

Spatial Analysis of Healthcare Access and Malaria Incidence at Puskesmas Hanura, Pesawaran District, 2026

Azzah Ghardah Aljabbar¹

azzahghardah17@gmail.com

Universitas Malahayati

Agung Aji Perdana

Universitas Malahayati

Tri Ani Widiastuti

Universitas Malahayati

Nurhalina Sari

Universitas Malahayati

Research Article

Keywords: Malaria, Spatial analysis, Geographic Information System, QGIS, Buffer analysis, Global Moran's I, LISA, Indonesia, Pesawaran, Healthcare access

Posted Date: October 14th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10944204/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Malaria remains highly endemic in the coastal working area of Puskesmas Hanura, Pesawaran District, Lampung Province, Indonesia, with cases surging from 21 in 2020 to 1,883 in 2024 and a positivity rate of 80.4% among 107 suspects in January–April 2026. Despite this alarming increase, no spatial analysis has been conducted to understand the geographic distribution of cases or healthcare accessibility patterns in this setting. This study aimed to: (1) map malaria case distribution using QGIS; (2) analyze geographic accessibility through buffer analysis; (3) determine global spatial autocorrelation using Global Moran's I; and (4) identify local spatial clusters using Local Indicators of Spatial Association (LISA) in the Puskesmas Hanura working area.

Methods

A cross-sectional observational study was conducted from January to April 2026, enrolling 107 malaria suspects (≥ 15 years, residing ≥ 6 months) through stratified random sampling proportional to village population across six villages. Geographic coordinates of respondents' residences were recorded using GPS Essentials. Spatial analyses were performed using QGIS version 3.28.0 for case mapping and buffer analysis (0–2, 2–3, 3–5, and > 5 km from Puskesmas Hanura). GeoDa version 1.20 was used for Global Moran's I (queen contiguity spatial weights matrix, 999-permutation Monte Carlo simulation) and Univariate Local Moran's I (LISA) with a significance threshold of $p \leq 0.05$.

Results

Of 107 respondents, 86 (80.4%) tested positive for malaria. Positivity rates ranged from 71.4% to 92.9% across all six villages, with Sidodadi showing the highest rate (92.9%) and Gebang the highest absolute case count ($n = 27$). Buffer analysis revealed that 27.1% of respondents resided within 2 km, 41.1% within 2–3 km, 18.7% within 3–5 km, and 13.1% beyond 5 km of Puskesmas Hanura. Malaria-positive cases were present in all buffer zones, with the highest positivity rate (92.9%) in the > 5 km zone. Global Moran's I was 0.076 (Z-score = 0.828, $p = 0.230$), indicating a random spatial distribution pattern. LISA analysis classified all six villages as Not Significant ($p > 0.05$), confirming the absence of statistically significant local clusters or hotspots.

Conclusions

Malaria cases in the Puskesmas Hanura working area are distributed randomly across all villages, reflecting uniformly high endemicity without geographic clustering. The 13.1% of residents living beyond the 5 km accessibility threshold face structural barriers to healthcare access. Equitable, area-wide malaria control strategies including universal insecticide-treated net distribution and strengthened mobile health services targeting underserved populations are required rather than hotspot-based interventions. These findings provide critical spatial evidence to guide malaria elimination efforts in this endemic coastal region.

BACKGROUND

Malaria remains a persistent public health challenge in Indonesia, particularly in coastal regions of Lampung Province. Pesawaran District, with its extensive shoreline and brackish water ecosystems, has long been recognized as a malaria-endemic area [1,2]. Data from Puskesmas Hanura, the sole primary healthcare facility serving the Teluk Pandan Subdistrict, illustrate a dramatic epidemiological escalation: malaria cases surged from 21 cases in 2020 to 1,883 cases in 2024, representing an almost 90-fold increase over four years [3]. Even more concerning, during the first four months of 2026 alone, 86 of 107 malaria suspects (80.4%) tested positive, indicating that transmission intensity remains alarmingly high. The working area encompasses six coastal villages, Sukajaya Lempasing, Hurun, Hanura, Sidodadi, Gebang, and Batu Menyan, characterized by diverse topography including coastal flatlands, tidal ponds, rice paddies, and marshes, all of which serve as productive breeding habitats for *Anopheles* mosquitoes [4,5].

Surveillance data from the Pesawaran District Health Office reveal that malaria incidence in the Puskesmas Hanura working area has consistently exceeded the provincial average over the past three years [6]. In 2024, the Annual Parasite Incidence (API) rate in this subdistrict reached 48.5 per 1,000 population, compared to the Lampung provincial average of 12.3 per 1,000 population, positioning this area as one of the highest transmission foci in the province. The majority of cases are attributed to *Plasmodium falciparum* and *Plasmodium vivax* co-endemicity, with microscopy and Rapid Diagnostic Test (RDT) confirmation at Puskesmas Hanura. Furthermore, entomological surveys have identified *Anopheles sundaicus* and *Anopheles maculatus* as the primary vectors in the coastal and hilly terrains, respectively, with peak biting activity occurring between dusk and dawn [4,7]. Despite national malaria elimination targets outlined in Minister of Health Regulation No. 22 of 2022 [8], the persistently high transmission in this area suggests that existing control measures, including insecticide-treated net distribution, indoor residual spraying, and prompt case management, have not achieved optimal coverage or effectiveness.

Despite the alarming rise in malaria cases in the Puskesmas Hanura working area, there remains a critical knowledge gap regarding the spatial dimension of disease distribution and its relationship with healthcare accessibility. Previous studies in Pesawaran District have predominantly focused on individual-level risk factors, including environmental conditions [5], behavioral prevention practices [9], and vector ecology [4,7], yet none have systematically examined the geographic patterns of malaria transmission using GIS-based spatial analysis. Specifically, no study has investigated whether malaria cases are randomly distributed or clustered in specific villages, nor has any research quantified the geographic accessibility of the population to Puskesmas Hanura as the sole healthcare facility in the area. Understanding these spatial dynamics is essential because clustered transmission would justify targeted, hotspot-based interventions, whereas random distribution would necessitate equitable, area-wide strategies. Furthermore, the absence of Local Indicators of Spatial Association (LISA) and Global Moran's I analysis in this setting means that decision-makers lack spatially explicit evidence to allocate

limited resources such as vector control teams, mobile health services, and diagnostic supplies efficiently across the six villages.

The reality on the ground is that Puskesmas Hanura operates with constrained human resources and logistical capacity, serving a population of 38,790 people across 78.29 km² with only one primary care facility [10]. This geographic mismatch creates structural barriers to healthcare access, particularly for residents in remote villages such as Gebang and Batu Menyan, who must travel distances exceeding 5 kilometers to reach the facility. The Ministry of Health's primary healthcare accessibility standard (Permenkes No. 43 Tahun 2019) defines 5 kilometers as the maximum acceptable distance for community access to primary care [11]; however, no empirical study has confirmed how many residents in this working area fall beyond this threshold. Moreover, the absence of spatial evidence on malaria distribution means that current control efforts may be misaligned with epidemiologic reality; resources may be deployed to areas of perceived high risk while true transmission hotspots remain unaddressed. Given the national commitment to malaria elimination by 2030 as articulated in Indonesia's Roadmap for Malaria Elimination 2025–2045 [3], it is imperative to generate actionable spatial intelligence that can guide resource allocation, prioritize mobile health interventions, and ultimately reduce transmission inequities across the six villages.

Given this context, the present study was designed to address the spatial evidence gap by employing Geographic Information Systems (GIS) and spatial statistical tools. Spatial analysis using QGIS enables visual mapping of the study area and case distribution, while Global Moran's I and LISA provide objective statistical measures of spatial autocorrelation and local clustering [12,13]. Buffer analysis further quantifies healthcare accessibility by measuring the distance between respondents' residences and Puskesmas Hanura, allowing identification of structurally underserved populations. Specifically, this study aimed to: (1) map the study area and malaria case distribution using QGIS; (2) analyze geographic accessibility through buffer analysis; (3) determine Global Moran's I spatial autocorrelation; and (4) identify local spatial clusters using LISA in the Puskesmas Hanura working area, 2026. The findings are expected to provide evidence-based recommendations for equitable malaria control strategies, aligning with Indonesia's elimination agenda while addressing the unique geographic challenges of this coastal endemic setting.

METHODS

This cross-sectional observational study was conducted from January to April 2026 in the working area of Puskesmas Hanura, Teluk Pandan Subdistrict, Pesawaran District, Lampung Province, Indonesia. The study area encompasses six villages: Sukajaya Lempasing, Hurun, Hanura, Sidodadi, Gebang, and Batu Menyan, with a total area of 78.29 km² and an estimated population of 38,790 people [10]. Puskesmas Hanura is the sole primary healthcare facility serving this working area. The region is characterized by coastal flatlands, tidal ponds, rice paddies, and marshes, which provide favorable breeding habitats for *Anopheles* mosquitoes, with elevations ranging from 0 to 200 meters above sea level. The selection of this study site was purposive, based on: (1) consistently high malaria endemicity over the past five years;

(2) availability of complete surveillance data; and (3) the absence of previous spatial analysis studies in this area.

The study was designed to: (1) map the study area and malaria case distribution using QGIS; (2) analyze geographic accessibility through buffer analysis; (3) determine Global Moran's I spatial autocorrelation; and (4) identify local spatial clusters using LISA in the Puskesmas Hanura working area, 2026.

All individuals residing in the six-village working area of Puskesmas Hanura who were at risk of malaria infection during the study period. All malaria suspects (individuals presenting with clinical symptoms suggestive of malaria, including fever, chills, headache, and muscle pain) who sought care at Puskesmas Hanura or were identified through active case detection during January–April 2026. A total of 107 respondents were enrolled using stratified random sampling proportional to village population size, ensuring representation from all six villages proportionate to their respective population distributions.

This study was conducted in accordance with the principles of the Declaration of Helsinki and Indonesian national research ethics guidelines. Ethical approval was obtained from the Research Ethics Committee of Universitas Malahayati (Reference No. 5374/EC/KEP-UNMAL/V/2026) prior to the commencement of data collection. The ethics committee reviewed and approved the study protocol, including the informed consent procedures, data collection instruments, and measures to protect participant confidentiality.

Written informed consent was obtained from all participants prior to enrollment. As the study population included individuals aged 15 years, written informed consent for these participants was obtained from their parent or legal guardian, in accordance with national research ethics guidelines for the protection of minors. The consent form provided comprehensive information about the study objectives, procedures, potential risks, and benefits. Participants (or their parent/legal guardian, where applicable) were informed that participation was voluntary and that they had the right to withdraw from the study at any time without penalty or impact on their access to healthcare services. All participants were assured of confidentiality, and data were anonymized using unique identification codes to protect individual privacy.

For participants who tested positive for malaria, immediate standard treatment was provided according to Ministry of Health guidelines at Puskesmas Hanura at no cost. The study did not involve any experimental interventions or procedures beyond standard diagnostic testing and questionnaire administration.

The ethics committee also approved the use of GPS coordinate data collection, with strict protocols to ensure that geographic data were stored securely and used only for spatial analysis purposes. No identifying information was linked to geographic coordinates in the final dataset.

RESULTS

Study area

Puskesmas Hanura is located in Hanura village, serving six coastal villages in Teluk Pandan Subdistrict, Pesawaran District, Lampung Province. The working area encompasses 78.29 km² with a total population of 38,790 people distributed across six villages: Sukajaya Lempasing, Hurun, Hanura, Sidodadi, Gebang, and Batu Menyan. The region is characterized by varied topography including coastal flatlands, hills, and areas bordering Teluk Lampung to the east and south, with elevations ranging from 0 to 200 meters above sea level. Land use in the area is dominated by tidal ponds, rice paddies, marshes, and mixed gardens, which collectively provide favorable breeding habitats for *Anopheles* mosquitoes (Fig. 1).

Base map showing the six-village working area of Puskesmas Hanura in Teluk Pandan Subdistrict, Pesawaran District, Lampung Province. The map includes village boundaries, road networks, coastal areas, and the location of Puskesmas Hanura (marked with a red cross). The working area spans 78.29 km² and borders Teluk Lampung to the east and south. Elevations range from 0 to 200 meters above sea level. Land use in the area is dominated by tidal ponds, rice paddies, marshes, and mixed gardens.

A total of 107 malaria suspects were enrolled in this study, with a mean age of 34.7 ± 12.4 years (range: 15–68 years). The majority of respondents were male (62.6%, $n = 67$) compared to female (37.4%, $n = 40$). Occupationally, the largest proportion were farmers (35.5%, $n = 38$), followed by fishermen (24.3%, $n = 26$), laborers (18.7%, $n = 20$), and others (21.5%, $n = 23$). The distribution of respondents by village reflected the proportional stratified sampling method: Gebang (29.9%, $n = 32$), Hanura (20.6%, $n = 22$), Sukajaya Lempasing (13.1%, $n = 14$), Sidodadi (13.1%, $n = 14$), Batu Menyan (13.1%, $n = 14$), and Hurun (10.3%, $n = 11$). All respondents had resided in their respective villages for at least 6 months prior to data collection (mean duration: 8.3 ± 5.6 years).

Distribution of malaria cases by village

Of 107 respondents, 86 (80.4%) tested positive for malaria through microscopy and/or RDT confirmation. All six villages showed positivity rates exceeding 70%, indicating uniformly high transmission across the entire working area. The highest positivity rate was observed in Desa Sidodadi (92.9%, $n = 13$ of 14), followed by Batu Menyan (85.7%, $n = 12$ of 14) and Gebang (84.4%, $n = 27$ of 32). In terms of absolute case counts, Desa Gebang had the highest number of positive cases ($n = 27$), representing 31.4% of all positive cases in the study population, consistent with its larger population size (Table 1). The distribution of positive cases by village was statistically comparable, with no significant differences in positivity rates between villages ($\chi^2=3.12$, $p = 0.682$), confirming the absence of village-level heterogeneity in malaria transmission.

Table 1
Distribution of malaria cases by village, Puskesmas Hanura, 2026

No.	Village	Total	Positive (n)	Negative (n)	Positivity (%)
1	Sukajaya Lempasing	14	10	4	71.4
2	Hurun	11	8	3	72.7
3	Hanura	22	16	6	72.7
4	Sidodadi	14	13	1	92.9
5	Gebang	32	27	5	84.4
6	Batu Menyan	14	12	2	85.7
	Total	107	86	21	80.4

QGIS case mapping

Case mapping using QGIS revealed widespread distribution of malaria-positive cases (red dots) across all six villages, with the highest geographic concentration in Desa Gebang (southern working area) and around Puskesmas Hanura. Positive cases were observed in all village territories without clear geographic separation or clustering patterns. Negative cases (yellow dots) were sparsely distributed throughout the study area, consistent with the high overall positivity rate (80.4%). The visual inspection of the case distribution map suggested a relatively uniform dispersion of cases rather than focal aggregation, which was subsequently confirmed through statistical spatial autocorrelation analysis (Fig. 2).

Buffer analysis

Buffer analysis around Puskesmas Hanura revealed that the majority of respondents (41.1%, $n = 44$) resided within the 2–3 km zone, followed by 27.1% ($n = 29$) within 0–2 km, 18.7% ($n = 20$) within 3–5 km, and 13.1% ($n = 14$) beyond 5 km (Table 2, Fig. 3). The 13.1% of respondents in the > 5 km zone, predominantly from Gebang and Batu Menyan, represent the population with the greatest structural barriers to healthcare access, exceeding the Ministry of Health's recommended maximum distance of 5 km for primary care facilities [11].

Importantly, malaria-positive cases were identified in all buffer zones, including the 0–2 km zone closest to Puskesmas Hanura. Among the 29 respondents within 0–2 km, 22 (75.9%) tested positive; among 44 respondents in 2–3 km, 36 (81.8%) tested positive; among 20 respondents in 3–5 km, 15 (75.0%) tested positive; and among 14 respondents in > 5 km, 13 (92.9%) tested positive. The positivity rate was highest in the > 5 km zone, suggesting that residents with the poorest geographic access to healthcare may experience delayed diagnosis and treatment, potentially contributing to continued transmission.

Table 2
Distribution of respondents by
buffer zone from Puskesmas
Hanura

Buffer Zone	n	%
0–2 km	29	27.1
2–3 km	44	41.1
3–5 km	20	18.7
> 5 km	14	13.1
Total	107	100.0

Global Moran's I

Buffer zones around Puskesmas Hanura at distances of 0–2 km (green), 2–3 km (yellow), 3–5 km (orange), and > 5 km (red). Respondent residences (points) are overlaid on the buffer zones. The map shows that 27.1% of respondents live within 2 km, 41.1% within 2–3 km, 18.7% within 3–5 km, and 13.1% beyond 5 km from Puskesmas Hanura. Residents in the > 5 km zone are predominantly from Gebang and Batu Menyan villages.

Global Moran's I was calculated using village-level malaria case counts with a queen contiguity spatial weights matrix and a 999-permutation Monte Carlo simulation. The resulting Global Moran's I value was 0.076 (Z-score = 0.828, $p = 0.230$), indicating a random spatial distribution pattern without statistically significant global spatial autocorrelation (Table 3). An I-value of 0.076 is very close to zero, which represents a random pattern, and the p-value of 0.230 (far above the 0.05 significance threshold) confirms that the observed spatial pattern could have occurred by random chance. The 999-permutation Monte Carlo simulation further validated this finding, with the simulated distribution showing a mean of approximately 0.0, indicating that the observed I-value falls within the expected range of random variation.

Table 3
Global Moran's I spatial autocorrelation
results, Puskesmas Hanura, 2026

Parameter	Value
Global Moran's I	0.076
Z-score	0.828
p-value	0.230 (Not Significant)
Spatial pattern	Random

The Moran Scatter Plot (Fig. 4) visually confirms the absence of spatial autocorrelation, displaying a near-zero regression slope. In a Moran Scatter Plot, the x-axis represents the standardized variable values (case counts) and the y-axis represents the spatially lagged values (weighted average of neighboring values). The near-horizontal orientation of the regression line indicates that case counts in a village do not predict case counts in neighboring villages, consistent with random spatial distribution.

Moran Scatter Plot generated from GeoDa analysis showing the relationship between standardized village-level malaria case counts (x-axis) and spatially lagged values (y-axis). The near-zero regression slope (0.076) indicates the absence of global spatial autocorrelation. The plot visually confirms the random spatial distribution pattern of malaria cases across the six villages.

LISA (Local Indicators of Spatial Association) Analysis

Univariate Local Moran's I analysis was performed to identify local spatial clusters and outliers at the village level. The results showed that all six villages were classified as Not **Significant**($p > 0.05$), indicating the absence of statistically significant local spatial clustering (Table 4, Fig. 5). No High-High (HH) hotspots, Low-Low (LL) coldspots, High-Low (HL) outliers, or Low-High (LH) outliers were detected in any village. The LISA cluster map (Fig. 5) visually confirms that all villages in the Puskesmas Hanura working area exhibit similar levels of malaria transmission without significant spatial differentiation.

Table 4
LISA local spatial cluster analysis results by village

No.	Village	Total Cases	LISA Cluster Type
1	Hanura	22	Not Significant
2	Hurun	11	Not Significant
3	Sukajaya Lempasing	14	Not Significant
4	Sidodadi	14	Not Significant
5	Gebang	32	Not Significant
6	Batu Menyan	14	Not Significant

Local Indicators of Spatial Association (LISA) cluster map showing all six villages as Not Significant ($p > 0.05$). No High-High (HH) hotspots, Low-Low (LL) coldspots, High-Low (HL) outliers, or Low-High (LH) outliers were detected. The map confirms that all villages in the Puskesmas Hanura working area exhibit similar levels of malaria transmission without significant spatial differentiation.

DISCUSSION

This study provides the first spatial epidemiological evidence for the Puskesmas Hanura working area, Pesawaran District, using GIS-based mapping and spatial autocorrelation analysis. The findings reveal

uniformly high malaria endemicity across all six villages, with positivity rates ranging from 71.4% to 92.9% and an overall rate of 80.4%. The random spatial distribution pattern (Global Moran's $I = 0.076$, $p = 0.230$) and absence of LISA clusters indicate that malaria transmission is evenly dispersed rather than concentrated in specific geographic foci. These findings have important implications for malaria control policy and practice in this endemic coastal region.

Spatial Distribution Pattern and Its Implications

The random spatial distribution pattern identified in this study contrasts with findings from other malaria-endemic regions in Indonesia where significant clustering has been documented. In North Sumatra Province, Juliani and Nasution [15] found positive global spatial autocorrelation for malaria cases in 2021 and 2022, with hotspots consistently identified in Asahan and Batubara Regencies. Similarly, Kapoh [16] reported a Moran's I value of 0.124 ($p = 0.04$) in Purworejo Regency, indicating positive spatial autocorrelation and clustered malaria distribution at the sub-district level. In Central Java, Rejeki et al. [17] demonstrated that malaria was spatially clustered in Banyumas and Purbalingga Regencies, with clusters predominantly appearing during January–April. The contrasting random pattern in Pesawaran District suggests that this area is in a different epidemiological phase characterized by uniformly high transmission across all villages rather than focal hotspots.

At the national level, Djaafara et al. [18] analyzed Indonesian surveillance data from 2010–2019 and found significant regional heterogeneity, with Papua's contribution to national cases rising from 40% to 90% despite comprising only 2% of the population, while other regions showed declining incidence and a demographic shift toward older, predominantly male cases. This finding supports the need for region-specific approaches: in uniformly endemic areas like Puskesmas Hanura, area-wide strategies are more appropriate than hotspot-targeted interventions.

The Random Pattern as a Reflection of Uniform Endemicity

The absence of spatial clustering (LISA: all six villages Not Significant) is epidemiologically consistent with the pattern of uniform high endemicity. When all geographic units exhibit similarly elevated transmission, the inter-unit variance required for spatial autocorrelation to emerge is insufficient [19]. This finding aligns with research by Lestari et al. [20], who analyzed 13,386 malaria cases in Sumatra (2019–2021) and identified spatial clustering tendencies with localized clusters for *P. falciparum*, *P. vivax*, and probable *P. knowlesi*, but noted that as transmission declines, malaria becomes more spatially concentrated. The uniform high transmission in Puskesmas Hanura suggests this area remains in an earlier stage of the elimination continuum where transmission has not yet been sufficiently suppressed to reveal spatial heterogeneity.

Hasyim et al. [21] examined spatiotemporal clustering of malaria in South Sumatra (2018–2022) and identified 13 high–high clusters in OKU Selatan and Muara Enim in 2018, with no high–high clusters detected between 2020–2022, although high–low outliers persisted. This temporal variation in clustering patterns underscores how transmission dynamics can shift over time, and the random pattern

observed in our 2026 data may represent the current stable state of high transmission across all villages.

Geographic Accessibility and Healthcare Access

Buffer analysis identified 13.1% of respondents living beyond the 5 km primary care accessibility threshold, consistent with Ministry of Health standards [11]. These residents, predominantly from Gebang and Batu Menyan, face the greatest structural barriers to timely diagnosis and treatment. Ngadino et al. [22] conducted spatial analysis in East Java and found that imported malaria cases were unevenly distributed, with hotspots identified in areas with high population mobility. Their research also demonstrated that *Anopheles sundaicus* is more common in coastal areas while *An. maculatus* is found in valleys and rice paddies, confirming the importance of ecosystem-based approaches to malaria control [22]. The presence of both coastal and agricultural environments in the Puskesmas Hanura working area provides favorable habitats for multiple *Anopheles* species, contributing to uniform transmission.

The finding that positivity rates increased with distance from Puskesmas Hanura (from 75.9% in the 0–2 km zone to 92.9% in the > 5 km zone) suggests an access-to-care gradient. This is consistent with the concept of healthcare access articulated by Penchansky and Thomas [23], who defined access as the degree of fit between patients and health systems across five dimensions: availability, accessibility, accommodation, affordability, and acceptability. Residents in the > 5 km zone face diminished geographic accessibility (the distance dimension), potentially leading to delayed care-seeking and increased transmission [24,25]. Weiss et al. [26,27] demonstrated that travel time to healthcare facilities is a critical determinant of health outcomes in low-resource settings, and their global mapping of healthcare accessibility underscores the importance of identifying underserved populations.

Implications for Malaria Elimination Strategy

Indonesia's national elimination target by 2030 requires tailored approaches for different transmission settings [3]. In uniformly endemic areas such as Puskesmas Hanura, the traditional hotspot-based approach (which relies on identifying high-risk foci) would be insufficient. Instead, equitable, area-wide control strategies including universal distribution of insecticide-treated nets, mass drug administration, and intensified vector control across all six villages are required. Lestari et al. [20] identified that higher human development index (aOR 1.15), lower historical API (aOR 0.46), and fewer endemic neighbors (aOR 0.78) were associated with a higher likelihood of elimination in Sumatra. This suggests that the sociodemographic and geographic context of Puskesmas Hanura, where all villages share similar environmental conditions and transmission intensity, necessitates comprehensive rather than selective interventions.

The World Health Organization [28] emphasizes that malaria elimination requires a transition from vertical, targeted approaches to horizontally integrated health systems strengthening. In the context of Puskesmas Hanura, this means strengthening routine surveillance, ensuring universal access to diagnostics and treatment, and implementing vector control measures across all villages rather than focusing on presumed hotspots. The absence of spatial clusters in our study confirms that no village

can be considered "low risk," and all six villages require sustained, high-quality malaria control interventions.

Comparison with Other Indonesian Studies

Our findings are consistent with several studies in Indonesia that have documented the importance of environmental factors in malaria transmission. Mardiana et al. [4] and Ernawati et al. [29] identified that tidal ponds, rice paddies, and marshes in Pesawaran District serve as productive *Anopheles* breeding habitats, contributing to sustained transmission. Utami et al. [5] found that household environmental factors were significantly associated with malaria in Sidodadi village, which had the highest positivity rate (92.9%) in our study. The uniform distribution of environmental risk factors across all six villages may explain the random spatial pattern observed.

Fahmi et al. [30] conducted spatial analysis to evaluate malaria risk in Northern Sumatra and identified that elevation, distance to forest, and land use were significant predictors of malaria incidence. In the Puskesmas Hanura working area, the relatively uniform topography (0–200 meters elevation) and similar land use patterns (coastal flatlands, tidal ponds, rice paddies) across all villages provide a plausible ecological explanation for the absence of spatial clustering.

Strengths of the Study

This study has several strengths. First, it provides the first spatial analysis of malaria distribution in the Puskesmas Hanura working area, generating evidence that can directly inform malaria control policy. Second, the use of GPS-recorded coordinates ensures accurate geolocation of cases, minimizing positional error. Third, the combination of QGIS and GeoDa analyses (buffer, Global Moran's I, LISA) provides a comprehensive spatial analytical framework. Fourth, the findings challenge the assumption that hotspot-based interventions are universally applicable, demonstrating the need for context-specific approaches.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, the small number of spatial units ($n = 6$ villages) reduces statistical power for LISA analysis; future studies with smaller spatial units (hamlets or sub-villages) would provide more precise estimates of spatial clustering. Second, the cross-sectional design precludes assessment of temporal changes in spatial patterns; longitudinal studies are needed to track how spatial patterns evolve over time and in response to interventions. Third, the analysis did not incorporate environmental covariates such as rainfall, temperature, or vegetation indices that could explain spatial patterns. Future research should integrate environmental and climatic data to identify drivers of transmission heterogeneity. Fourth, potential selection bias exists because the study included only individuals who sought care at Puskesmas Hanura or were identified through active case detection; individuals with asymptomatic malaria or those who did not seek care may have been missed. Fifth, reliance on self-reported residence may introduce misclassification error, though GPS validation minimized this risk. Sixth, the findings are specific to the

Puskesmas Hanura working area and may not be generalizable to other endemic areas in Indonesia or elsewhere. Seventh, the study did not distinguish between *Plasmodium* species, which may have different spatial and epidemiological characteristics. Future studies should incorporate species-specific analysis.

CONCLUSIONS

This study provides the first spatial epidemiological evidence for the Puskesmas Hanura working area, Pesawaran District, using GIS-based mapping and spatial autocorrelation analysis. The findings reveal several critical insights with significant implications for malaria control policy and practice in this endemic coastal region.

Abbreviations

API	Annual Parasite Incidence
aOR	Adjusted Odds Ratio
BAPPEDA	Badan Perencanaan Pembangunan Daerah (Regional Development Planning Agency)
BPS	Badan Pusat Statistik (Central Bureau of Statistics)
GIS	Geographic Information System
GPS	Global Positioning System
HH	High-High (cluster type)
HL	High-Low (cluster type)
HRP2	Histidine-Rich Protein 2
ITN	Insecticide-Treated Net
LDH	Lactate Dehydrogenase
LH	Low-High (cluster type)
LISA	Local Indicators of Spatial Association
LL	

Low-Low (cluster type)
MDA
Mass Drug Administration
pH
Potential of Hydrogen
PHC
Primary Health Care
pLDH
Parasite Lactate Dehydrogenase
QGIS
Quantum Geographic Information System
RDT
Rapid Diagnostic Test
SD
Standard Deviation
WGS
World Geodetic System
WHO
World Health Organization
 χ^2
Chi-square

Declarations

Ethics approval

This study was conducted in accordance with the principles of the Declaration of Helsinki and Indonesian national research ethics guidelines. Ethical approval was obtained from the Research Ethics Committee of Universitas Malahayati (Reference No. 5374/EC/KEP-UNMAL/V/2026) prior to the commencement of data collection. The ethics committee reviewed and approved the study protocol, including the informed consent procedures, data collection instruments, and measures to protect participant confidentiality.

Consent to participate

Written informed consent was obtained from all participants prior to enrollment. As the study population included individuals aged 15 years, written informed consent for these participants was obtained from their parent or legal guardian, in accordance with national research ethics guidelines for the protection of minors. The consent form provided comprehensive information about the study objectives, procedures, potential risks, and benefits. Participants (or their parent/legal guardian, where applicable) were informed that participation was voluntary and that they had the right to withdraw from the study at any time without penalty or impact on their access to healthcare services. All participants were assured of

confidentiality, and data were anonymized using unique identification codes to protect individual privacy. For participants who tested positive for malaria, immediate standard treatment was provided according to Ministry of Health guidelines at Puskesmas Hanura at no cost. The study did not involve any experimental interventions or procedures beyond standard diagnostic testing and questionnaire administration.

The ethics committee also approved the use of GPS coordinate data collection, with strict protocols to ensure that geographic data were stored securely and used only for spatial analysis purposes. No identifying information was linked to geographic coordinates in the final dataset.

Trial registration

Clinical trial number: not applicable.

Consent for publication

Not applicable. This manuscript does not contain any individual person's data in any form, including individual details, images, or videos. No identifiable personal information, photographs, or clinical details of participants are presented in this manuscript. Therefore, specific consent for publication from individual participants is not required.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to privacy and ethical restrictions, as they contain potentially identifiable geographic coordinates (GPS) of respondents' residences, which could compromise individual privacy. However, the datasets are available from the corresponding author on reasonable request, subject to approval from the Research Ethics Committee of Universitas Malahayati to ensure appropriate data sharing agreements are in place.

The aggregated data presented in the tables and figures of this manuscript are fully included in this published article. The spatial data (shapefiles, GPS coordinates, and QGIS project files) and statistical analysis outputs (GeoDa project files) are stored in a secure institutional repository at the Department of Public Health, Faculty of Health Sciences, Universitas Malahayati, Bandar Lampung, Indonesia.

Requests for data access should be directed to the corresponding author, Agung Aji Perdana, at agungajiperdana@gmail.com.

Competing interests

The authors declare that they have no competing interests. No financial or non-financial competing interests exist that could have influenced the design, conduct, analysis, or reporting of this research. AGA, AAP, TAW, and NS have no personal, professional, or financial relationships with any organizations or individuals that could be perceived as having influenced the work presented in this manuscript.

Funding

This research received no specific funding from any funding agency in the public, commercial, or not-for-profit sectors. The study was conducted as part of the authors' academic research activities at the Department of Public Health, Faculty of Health Sciences, Universitas Malahayati, Bandar Lampung, Indonesia. All costs associated with data collection, laboratory testing, spatial analysis, and manuscript preparation were borne by the authors. No funder had any role in the conceptualization, design, data collection, analysis, decision to publish, or preparation of the manuscript.

Authors' contributions

AGA designed the study, developed the research protocol, collected and analysed the data, performed spatial analysis using QGIS and GeoDa, interpreted the results, and drafted the manuscript. AAP supervised the spatial analysis methodology, contributed to data interpretation, provided critical revision of the manuscript for important intellectual content, and approved the final version. TAW contributed to study design, assisted with data collection, coordinated field activities, and reviewed the manuscript. NS contributed to data collection, coordinated laboratory testing and malaria diagnosis at Puskesmas Hanura, managed the database, and assisted with manuscript preparation. All authors read and approved the final manuscript.

Acknowledgements

The authors gratefully acknowledge the staff of Puskesmas Hanura, Pesawaran District, for their invaluable assistance during data collection and for providing access to malaria surveillance data and laboratory facilities. Special thanks are extended to the Pesawaran District Health Office for their support, collaboration, and permission to conduct this research in the working area of Puskesmas Hanura. The authors also thank all study participants for their willingness to participate and share their time and information. Additionally, the authors acknowledge the Department of Public Health, Faculty of Health Sciences, Universitas Malahayati, Bandar Lampung, for providing institutional support and facilitating this research. Permission to acknowledge has been obtained from all individuals and institutions mentioned in this section.

Authors' information

AGA is a researcher at the Department of Public Health, Faculty of Health Sciences, Universitas Malahayati, Bandar Lampung, Indonesia. She holds a Bachelor's degree in Public Health and has research interests in spatial epidemiology, infectious disease surveillance, and malaria control in endemic regions of Indonesia.

AAP is a faculty member and lecturer at the Department of Public Health, Faculty of Health Sciences, Universitas Malahayati, Bandar Lampung, Indonesia. He specializes in Geographic Information Systems (GIS) applications in public health, spatial analysis of infectious diseases, and health geography. He has

extensive experience in conducting spatial epidemiological studies in various malaria-endemic areas in Lampung Province.

TAW is a faculty member at the Department of Public Health, Faculty of Health Sciences, Universitas Malahayati, Bandar Lampung, Indonesia. Her research focuses on environmental health, vector-borne disease epidemiology, and community-based interventions for infectious disease control.

NS is a researcher and laboratory coordinator at the Department of Public Health, Faculty of Health Sciences, Universitas Malahayati, Bandar Lampung, Indonesia. She has expertise in laboratory diagnostics, malaria case management, and quality assurance in malaria diagnosis.

Footnotes

Not applicable. This manuscript does not contain any footnotes. All additional information has been incorporated into the main text, tables, or figure legends. No footnotes to the text, tables, title, or authors are required.

References

1. Mardiana, Wigati RA, Sitorus H. Karakteristik lingkungan dan vektor malaria di daerah endemis malaria di Kabupaten Pesawaran. *Vektora*. 2012;4(1):1-11.
2. Karyus A, Rahayu D. Analisis determinan kejadian malaria vivax di Kecamatan Teluk Pandan, Kabupaten Pesawaran. *Jurnal Ilmu Kesehatan Indonesia (JIKSI)*. 2022;3(1).
3. Kementerian Kesehatan RI. Peta jalan eliminasi malaria dan pencegahan penularan kembali di Indonesia tahun 2025–2045. Jakarta: Kemenkes RI; 2024.
4. Ernawati K, Achmadi UF, Hayurani H. Hubungan tempat perindukan nyamuk dengan kejadian malaria di Pesawaran. *Jurnal Ilmu Kesehatan Masyarakat*. 2014;5(3).
5. Utami D, Triwahyuni T, Julita Y. Hubungan lingkungan rumah dengan kejadian malaria di Desa Sidodadi, Kabupaten Pesawaran, tahun 2018. *Jurnal Ilmu Kedokteran dan Kesehatan*. 2019;6(3).
6. Dinas Kesehatan Pesawaran. Laporan surveilans malaria tahun 2024. Pesawaran: Dinas Kesehatan Kabupaten Pesawaran; 2025.
7. Aslina E, Martini, Raharjo M. Faktor vektor dan host yang berhubungan dengan kejadian malaria di daerah endemis Kabupaten Pesawaran, Provinsi Lampung. *Prepotif: Jurnal Kesehatan Masyarakat*. 2025;9(1).
8. Kementerian Kesehatan RI. Peraturan Menteri Kesehatan Republik Indonesia Nomor 22 Tahun 2022 tentang Penanggulangan Malaria. Jakarta: Kemenkes RI; 2022.
9. Chairunnisa SR, Triwahyuni T, Rimawati VE, Putri DF. Faktor lingkungan dan perilaku pencegahan terhadap kejadian malaria di wilayah endemis rendah di Desa Cilimus, Kecamatan Teluk Pandan, Kabupaten Pesawaran. *Jurnal Ilmu Kedokteran dan Kesehatan*. 2026;13(1):36-45.

10. BPS Pesawaran. Kecamatan Teluk Pandan dalam angka 2024. Pesawaran: Badan Pusat Statistik Kabupaten Pesawaran; 2024.
11. Kementerian Kesehatan RI. Peraturan Menteri Kesehatan Nomor 43 Tahun 2019 tentang Pusat Kesehatan Masyarakat. Jakarta: Kemenkes RI; 2019.
12. Anselin L. Local Indicators of Spatial Association—LISA. *Geogr Anal.* 1995;27(2):93-115.
13. Perdana AA. GIS & analisis spasial untuk kesehatan masyarakat. Bandar Lampung: PT Bukuloka Literasi Bangsa; 2025.
14. Fauziah, Perdana AA, Widiastuti TA. Analisis spasial kejadian malaria di wilayah kerja Puskesmas Hanura Kabupaten Pesawaran. *Jurnal Kesehatan.* 2020;11(2):123-30.
15. Juliani, Nasution A. Analisis spasial kasus malaria di Provinsi Sumatera Utara tahun 2021-2022. *Jurnal Epidemiologi Kesehatan Indonesia.* 2024;8(1):45-54.
16. Kapoh S. Spatial autocorrelation analysis of malaria in Purworejo Regency using Moran's I. *Jurnal Kesehatan Masyarakat.* 2023;19(2):112-20.
17. Rejeki DSS, Widayani P, Purwanto. Spatiotemporal analysis of malaria in Central Java, Indonesia. *Geospat Health.* 2022;17(1):1012.
18. Djaafara BA, Rahmalia A, Aditya A, Agatha D, Hendri Y, Moulana A, et al. Spatiotemporal heterogeneity in malaria transmission across Indonesia: analysis of surveillance data 2010–2019. *Lancet Reg Health Southeast Asia.* 2025;32:100456.
19. Fauziah, Perdana AA, Sari N. Analisis pola sebaran spasial kasus malaria di Kabupaten Pesawaran. *Jurnal Kesehatan.* 2020;11(2).
20. Lestari KD, Perdana AA, Widiastuti TA, Hasyim H. Spatial clustering and determinants of malaria elimination in Sumatra, Indonesia. *Malar J.* 2025;24(1):123.
21. Hasyim H, Dalvi M, Mardiana, Sitorus H, Andiarsa D, Negara W, et al. Spatiotemporal clustering of malaria in South Sumatra, Indonesia, 2018–2022. *Geospat Health.* 2025;20(1):1290.
22. Ngadino, Setiawan B, Handayani D. Spatial analysis of imported malaria cases in East Java, Indonesia. *J Vector Borne Dis.* 2024;61(2):210-8.
23. Penchansky R, Thomas JW. The concept of access: definition and relationship to consumer satisfaction. *Med Care.* 1981;19(2):127-40.
24. Levesque JF, Harris MF, Russell G. Patient-centred access to health care: conceptualising access at the interface of health systems and populations. *Int J Equity Health.* 2013;12:18.
25. O'Meara WP, Noor A, Gatakaa H, Tsofa B, McKenzie FE, Marsh K. The impact of primary health care on malaria morbidity: defining access by disease burden. *Trop Med Int Health.* 2009;14(1):29-35.
26. Weiss DJ, Nelson A, Gibson HS, Temperley W, Peedell S, Lieber A, et al. A global map of travel time to cities to assess inequalities in accessibility in 2015. *Nature.* 2018;553(7688):333-6.
27. Weiss DJ, Nelson A, Vargas-Ruiz CA. Global maps of travel time to healthcare facilities. *Nat Med.* 2020;26(12):1835-8.
28. World Health Organization. World malaria report 2023. Geneva: WHO; 2023.

29. Epstein A, Namuganga JF, Kanya EV, Nankabirwa JI, Bhatt S, Rodriguez-Barraquer I, et al. Estimating malaria incidence from routine health facility-based surveillance data in Uganda. *Malar J.* 2020;19:445.
30. Fahmi F, Pasaribu AP, Theodora M, Wangdi K. Spatial analysis to evaluate risk of malaria in Northern Sumatera, Indonesia. *Malar J.* 2022;21:241.

Figures

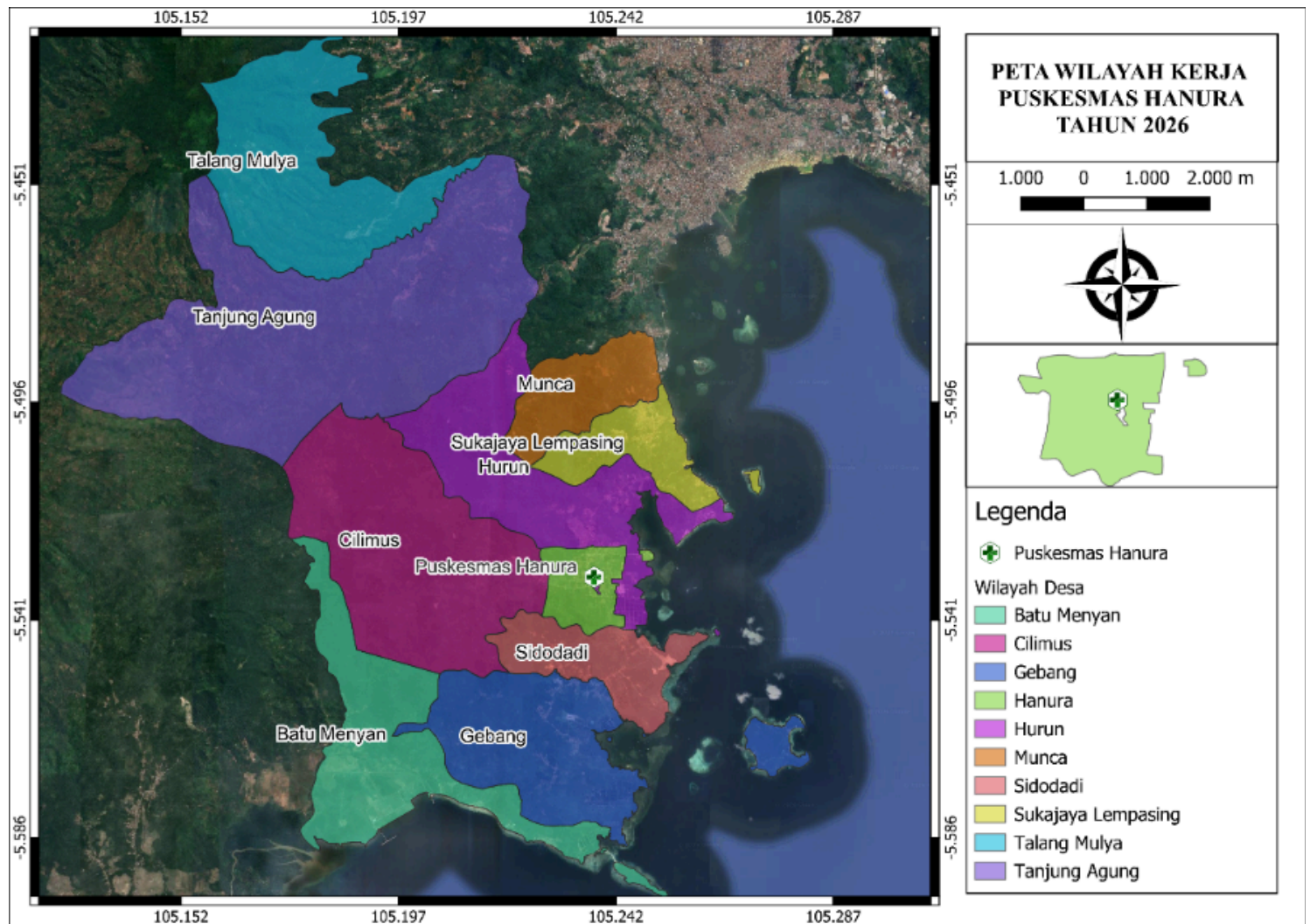


Figure 1

Map of Puskesmas Hanura Working Area, Pesawaran District, 2026.

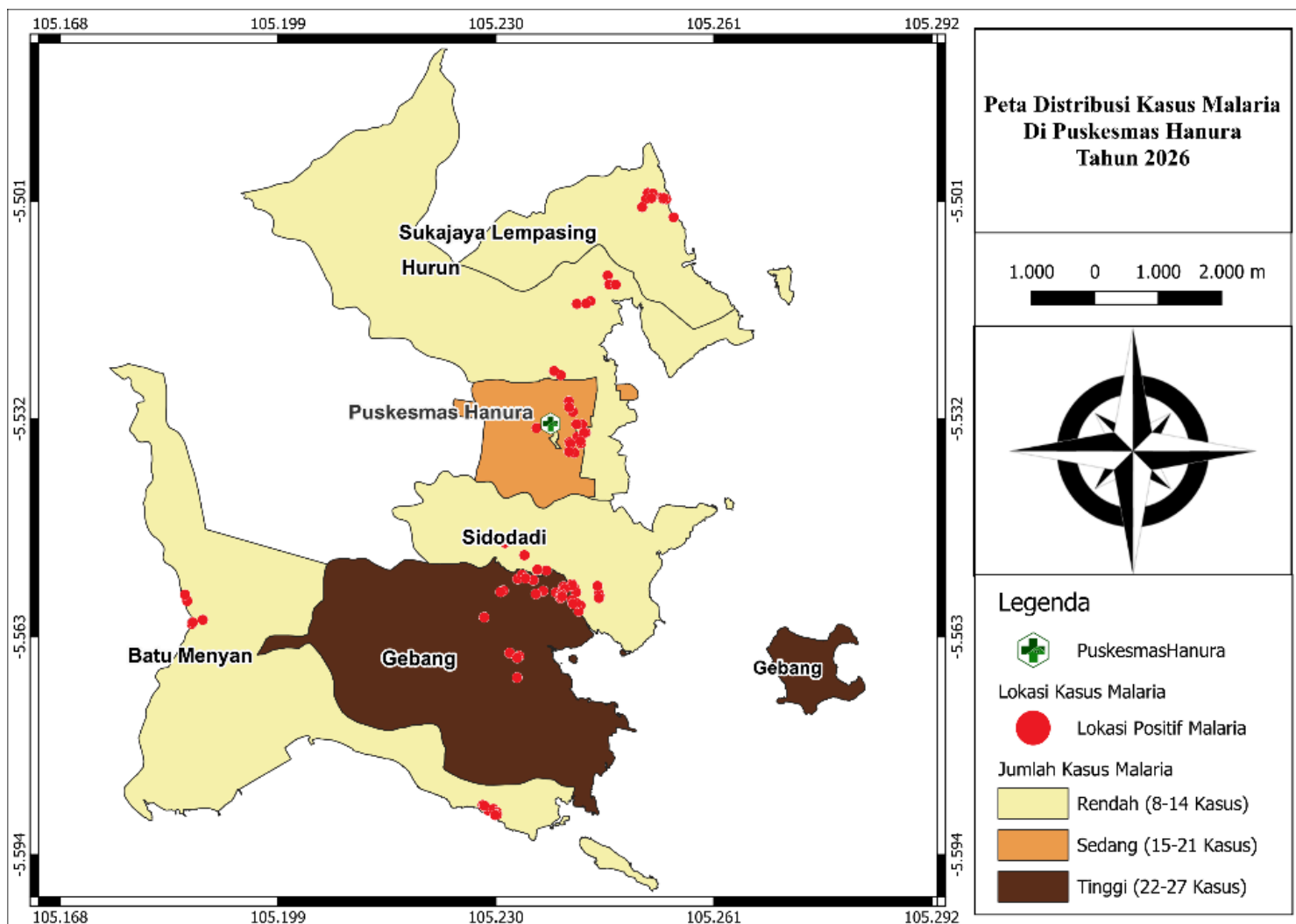


Figure 2

Spatial Distribution of Malaria Cases, Puskesmas Hanura Working Area, 2026

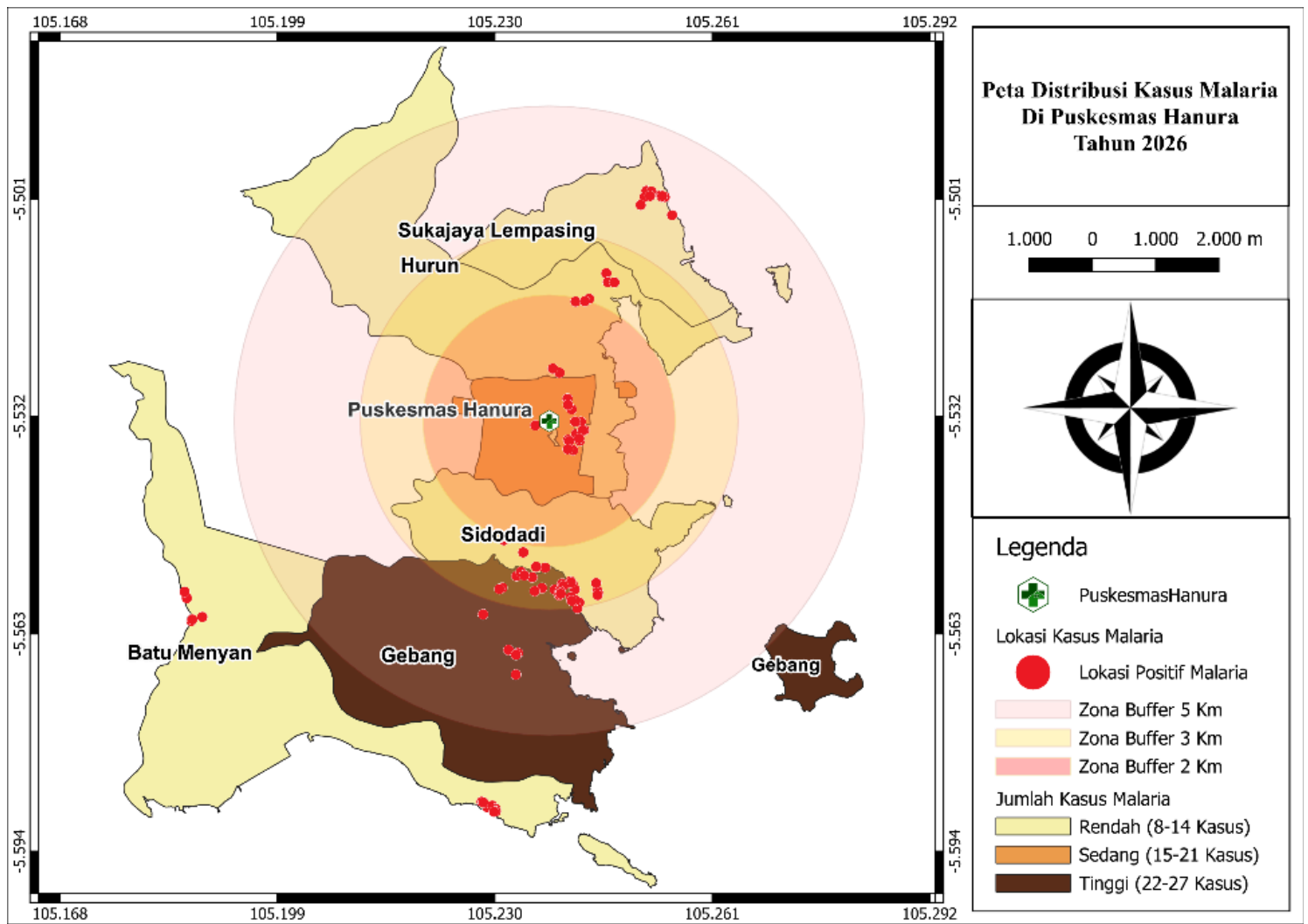
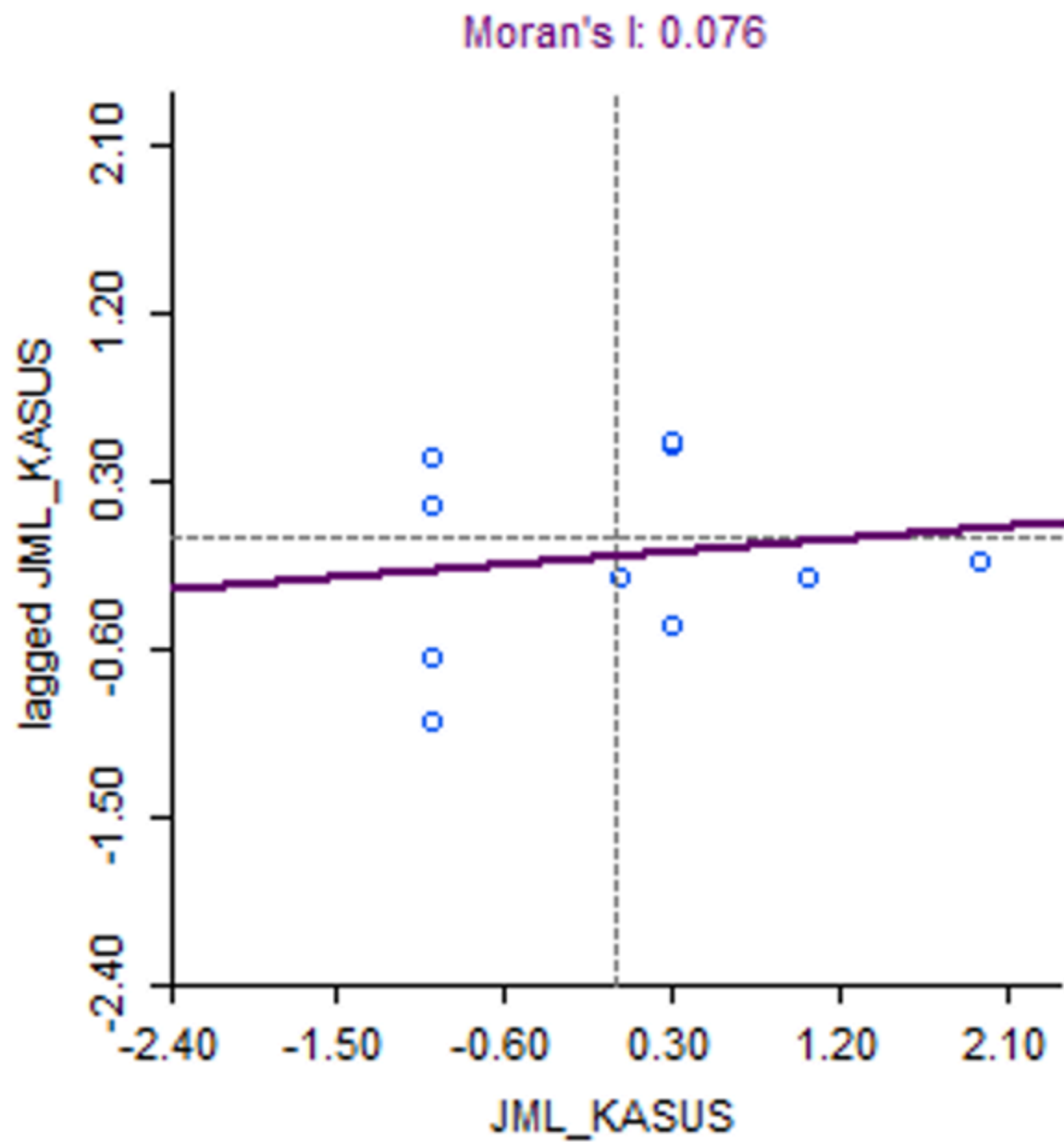


Figure 3

Buffer Analysis Map, Puskesmas Hanura Working Area, 2026



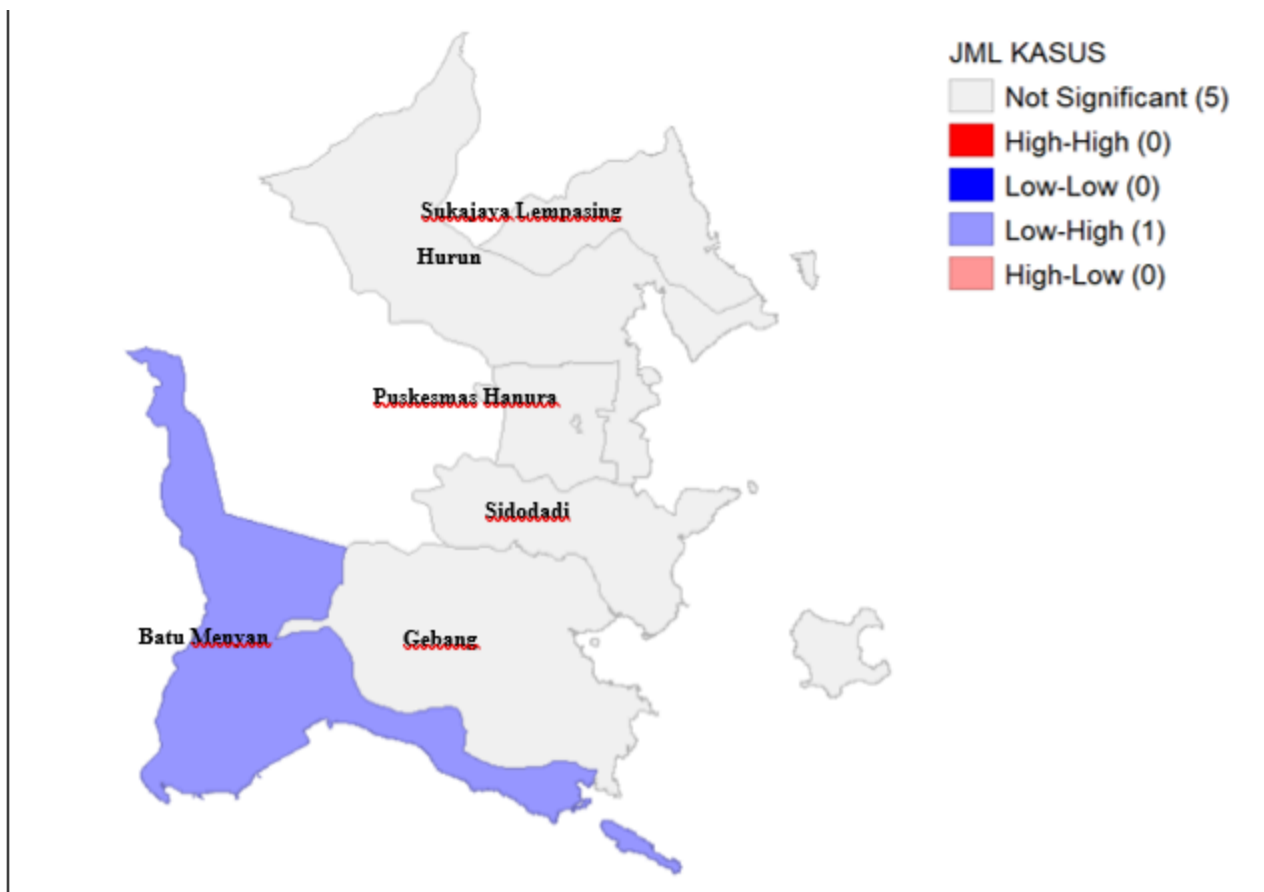


Figure 5

LISA Cluster Map, Distribution of Malaria Cases, Puskesmas Hanura, 2026