within an urban spatial context, which is appropriate for understanding dengue transmission patterns at the neighbourhood scale.

Study area

The study was conducted in Klang district, Selangor, a highly urbanized area recognized as one of Malaysia's dengue hotspots. Recent surveillance data from the Selangor State Health Department reported that the Klang mukim recorded among the highest cumulative dengue cases in Selangor in 2025, with 1,449 cumulative cases by Epidemiological Week 18, placing Klang among the top affected localities statewide. Other than that, Klang is characterized by dense residential development, heterogeneous land-use patterns, and diverse sociodemographic profiles, making it a suitable setting for examining socio-environmental determinants of dengue transmission. Five residential localities were selected for the study: Bandar Puteri, Bandar Putera, Taman Sri Andalas, Taman Sentosa, and Taman Setia. These areas were identified based on consistent dengue case reporting, prolonged outbreak history, and limited locality-specific empirical studies. The selected neighbourhoods predominantly comprise terrace housing within high population density zones, where outdoor environmental conditions, household practices, and community dynamics are expected to influence mosquito breeding and disease transmission. For analytical purposes, the selected residential neighbourhoods were grouped into four ovitrap sampling zones (Zone A–D) based on spatial proximity and deployment layout rather than administrative boundaries.

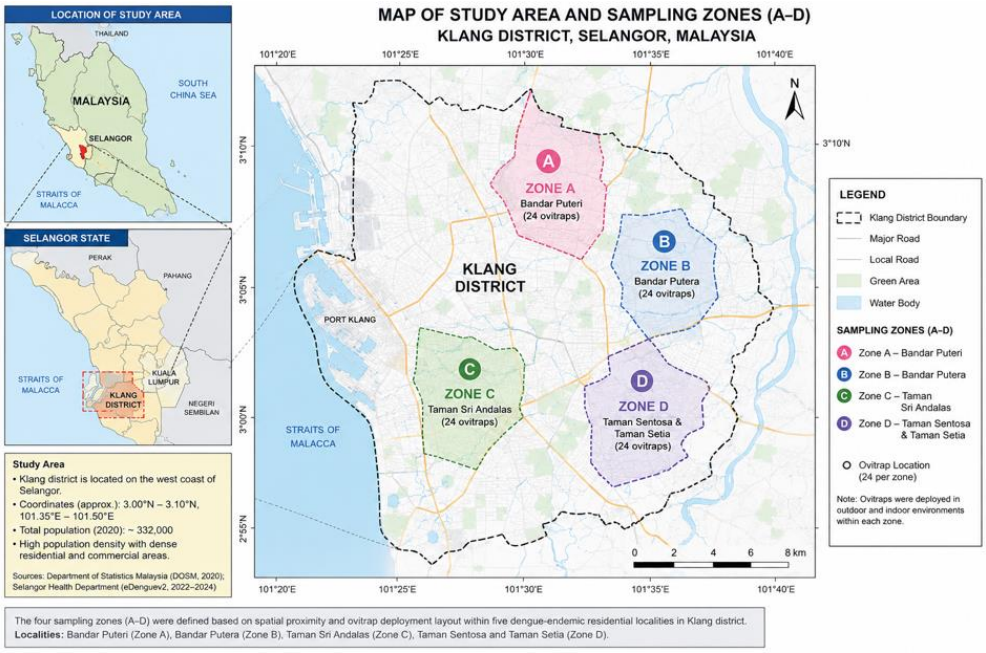

Figure 1. Map of the study area

Sampling and data collection

A stratified random sampling method was applied to ensure proportional representation across the selected residential areas. A total sample size of 384 respondents was determined using standard sample size estimation for cross-sectional studies and distributed proportionally according to population size in each locality. A pilot study involving 20 respondents outside the selected study area was conducted prior to the actual data collection to assess the clarity, suitability, and reliability of the questionnaire instrument. Minor revisions to the wording and structure of several questions were made based on participant feedback obtained during the pilot phase. Reliability analysis using Cronbach's alpha demonstrated acceptable internal consistency for the questionnaire sections related to dengue prevention practices and community participation ($\alpha > 0.70$), indicating satisfactory reliability of the survey instrument.

Although the minimum estimated sample size was 384 respondents, only 106 complete and usable questionnaires were successfully obtained during the fieldwork period due to respondent availability, time limitations, and incomplete survey returns. Incomplete questionnaires with missing data were excluded from the final analysis. Despite the smaller final sample, the study remains exploratory in nature and provides important neighbourhood-scale insights into socio-environmental determinants of dengue risk in endemic urban settings.

Primary data were collected using structured household questionnaires to obtain information on sociodemographic characteristics, housing conditions, and community practices related to dengue prevention. The sampling frame consisted of households located within the selected dengue-endemic residential neighbourhoods of Klang district, namely Bandar Puteri, Bandar Putera, Taman Sri Andalas, Taman Sentosa, and Taman Setia. Residential areas were selected purposely based on repeated dengue hotspot reports, high population density, and historical dengue outbreak records obtained from local health surveillance data. Within each locality, households were selected using stratified random sampling to ensure proportional

representation across the residential zones. Houses were approached systematically based on street and housing layout, and one eligible adult respondent was selected from each household to participate in the survey. Only fully completed questionnaires were included in the final statistical analysis.

The inclusion criteria were:

1. Residents aged 18 years and above;
2. Individuals residing in the study area for at least six months;
3. Residents willing to provide informed consent;
4. Residents living within the identified dengue-endemic residential zones.

The exclusion criteria were:

1. Temporary residents or visitors;
2. Individuals below 18 years of age;
3. Residents unable to communicate effectively during the survey process;
4. Incomplete or substantially missing questionnaire responses.

Environmental risk assessments were conducted to identify potential mosquito breeding sites within and around residential premises. In addition, ovitrap surveillance was implemented across multiple zones to assess mosquito density and breeding activity in both indoor and outdoor environments. A total of 96 ovitraps were deployed across four sampling zones (Zone A–D), with 24 ovitraps allocated to each zone. Within each zone, ovitraps were distributed equally between indoor and outdoor environments to enable comparison of mosquito breeding activity across different micro-environmental settings.

Indoor ovitraps were placed in shaded and undisturbed areas inside residential premises, such as kitchens, bathrooms, or storage areas, where mosquito activity was likely to occur. Outdoor ovitraps were positioned in shaded locations around residential compounds, near drainage areas, vegetation, discarded containers, or other potential mosquito breeding habitats. Trap placement avoided direct exposure to heavy rainfall and strong sunlight to minimise disturbance and evaporation.

Each ovitrap consisted of a dark plastic container partially filled with water and fitted with an oviposition paddle to attract egg-laying female mosquitoes. The ovitraps were exposed for a period of five to seven days before collection. Ovitrap monitoring and collection were conducted weekly throughout the study period between January and March 2025. Following collection, the ovitrap contents were examined for mosquito larvae and eggs. Positive ovitraps were recorded and used to calculate ovitrap positivity rates as indicators of mosquito density. Where applicable, larvae were identified morphologically at the genus level (Aedes spp.) using standard entomological identification keys.

Secondary data on dengue fever cases were obtained from the Klang Health District Office through the e-Notifikasi and e-Dengue surveillance systems to provide verified records of disease prevalence during the study period.

Data analysis

Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 27. Descriptive statistical techniques were applied to summarize sociodemographic characteristics, community practices related to dengue prevention, and environmental risk indicators, with results

presented as frequencies and percentages. Environmental risk scores were further classified into low (0–2), moderate (3–4), and high (5–7) environmental risk categories based on the cumulative checklist scoring system. These descriptive measures provided an overview of population characteristics and the distribution of dengue-related risk factors within the study area.

Comparative analysis was conducted to examine spatial variation in mosquito density across the study zones. Differences in ovitrap positivity rates between zones and between indoor and outdoor environments were assessed descriptively and comparatively to identify patterns of mosquito breeding activity at neighbourhood level. This approach enabled comparison of environmental risk conditions across residential settings.

Inferential statistical analysis was used to examine associations between selected sociodemographic and environmental variables and mosquito density indicators. The variables tested in this study included sociodemographic factors (age, gender, ethnicity, education level, household density, and neighbourhood population density), vector management practices (fogging, health inspections, environmental surveys, household mosquito prevention measures, and community dengue programmes), and environmental risk indicators in relation to mosquito density and dengue prevalence. Pearson's Chi-square test was used to assess associations between categorical variables, while correlation analysis using the Phi coefficient (φ) was applied to determine the strength and direction of relationships between selected variables and mosquito density outcomes. A p-value of less than 0.05 was considered statistically significant for all inferential analyses.

Ethical considerations

Ethical approval for this study was obtained from the Faculty of Nursing and Allied Health Sciences – Research Ethics Committee (FONAHS-REC) prior to data collection. The study was approved under the minimal risk category with Ethics Approval Number: FONAHS-REC/2025/01/004. Informed consent was obtained from all participants before participation, and confidentiality was maintained by anonymizing personal identifiers and securely storing all collected data.

Results and discussion

Sociodemographic characteristics and dengue risk

Among the 106 respondents, the majority were aged between 20–39 years (59.4%), followed by respondents aged 40 years and above (39.6%). Gender distribution was relatively balanced, comprising 50.9% males and 49.1% females. Most respondents had tertiary education (62.3%), while the remaining respondents reported secondary education or below. The majority of respondents resided in high-density residential neighbourhoods and belonged to the B40 income category.

The study findings indicate that dengue risk in the selected endemic areas of Klang is embedded within a dense urban and socioeconomically constrained context. The sociodemographic profile of respondents across the selected dengue-endemic residential areas of Klang is summarised in Table 1. The majority of respondents were within the economically active age group of 20–39 years, reflecting a population with high daily mobility and frequent outdoor

exposure. Gender distribution was balanced, suggesting comparable exposure risk among male and female residents.

All respondents belonged to the B40 income group, indicating uniform socioeconomic vulnerability that may limit household capacity to implement effective and sustained mosquito control measures. Nearly all respondents (96.2%) resided in high population density neighbourhoods dominated by terrace housing, a settlement pattern commonly associated with increased human–mosquito contact due to shared outdoor spaces and close housing proximity.

Household sizes were predominantly moderate (3–5 persons), which may elevate indoor exposure when breeding sites exist within or near residential environments. Although most respondents attained tertiary education, education level alone did not translate into lower mosquito density, highlighting that awareness without enabling environmental and collective action is insufficient for dengue risk reduction.

Table 1. Sociodemographic characteristics of respondents in selected dengue-endemic areas of Klang

Variable	Category	n	%
Age group	20–39 years	63	59.4
	≥ 40 years	42	39.6
Gender	Male	54	50.9
	Female	52	49.1
Education level	Secondary or below	40	37.7
	Tertiary	66	62.3
Household size	≤2 persons	13	12.3
	3–5 persons	62	58.5
	≥ 6 persons	31	29.2
Income group	B40	106	100
Population density	High density	102	96.2
Ethnic	Malay	63	59.4
	Chinese	29	18.9
	Indian	19	19.9
	Others	4	3.8
Formal education attainment	Enrolled in an educational program	43	40.6

Vector management practices and community engagement

Most respondents reported the presence of institutional vector-control measures within their residential areas. Fogging activities were reported by 78.3% of respondents, while 61.3% indicated that health inspections had been conducted within their neighbourhoods. Household mosquito-prevention practices were reported by 76.4% of respondents.

In contrast, only 40.6% of respondents reported the presence of organised community dengue programmes, while joint community participation activities were reported by only 25.5% of respondents. These findings suggest relatively limited neighbourhood-level community engagement despite the frequent implementation of institutional interventions.

Household-level vector prevention practices were widely reported, with over three-quarters of respondents using mosquito nets, repellents, or grills. Despite this, mosquitoes were almost universally present indoors and outdoors, indicating that individual protection measures alone are inadequate in neighbourhoods where environmental breeding sites persist (Sougoufara et al., 2020). Effective dengue control necessitates a coordinated community effort that combines individual protective measures with collective action to eliminate breeding sites and enhance public health education (Low et al., 2025).

Institutional vector control activities, including fogging, health inspections, and environmental surveys, were commonly observed. However, inferential analysis revealed that these reactive measures were not significantly associated with reduced mosquito density. This suggests that episodic control interventions provide only short-term suppression of adult mosquitoes and do not address larval habitats that sustain mosquito populations (Fillinger et al., 2011).

Community engagement in dengue prevention was limited. Less than half of respondents reported the presence of organised community dengue programmes, and only a quarter observed active neighbourhood involvement in joint prevention activities. This gap between awareness and action reflects weak social cohesion in dengue control efforts and underscores the importance of collective participation for sustainable vector management (Siyam et al., 2024). Vector management practices and community engagement measures are summarized in Table 2.

Table 2. Vector management practices and community participation

Indicator	Yes (%)	No (%)
Household mosquito prevention	76.4 (n=81)	23.6 (n=25)
Health officer inspection (past month)	61.3 (n=65)	38.7 (n=41)
Fogging activities observed	78.3 (n=83)	21.7 (n=23)
Community dengue programmes*	40.6 (n=43)	59.4 (n=63)
Neighbourhood joint activities**	25.5 (n=27)	74.5 (n=79)

* Community dengue programmes referred to organised neighbourhood-based dengue prevention initiatives such as awareness campaigns, gotong-royong activities, and coordinated source-reduction programmes conducted within residential areas

**Joint community activities referred to collective resident participation in cleaning campaigns, breeding-site inspections, and dengue-prevention activities organised at neighbourhood level

Mosquito density patterns and entomological surveillance

Ovitrap surveillance was conducted to quantify mosquito breeding activity and to examine spatial variation in mosquito density across residential zones. Figure 2 illustrates the indoor and outdoor ovitrap positivity rates by residential zone. Outdoor ovitrap positivity rates were consistently

higher than indoor positivity rates across all study zones. Zone B recorded the highest outdoor ovitrap positivity rate (72.0%), followed by Zone C (68.0%). Indoor positivity rates were comparatively lower, with 48.0% recorded in Zone B and 44.0% in Zone C. Zones A and D demonstrated relatively lower ovitrap positivity rates in both indoor and outdoor environments. These findings indicate that mosquito breeding activity was more dominant in outdoor neighbourhood environments compared to indoor household settings (Astuti et al., 2022).

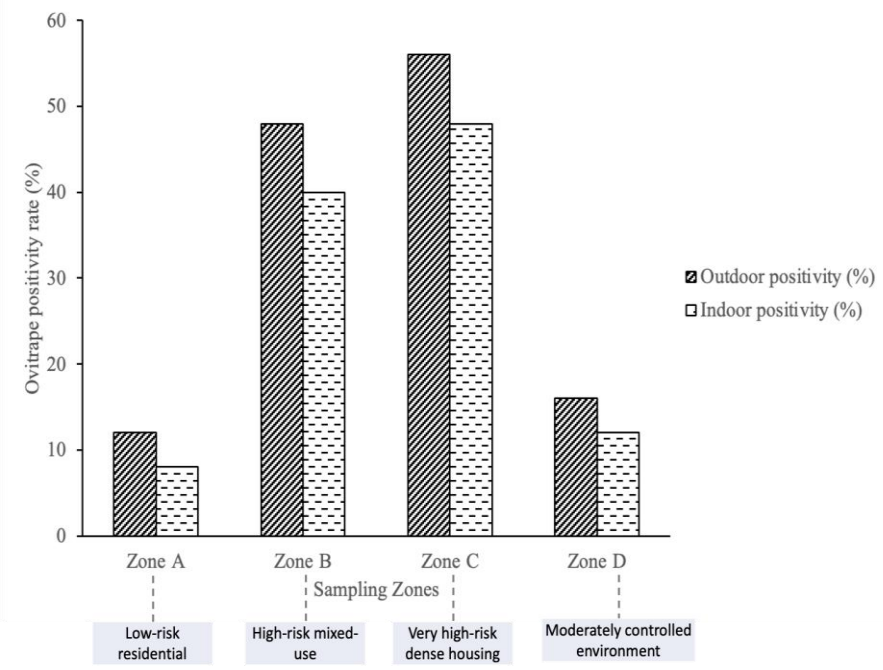

Figure 2. Ovitrap positivity rates by zone and environment

Collectively, these findings demonstrate that dengue risk in Klang is spatially heterogeneous and strongly influenced by micro-environmental conditions at the neighbourhood level. Effective dengue control therefore requires a shift from predominantly reactive measures towards proactive environmental management strategies that target shared outdoor spaces, improve drainage infrastructure, and reduce potential breeding habitats within high-risk residential zones.

Bivariate associations between socio-demographic factors, vector management, and mosquito density

Bivariate analysis was performed to examine associations between respondent characteristics, community vector-management practices, and mosquito density category (high vs low). None of the examined sociodemographic variables showed statistically significant associations with mosquito density ($p > 0.05$). Age, gender, ethnicity, education level, household density, and neighbourhood population density were not significantly associated with mosquito density categories. These findings suggest that mosquito proliferation within the study area may be more

strongly influenced by environmental conditions and collective neighbourhood practices than by individual demographic characteristics alone.

Socio-demographic and economic (social) factors

Overall, most socio-demographic variables were not significantly associated with mosquito density (Table 3). Age was not associated with mosquito density ($\chi^2 = 0.208$, $p = 0.648$; $\varphi = 0.044$), suggesting that mosquito exposure risk in this setting is not differentiated by age structure. Similarly, gender showed no association ($\chi^2 = 0.039$, $p = 0.843$; $\varphi = 0.019$), indicating comparable exposure patterns across male and female respondents. Formal education attainment was not significant ($\chi^2 = 0.391$, $p = 0.532$; $\varphi = 0.061$), and education level (secondary or below vs post-secondary) also showed no significant association ($\chi^2 = 0.125$, $p = 0.724$; $\varphi = 0.034$). Ethnicity ($\chi^2 = 3.768$, $p = 0.052$; $\varphi = 0.189$), neighbourhood population density ($\chi^2 = 3.206$, $p = 0.073$; $\varphi = 0.174$), and household density ($\chi^2 = 0.266$, $p = 0.606$; $\varphi = 0.050$) were also not significantly associated with mosquito density. These findings suggest that mosquito density within the study area may be influenced more strongly by neighbourhood environmental conditions and collective community practices than by individual sociodemographic characteristics alone.

Table 3. Association between socio-demographic factors and mosquito density (high vs low)

Factor	Categories compared	χ^2	p-value	Effect size (φ)
Age	< 40 vs ≥ 40	0.208	0.648	0.044
Gender	Male vs Female	0.039	0.843	0.019
Ethnicity	Malay vs Other	3.768	0.052	0.189
Education background	Enrolled vs Not enrolled	0.391	0.532	0.061
Education level	≤Secondary vs > Secondary	0.125	0.724	0.034
Household density	< 5 vs ≥ 5 persons	0.266	0.606	0.05
Neighbourhood population density	High vs Low	3.206	0.073	0.174

Note: φ reported for 2×2 comparisons (n = 106)

Vector management and community practices

In contrast to socio-demographic variables, several vector-management and community-practice variables demonstrated statistically significant associations with mosquito density (Table 4). Community knowledge of dengue prevention was assessed using questionnaire items related to awareness of mosquito breeding habitats, dengue prevention practices, and participation in dengue-control activities. Responses were combined into a composite score and subsequently categorised into lower and higher knowledge groups based on overall respondent scores. Community knowledge of dengue prevention was significantly associated with mosquito density ($\chi^2 = 4.905$, $p = 0.027$; $\varphi = 0.215$). Communities with better dengue prevention knowledge tended

to show lower mosquito density, suggesting that neighbourhood-level awareness and preventive practices may contribute to mosquito reduction.

The presence of a community dengue programme was also significantly associated with mosquito density ($\chi^2 = 7.880$, $p = 0.005$; $\varphi = 0.273$), while neighbourhood checking for mosquito breeding sites demonstrated the strongest significant association ($\chi^2 = 10.367$, $p = 0.001$; $\varphi = 0.313$). These findings indicate that organised community participation and collective environmental management may contribute more effectively to sustained mosquito reduction.

Fogging ($\chi^2 = 1.233$, $p = 0.267$; $\varphi = 0.108$), environmental surveys ($\chi^2 = 0.348$, $p = 0.555$; $\varphi = 0.057$), health inspections ($\chi^2 = 1.326$, $p = 0.249$; $\varphi = 0.112$), and household mosquito prevention measures ($\chi^2 = 2.923$, $p = 0.087$; $\varphi = 0.166$) were not significantly associated with mosquito density. Dengue cases reported in the past month also showed no significant association with mosquito density ($\chi^2 = 0.151$, $p = 0.698$; $\varphi = 0.038$). These findings suggest that episodic institutional interventions alone may not provide sustained reductions in mosquito density when environmental breeding habitats remain available within neighbourhood environments.

Table 4. Association between vector management/community practices and mosquito density (high vs low)

Factor	χ^2	p-value	Effect size (φ)
Household mosquito prevention measures	2.923	0.087	0.166
Community knowledge of dengue prevention	4.905	0.027	0.215
Dengue cases reported in neighbourhood (past month)	0.151	0.698	0.038
Health inspections (past month)	1.326	0.249	0.112
Environmental surveys observed	0.348	0.555	0.057
Fogging observed (past month)	1.233	0.267	0.108
Presence of mosquitoes in household area	3.206	0.073	0.174
Mosquitoes around residential area	0.001	0.979	0.003
Community dengue programme exists	7.88	0.005	0.273
Neighbourhood involvement in joint community work	3.584	0.058	0.184
Neighbourhood checks breeding sites	10.367	0.001	0.313
Neighbourhood cleans breeding sites	1.322	0.25	0.112

Note: φ reported for 2×2 comparisons (n = 106)

Environmental determinants of mosquito proliferation

Environmental assessments identified poor waste management, accumulation of scrap materials, illegal land cultivation, and inadequate drainage as dominant contributors to mosquito breeding. Discarded containers, tyres, construction debris, and water-retaining concrete structures created persistent larval habitats, particularly in high-density zones (Dharmamuthuraja et al., 2023).

Urban infrastructure characterised by impermeable surfaces and poorly maintained drainage systems further exacerbated water stagnation, while unregulated agricultural activities contributed additional breeding sites near residential areas. These environmental drivers operate

at the neighbourhood scale and cannot be effectively addressed through household-level interventions alone.

Integrated socio-environmental interpretation of dengue risk

The findings demonstrate that dengue risk in Klang is driven by the interaction between dense urban environments, environmental breeding conditions, and varying levels of community engagement. High mosquito density persists where environmental risks intersect with weak collective action, even in areas with frequent fogging and inspections. Zones B and C represent high-risk environments requiring intensified, targeted interventions, while Zones A and D, although currently lower risk, remain vulnerable due to the persistence of potential breeding habitats.

Figure 3 illustrates the interaction between population density, environmental risk factors, socioeconomic vulnerability, and community participation in shaping mosquito density and dengue prevalence in urban residential settings. The framework highlights how environmental exposure and social conditions jointly influence dengue transmission risk at neighbourhood scale.

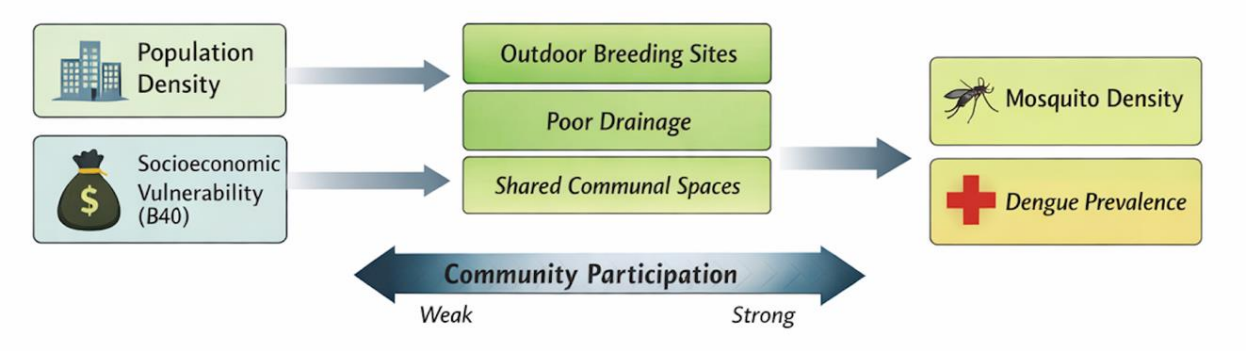

Figure 3. Conceptual framework of socio-environmental determinants of dengue risk in Klang

Implications for public health and urban planning

From a public health perspective, the results highlight the need to prioritize high-risk neighbourhoods using mosquito density indices rather than relying solely on reported dengue cases. Strengthening community dengue programmes, improving neighbourhood-level governance, and integrating environmental risk mapping into urban planning are essential for sustainable dengue prevention.

Urban development strategies should incorporate improved drainage design, systematic waste management, and enforcement against illegal land use to reduce mosquito breeding habitats. Public health interventions must move beyond awareness campaigns to foster active and sustained community participation in dengue control.

Limitation of the study

Several limitations should be acknowledged in this study. First, the cross-sectional study design limits the ability to establish causal relationships between socio-environmental factors and mosquito density. Second, the final analysed sample size was lower than the initially estimated sample size, which may affect the generalisability of findings. Third, mosquito density was assessed using ovitrap positivity rates rather than direct adult mosquito abundance measurements. Despite these limitations, the study provides important neighbourhood-scale insights into socio-environmental determinants of dengue risk within dense urban residential environments.

Conclusion

This study found that mosquito density and dengue risk in the selected urban neighbourhoods of Klang were influenced more strongly by neighbourhood-level environmental conditions and collective community participation than by individual sociodemographic characteristics alone. Outdoor ovitrap positivity rates were consistently higher than indoor positivity rates across all study zones, indicating the importance of shared outdoor environmental conditions in supporting mosquito breeding activity. Significant associations were observed between mosquito density and community knowledge of dengue prevention, organised community dengue programmes, and neighbourhood breeding-site inspections, while sociodemographic variables showed no significant associations with mosquito density.

The findings suggest that sustained community participation and proactive neighbourhood environmental management may contribute more effectively to long-term mosquito reduction compared to episodic institutional interventions such as fogging and routine inspections alone. These results highlight the importance of strengthening community-based dengue prevention strategies alongside improved environmental management within high-density urban residential settings.

Future studies are recommended to adopt larger sample sizes and longitudinal study designs to better examine temporal variations in mosquito density and dengue transmission patterns. Additional investigations incorporating climatic variables, geospatial analysis, and adult mosquito surveillance are also recommended to improve understanding of neighbourhood-scale dengue dynamics. Comparative studies across different urban districts in Malaysia may further strengthen understanding of how varying environmental and social conditions influence mosquito proliferation and dengue risk.

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