

SPATIAL DISTRIBUTION OF MALARIA PATIENTS IN ENDEMIC AREAS USING GEOGRAPHIC INFORMATION SYSTEMS: A CASE STUDY OF MUARA TAMI DISTRICT, JAYAPURA CITY, INDONESIA

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ABSTRACT

Malaria remains a major public health problem in Papua Province, Indonesia, particularly in Jayapura City. Muara Tami District is one of the endemic areas with substantial malaria transmission, influenced by environmental conditions and human activities that support mosquito-vector exposure. This study aimed to identify the demographic characteristics of malaria patients and examine their spatial distribution in Muara Tami District using a Geographic Information System (GIS). An observational study with descriptive and spatial analysis was conducted using malaria case data recorded in 2025 from the Jayapura City Health Office and primary health centers in Muara Tami District. Patient characteristics were analyzed according to sex and age group, while GIS was used to visualize the distribution of cases at the village level. The results identified 10,869 malaria cases, with males accounting for a greater proportion of cases than females. The highest proportion was observed among individuals aged 21–30 years, indicating a substantial burden among the productive-age population. Spatial analysis showed an uneven distribution of cases, with the highest concentration occurring in Koya Barat, followed by Holtekamp, Koya Timur, and Koya Tengah. The study contributes a village-level spatial perspective by integrating demographic characteristics with malaria case distribution in an endemic border district. The findings indicate that GIS-based mapping can support the identification of priority areas and population groups for more spatially targeted malaria surveillance and control interventions in Muara Tami District.

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INTRODUCTION

Malaria remains one of the most important vector-borne diseases and continues to pose a major public health challenge in tropical and subtropical regions. (Weiss et al., 2019; World Health Organization, 2024). Despite continued efforts to reduce malaria transmission, the disease remains endemic in several parts of Indonesia, particularly in eastern Indonesia. Papua Province continues to experience a substantial malaria burden and remains an important region for malaria control and elimination efforts. In Jayapura City, malaria transmission remains high, with 45,247 reported cases and an Annual Parasite Incidence (API) of 143 cases per 1,000 population in 2024. Local health records also reported 68,785 confirmed malaria cases from 380,842 examinations in 2025, indicating that malaria remains a persistent public health concern in the region. These conditions reinforce the importance of strengthening malaria surveillance and geographically targeted control strategies in high-transmission areas (World Health Organization, 2024, 2025)

Malaria transmission is influenced by interactions between environmental, demographic, and human behavioral factors. Environmental characteristics such as wetlands, stagnant water, vegetation, agricultural land, and forested areas may provide suitable habitats for Anopheles mosquitoes and consequently influence malaria transmission (Fahmi et al., 2022; Sipe & Dale, 2003). Human mobility, occupational exposure, settlement patterns, and access to health services can further modify the spatial distribution of malaria cases. GIS-based malaria research in Indonesia has emphasized the importance of integrating disease, environmental, demographic, and geographic information to understand malaria distribution and support control strategies (Sipe & Dale, 2003; Widartono et al., 2022). Therefore, malaria should not only be understood as a health problem but also as a spatial phenomenon in which disease burden varies substantially across geographic areas.

Muara Tami District is an important setting for examining this spatial phenomenon. Located in the eastern part of Jayapura City and adjacent to the Indonesia–Papua New Guinea border, the district contains agricultural areas, wetlands, vegetation-covered areas, and dispersed settlements. These characteristics may provide opportunities for human-vector interaction. Previous research in Jayapura has documented spatial differences in malaria occurrence, while studies in other parts of Papua have demonstrated that environmental and geographic conditions contribute to substantial variation in malaria risk (Hanandita & Tampubolon, 2016; Hastuty & Setyowati, 2021). The geographical context of Muara Tami therefore provides an important basis for examining malaria distribution at a more localized administrative scale.

Recent evidence demonstrates that malaria transmission in Papua is highly heterogeneous. (Fadilah et al., 2022) analyzed nearly half a million malaria surveillance records from Papua and West Papua and found substantial spatial heterogeneity in transmission intensity. Their findings emphasized that malaria cases were disproportionately distributed across geographic areas and that different transmission settings exhibited different sociodemographic characteristics. The authors consequently recommended spatially targeted interventions and the use of routine surveillance data to guide resource allocation. This finding is particularly relevant to Muara Tami because district-level averages may conceal substantial differences between individual villages.

Geographic Information Systems provide an important framework for examining the spatial dimension of malaria. GIS can integrate epidemiological information with administrative, environmental, and demographic data to visualize disease distribution and identify areas requiring greater attention. (Ngadino et al., 2024; Pfeffer et al., 2018; Sipe & Dale, 2003). (Sipe & Dale, 2003) highlighted the potential of GIS for malaria control in Indonesia, while spatial mapping studies have demonstrated the usefulness of geospatial information for identifying malaria risk and vulnerability (Aheto, 2022; Pfeffer et al., 2018). More recent Indonesian studies have applied spatial data and GIS to identify malaria vulnerability and environmental risk, including integrated spatial modeling in the Menoreh Hills (Widartono et al., 2022) and malaria vulnerability mapping in Papua (Tommi et al., 2025).

Previous research in Indonesian Papua has also demonstrated that malaria distribution is associated with both geographic and sociodemographic characteristics. (Fadilah et al., 2022; Hanandita & Tampubolon, 2016; Maulana et al., 2025). (Hanandita & Tampubolon, 2016) found significant spatial variation in malaria risk across districts in Papua and identified differences according to age and gender, even after accounting for socioeconomic characteristics. These findings indicate that demographic characteristics can provide useful complementary information when interpreting spatial malaria patterns. However, previous studies differ from the present study in their spatial scale and analytical focus. (Hanandita & Tampubolon, 2016) examined district-level malaria risk using a Bayesian hierarchical spatial model, while (Fadilah et al., 2022) quantified spatial heterogeneity across districts and health units using surveillance data and the Gini index. More recent research in Jayapura has applied environmental variables, remote sensing, and machine-learning approaches to model malaria

risk (Rumbiak et al., 2026), while other GIS studies have focused on environmental vulnerability and spatial risk assessment (Maulana et al., 2025; Tommi et al., 2025; Widartono et al., 2022) The present study addresses this gap by integrating demographic characteristics of confirmed malaria patients with village-level spatial distribution in Muara Tami District, an endemic border area of Jayapura City.

The selection of sex and age as the principal demographic variables is based on their relevance for identifying population groups with potentially different patterns of malaria exposure. Sex may reflect differences in occupational activities, mobility, and outdoor exposure, while age can reflect differences in daily activities, mobility, and exposure throughout the life course. Importantly, both variables are routinely recorded in malaria surveillance systems, making them suitable for descriptive analysis alongside spatial information. Previous research in Papua has demonstrated that age and sex distributions can vary according to malaria transmission intensity (Fadilah et al., 2022; Hanandita & Tampubolon, 2016; Ngadino et al., 2024).

The scientific contribution of this study lies in integrating routine malaria surveillance data, demographic characteristics, and village-level GIS mapping in Muara Tami District. Rather than developing a statistical risk model, the study provides a localized descriptive spatial perspective that identifies both the population groups with the largest burden and the villages where reported cases are concentrated. This approach can complement broader regional malaria studies by translating routine surveillance data into geographically explicit information that can be used for local intervention planning. Therefore, this study aims to identify the characteristics of malaria patients based on sex and age group and to analyze the spatial distribution of malaria cases at the village level in Muara Tami District, Jayapura City, using a Geographic Information System (GIS). The findings are expected to contribute to a better understanding of demographic and spatial patterns of malaria and provide evidence to support geographically targeted malaria surveillance, control, and regional planning strategies

METHOD

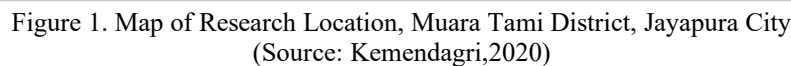
The study used primary and secondary data. Primary data were collected through field observations to identify environmental characteristics potentially associated with malaria transmission, including land use, vegetation, water bodies, and settlement conditions. Secondary data were obtained from the Jayapura City Health Office and primary health centers (Puskesmas) in Muara Tami District. The secondary data consisted of confirmed malaria cases recorded in 2025, patient demographic characteristics, administrative boundary data, and population data.

The malaria data were classified according to sex, age group, and residential location. Patient residential information was subsequently aggregated at the village level for spatial analysis. This aggregation was intended to describe population-level patterns while avoiding the presentation of individual patient locations.

This study was conducted in Muara Tami District, Jayapura City, Papua Province, Indonesia. Muara Tami is one of the districts with a high malaria burden in Jayapura City and is located in the eastern part of the city, adjacent to the Indonesia–Papua New Guinea border. The district consists of eight administrative villages: Koya Barat, Koya Tengah, Koya Timur, Holtekamp, Skow Mabo, Skow Sae, Skow Yambe, and Mosso. The research was conducted from April to July 2026, while the malaria data analyzed covered cases recorded during 2025.

An observational research design was employed using descriptive and spatial analysis. The study aimed to identify the demographic characteristics of malaria patients and describe the spatial distribution of confirmed malaria cases at the village level using a Geographic Information System (GIS).

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The study utilized malaria surveillance data obtained from the Jayapura City Health Office and primary health centers in Muara Tami District. Data were analyzed in aggregated form and presented at the village level. Individual names, exact residential addresses, and other directly identifying patient information were not presented in the manuscript. The

analysis therefore focused on population-level patterns of malaria distribution and maintained the confidentiality of individual patients.

RESULT AND DISCUSSION

Characteristics of Malaria Patients

A total of 10,869 malaria cases were recorded in Muara Tami District in 2025. The distribution of cases varied substantially according to sex and age group. Male patients accounted for 6,834 cases, while female patients accounted for 4,035 cases. When compared with the respective population groups, the proportion of reported malaria cases was 46.68% among males and 29.82% among females (Table 1). This difference indicates that males experienced a higher reported malaria burden than females in the study area.

Table 1. Malaria Cases by Sex in Muara Tami District, 2025

Sex	Malaria Cases	Population	Percentage (%)
Male	6,834	14,641	46.68
Female	4,035	13,529	29.82
Total	10,869	28,170	38.58

Source: Processed Research Data (2026)

The higher proportion among males may be associated with differences in exposure patterns, mobility, and daily activities. Outdoor activities such as farming, fishing, gardening, and other field-based occupations may increase the duration and frequency of contact between humans and malaria vectors. Previous research in Papua has also documented a higher proportion of malaria cases among males, although the magnitude of this difference varies according to the level of malaria transmission and geographic setting (Fadilah et al., 2022). Similarly, (Hanandita & Tampubolon, 2016) identified age and gender differentials in malaria prevalence across Indonesian Papua, indicating that demographic characteristics can contribute to the spatial and social distribution of malaria.

However, the higher proportion among males should not be interpreted as evidence that sex alone determines malaria infection. Malaria transmission results from interactions between the host, vector, environment, and patterns of human activity. The relatively high number of female cases also demonstrates that transmission occurs within the broader community and is not restricted to occupationally exposed populations. Consequently, malaria prevention in Muara Tami should combine population-wide interventions with more targeted approaches for groups with greater outdoor exposure.

The age distribution provides additional information regarding population vulnerability. The highest proportion of reported cases occurred among individuals aged 21–30 years, reaching 52.29%, followed by the 11–20-year group (46.16%), 31–40-year group (45.95%), and 1–10-year group (43.85%) (Table 2). The proportion subsequently declined among older age groups, reaching 8.02% among individuals aged 71 years and above.

Table 2. Malaria Cases by Age Group in Muara Tami District, 2025

Age Group (Years)	Malaria Cases	Population	Percentage (%)
1–10	2,040	4,652	43,85
11–20	2,267	4,911	46,16
21–30	2,364	4,521	52,29
31–40	2,043	4,446	45,95
41–50	1,268	3,804	33,33
51–60	620	2138	29,00
61–70	213	1098	19,40

Source: Processed Research Data, 2026

The high proportion of cases among individuals aged 21–30 years suggests that the productive-age population represents an important group for malaria surveillance in Muara Tami. This finding is consistent with the observation of (Fadilah et al., 2022), who found that age patterns varied according to transmission intensity in Papua, with adults and productive-age groups contributing substantially to malaria cases in some settings. The differences between locations indicate that age patterns should be interpreted within their specific geographic and epidemiological contexts rather than treated as universal characteristics of malaria transmission.

In Muara Tami, the productive-age population is likely to have relatively high mobility and greater participation in agricultural, economic, and outdoor activities. These activities may increase exposure to vector habitats. At the same time, the relatively high proportion of cases among children and adolescents indicates that malaria transmission is not restricted to occupational environments. The occurrence of cases across multiple age groups suggests that exposure may also take place around settlements and other community environments.

The progressive decline in the proportion of cases among older age groups should nevertheless be interpreted cautiously. The available data describe reported cases relative to population size and do not allow the study to determine whether age itself is a causal determinant of malaria infection. Other factors, including occupation, mobility, environmental exposure, healthcare-seeking behavior, and access to health services, may contribute to the observed pattern. Thus, age distribution should primarily be interpreted as an epidemiological profile that can assist in identifying priority groups for prevention and surveillance.

Spatial Distribution of Malaria Cases

The spatial analysis revealed substantial variation in malaria cases among the eight villages of Muara Tami District. Cases were concentrated in several villages, particularly Koya Barat, Holtekamp, Koya Timur, and Koya Tengah, while substantially fewer cases were recorded in Skow Yambe, Skow Sae, and Mosso. Similar spatial variation has been identified in GIS-based malaria studies in Indonesia, where geographic visualization has been used to identify areas with different levels of malaria burden (Ngadino et al., 2024; Nuraisyah et al., 2022). This spatial variation demonstrates that malaria burden is not evenly distributed across the district.

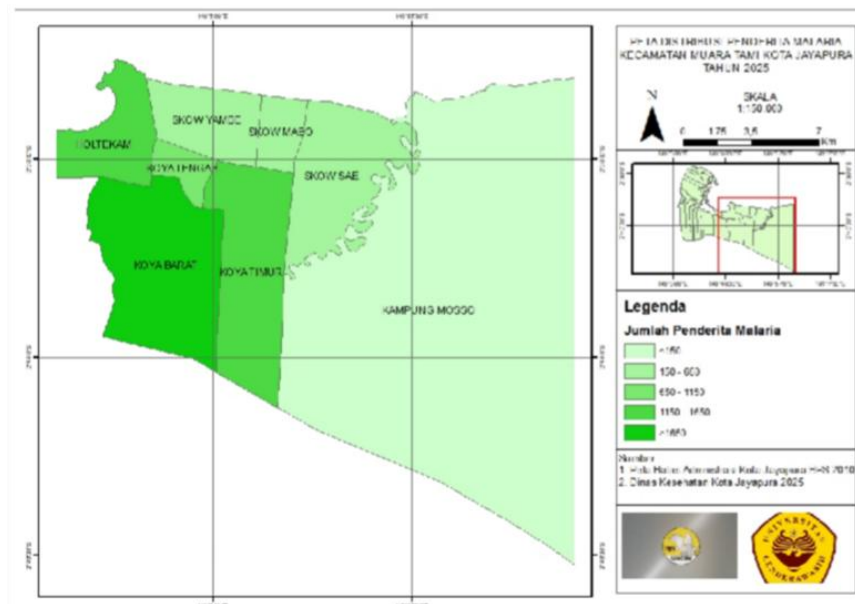


Figure 2. Spatial Distribution of Malaria Cases in Muara Tami District, 2025

Source: Processed Research Data, 2026

Koya Barat recorded the largest number of malaria cases, with 5,579 cases, representing approximately 51.33% of all reported cases in Muara Tami District. Holtekamp recorded 1,564 cases, followed by Koya Timur with 1,167 cases and Koya Tengah with 993 cases. In contrast, Mosso recorded only 149 cases (Table 3). The substantial differences between villages demonstrate the importance of examining malaria burden at a finer spatial scale rather than relying exclusively on district-level statistics.

Table 3. Distribution of Malaria Cases by Village in Muara Tami District, 2025

Village	Male	Female	Total
Koya Barat	3,643	1,936	5,579
Holtekamp	1,025	539	1,564
Koya Timur	678	489	1,167
Koya Tengah	623	370	993
Skow Mabo	336	293	629
Skow Sae	225	178	403
Skow Yambe	206	179	385
Mosso	98	51	149

Source: Processed Research Data, 2026

The uneven spatial distribution observed in this study is consistent with previous research demonstrating substantial spatial heterogeneity in malaria transmission in Papua. (Fadilah et al., 2022) found that malaria cases were disproportionately distributed across geographic areas of Papua and emphasized that areas with different transmission intensities exhibited distinct characteristics. This evidence supports the interpretation that malaria control should consider local geographic variation rather than treating endemic areas as spatially homogeneous.

The concentration of cases in Koya Barat, Holtekamp, Koya Timur, and Koya Tengah can be interpreted in relation to the environmental and demographic characteristics of these areas. Agricultural land, vegetation, wetlands, drainage features, and other open environments may provide suitable conditions for mosquito breeding and human-vector interaction. GIS-based studies in Indonesia have similarly emphasized the importance of integrating environmental and spatial information to identify malaria vulnerability and risk (Sipe & Dale, 2003; Tommi et al., 2025; Widartono et al., 2022) (Sipe & Dale, 2003; Widartono et al., 2023; Tommi et al., 2025).

Population distribution must also be considered when interpreting the number of cases. Areas with larger populations may naturally record more malaria cases because a greater number of individuals are potentially exposed. Therefore, the number of reported cases should not automatically be interpreted as an individual-level risk. (Hanandita & Tampubolon, 2016) demonstrated that spatial differences in malaria in Papua remain important even after considering socioeconomic and demographic factors, emphasizing that malaria distribution reflects multiple interacting dimensions.

The spatial concentration observed in Muara Tami also highlights the importance of human mobility and connectivity between villages. Movement associated with agriculture, employment, social activities, and access to services may connect areas with different levels of malaria transmission. In border areas, these mobility patterns require particular attention because malaria transmission can extend beyond administrative boundaries. Consequently, village-level surveillance should be complemented by broader coordination among health facilities and local government institutions.

The findings further support the concept of spatial epidemiology, in which disease occurrence is interpreted through the interaction of population, environment, and geographic location. GIS is valuable in this context because it enables epidemiological data to be linked with geographic information and presented in a form that can support planning and decision-making (Aheto, 2022; Pfeffer et al., 2018; Sipe & Dale, 2003). Recent research has also demonstrated the usefulness of

geospatial approaches for identifying malaria vulnerability and prioritizing intervention areas (Aheto, 2022; Tommi et al., 2025). Because this study used descriptive spatial analysis, the observed concentration of malaria cases should not be interpreted as statistically significant spatial autocorrelation. No Global Moran's I, Local Moran's I, Kernel Density Estimation, or Hotspot Analysis was performed. This limitation is important when interpreting the spatial pattern. Nevertheless, descriptive village-level mapping remains useful for identifying areas with a high reported burden and can serve as an initial basis for more advanced spatial analysis in subsequent studies.

Implications for Malaria Control and Regional Planning

The spatial distribution identified in this study provides a practical basis for prioritizing malaria control interventions. Koya Barat, Holtekamp, Koya Timur, and Koya Tengah should receive particular attention in surveillance and intervention planning because they accounted for the largest numbers of reported cases. This approach is consistent with evidence from Papua showing that malaria transmission is highly heterogeneous and that spatially targeted interventions can improve the prioritization of resources (Fadilah et al., 2022).

Interventions should include intensified case detection, timely diagnosis and treatment, distribution and use of insecticide-treated nets, vector control, environmental management, and community health education. WHO malaria guidance emphasizes the importance of surveillance information for identifying populations and areas requiring appropriate malaria interventions (World Health Organization, 2025).

The demographic findings also indicate the importance of tailoring interventions to population characteristics. Productive-age populations, particularly those involved in outdoor activities, can be targeted through health education and personal protection measures. At the same time, the substantial proportion of cases among children and adolescents indicates the need to maintain preventive measures within residential and community environments.

From a regional planning perspective, malaria information should be considered alongside settlement development, agricultural land management, drainage, and environmental management. Land-use changes may modify human exposure to mosquito habitats, while settlement expansion can increase interaction between populations and malaria-vector environments. Integrating health-related spatial information into regional planning can therefore support the development of healthier and more resilient settlements. Overall, the contribution of this study is not the development of a statistical malaria risk model, but the integration of routine malaria surveillance data, demographic characteristics, and village-level GIS mapping in Muara Tami. This localized approach complements broader spatial studies of malaria in Papua by providing information that can be directly interpreted at the local administrative level. The resulting spatial evidence can support local health authorities and planners in identifying priority areas for surveillance, prevention, and resource allocation.

CONCLUSION

This study demonstrates substantial demographic and spatial variation in reported malaria cases in Muara Tami District, Jayapura City. Male patients accounted for a higher proportion of reported cases than females, while the highest proportion occurred among individuals aged 21–30 years. At the village level, malaria cases were unevenly distributed, with the highest number of reported cases occurring in Koya Barat, followed by Holtekamp, Koya Timur, and Koya Tengah. The integration of routine malaria surveillance data, demographic characteristics, and village-level Geographic Information System (GIS) mapping provides localized information that can support the identification of priority population groups and geographic areas for malaria surveillance, prevention, and resource allocation. However, the spatial analysis was descriptive and did not statistically test spatial autocorrelation or significant malaria clusters, while environmental, climatic, land-use, and population-density variables were not quantitatively modeled as determinants of malaria occurrence. Future research should therefore integrate these variables with statistical spatial analysis to develop more comprehensive malaria risk models and strengthen evidence-based malaria control and regional planning in Muara Tami and other malaria-endemic areas of Papua.

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