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Landscape and Socio-Demographic Drivers of Malaria Transmission in North Sulawesi, Indonesia

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ABSTRACT

Malaria remains a public health problem in Indonesia, with a heterogeneous spatial distribution. Bitung City, as an endemic area with coastal and hilly geographical characteristics, shows fluctuations in cases that require in-depth analysis for effective control. This study aims to analyze the spatial-temporal distribution of malaria cases and identify risk factors that contribute to the incidence of malaria in Bitung City. This spatial ecology study uses secondary data on all confirmed malaria cases in Bitung City for the 2021-2023 period (n=379). The data was analyzed descriptively and spatially using the Geographic Information System (GIS) to map the distribution of cases, calculate the Annual Parasite Incidence (API), and overlay with maps of altitude and population density. There was a peak of cases in 2022 (212 cases) with a temporal pattern of three peaks in a year (March-April, July-August, November). As many as 58% of sufferers are men. Spatial analysis identified two sub-districts as epicenters or hotspots, namely South Lembeh (API 15.4‰) and Maesa (API 3.74‰), which accounted for nearly 80% of the total cases. This hotspot area is characterized by a combination of geographical factors such as the highlands (South Lembeh) and high population density with a potential mosquito breeding environment (Maesa). The distribution of malaria in Bitung City is clustered and is strongly influenced by location-specific environmental factors. Hotspot-focused control interventions in South Lembeh and Maesa Districts, such as environmental management and strengthening vector surveillance, are needed to effectively suppress malaria transmission

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INTRODUCTION

The World Health Organization (WHO) states that malaria affected about 219 million people in 2017 and caused 435,000 deaths worldwide in 2017. The burden of malaria pain and death is the result of more than a century of global efforts and research to improve malaria prevention, diagnosis, and treatment (WHO, 2018). In 2019, it is known that there are 229 million cases of malaria worldwide with a death toll of 409,000 people. About 3.3 billion people in 97 countries and territories are at risk of being infected with malaria and other emerging diseases. As many as 1.2 billion of them are at high risk of malaria (>1 out of 1000 potential malaria in a year) (WHO, 2020).

Data in Indonesia in 2018 shows that Papua Province has an Annual Parasite Incidence (API) rate of 41.34 per 1000 population and is the area with the highest malaria cases (Hamdani, 2020). In 2019, the malaria API in Indonesia increased from 0.84 to 0.93 per 1000 population compared to 2018 (Ministry of Health of the Republic of Indonesia, 2019). In 2020, malaria cases in Indonesia reached 254,050 cases with an API of 0.94 per 1000 population. In 2021, 90 thousand cases of malaria were found. The number of cases decreased when compared to 2020 (Ministry of Health of the Republic of Indonesia 2022).

There are 3 (three) main determinants in malaria transmission, namely the host, namely humans as intermediate hosts and mosquitoes as permanent hosts (defensive hosts) of the malaria-causing agent. The cause of malaria disease (agent) is *Plasmodium* sp. (*P. falciparum*, *P. vivax*, *P. ovale* and *P. malariae*). The environment such as the existence of lakes, puddles, forests, rice fields, fish ponds, and mines in an area increases the likelihood of malaria outbreaks, because these places are breeding grounds for malaria mosquitoes that affect each other so that there is natural transmission and spread of malaria (Ministry of Health of the Republic of Indonesia 2022; Suyono et al., 2021; Hasan, 2023).

Indonesia is included in areas with tropical and subtropical climates which are the habitat of *Anopheles* sp. Malaria can infect all age groups. Climate change factors related to the physical, chemical, biological and social environment as well as community behavior can influence the increasing incidence of malaria. The abundance of *Anopheles* sp., will be related to the high cases of malaria. Female mosquito larvae *Anopheles* sp., can live and develop in various nesting places such as freshwater, saltwater, swamps, mangroves, rice fields, grassy ditches, riverbanks, and temporary rainwater reservoirs (Hasan 2023).

Malaria is greatly influenced by climatic factors such as temperature, humidity, and rainfall. Malaria is spread in subtropical and tropical regions, because in those areas it is very suitable for the life and breeding of *Anopheles* and *Plasmodium* sp. in completing its life cycle in the mosquito's body. Temperature is an important element, because the temperature is below 20°C (68°F), so P. falciparum cannot complete its life cycle in the body of *Anopheles* sp. mosquitoes, so this mosquito cannot transmit malaria (Suwarja et al 2012; Sutarto 2017).

LITERATURE RIVIEW

The results of the study conducted in the Menoreh Hills explained that malaria cases are more common in areas with lower population density, near river headwaters and hillsides. Climatic conditions (rainfall and humidity) and migration also have an effect on the incidence of malaria in Purworejo Regency. The height / location of the house is proven to be related to malaria the results of the study in Menoreh show that the height of the dwelling is a risk factor for malaria. *Anopheles* sp., which plays a role as a vector of malaria transmission in Indonesia, also varies in type. Each of these species occupies a different topography. The habitat of this malaria vector can be found on beaches, mountains, hills, rice fields, forests and mining areas (Rejeki et al 2018; Rejeki et al 2019; Barcus et al 2002).

Demographic factors such as population density affect the process of transmission and transfer of diseases from one person to another (Achmadi, 2012). The results of Sulistyawati's (2012) research in Purworejo Regency showed that the number of malaria cases increased with the location of the village still in the low density classification because the environmental conditions were very supportive of the many potential breeding habitats for *Anopheles* mosquitoes.

North Sulawesi Province in 2020 and 2021, API was 0.4 per 1000 population. Southeast Minahasa Regency is the highest area of API, which is 3.0 per 1000 population in 2020 and 2.6 per 1000 population in 2021. API data in Bitung City was 0.1 per 100 population in 2020 and 2021 (BPS North Sulawesi, 2024). Malaria cases in Bitung City are still frequent. The number of malaria cases in Bitung City in 2018-2023 tends to increase. In 2018 there were 19 cases and an increase of 37 cases in 2019. In 2020 it dropped to 28 cases due to the Covid-19 pandemic, and in 2021 it increased again by 85 cases and peaked in 2022 at 145 cases. In 2023 with the number of cases being 28 cases (Bitung Health Office, 2023).

Geographically, Bitung City is located at the foot of Mount Dua Sudara and Mount Klabat with a sandy soil structure and is directly adjacent to the coastline. This allows the existence of brackish water as a breeding ground for malaria vectors. As a port city, Bitung City is a meeting place for many ethnicities and tribes, with a variety of livelihoods that are the background of the people's economy. Traffic of goods and services, sea transportation, fisheries, and industry are economic fields that can distinguish this city from other cities in North Sulawesi (BPS Sulut, 2024).

Monitoring carried out using tables and graphs has not been able to show trends spatially. Region-based malaria prevention is carried out to look spatially at the pattern of case distribution, demographic factors and environmental factors that have the potential to increase the incidence of malaria broadly and specifically in all work areas of Public Health Center. This is considered to make it easier for health center officers and health cadres to determine malaria control efforts in certain locations based on the pattern of case distribution, demographic factors and environmental factors.

Spatial-temporal analysis techniques in malaria cases are needed for the control of the disease because each region must have different characteristics and regional order so that the spatial description of cases makes it easier to see the case points and specific environmental conditions in each region in a certain period of time (Teurlai et al 2015; Sumampouw 2020; Ottay et al 2024).

Spatial analysis using the Geographic Information System (GIS) is a method that can be used to describe malaria cases per region, population density/house according to the region. Spatial analysis in GIS can be used to help identify areas at risk of malaria so that control efforts can be pursued (Dhaniasri, 2020). The purpose of this study is to analyze the distribution of malaria in Bitung City with a spatial analysis approach.

METHODOLOGY

This study uses an analytical observational design with a spatial ecology study approach. The data used are secondary obtained from medical records and annual reports of the Bitung City Health Office for the 2021-2023 period. The research was carried out in Bitung City, North Sulawesi Province in July-October 2025. The population in this study is all malaria cases recorded in Bitung City during the 2021-2023 period, which totals 379 cases. The sampling technique used total sampling, where the entire case population was analyzed. The research variables included the characteristics of the time (year and month of the event), people (gender), and place (sub-district). The primary data source is in the form of GPS coordinates of the case location, while secondary data including the population and area area are obtained from the Central Statistics Agency (BPS). The data is analyzed descriptively to see the frequency distribution. Spatial analysis was carried out using ArcGIS 10.8 Software to map the distribution of point patterns, calculate the Annual Parasite Incidence (API) per sub-district, create thematic maps based on area height and population density and create risk categories based on API values: Low (<1‰), Medium (1-5‰), and High (>5‰).

RESULT AND DISCUSSION

Distribution of Malaria Incidence in Bitung City by time

The distribution of malaria incidence in Bitung City shows fluctuations in the last 4 years where the number of cases from 2021 to 2022 has increased, then in 2023 there has been a decrease when compared to previous years. The highest cases were found in 2022 as many as 212 cases. Furthermore, the distribution of the incidence of monthly malaria can be seen in Figure 1.

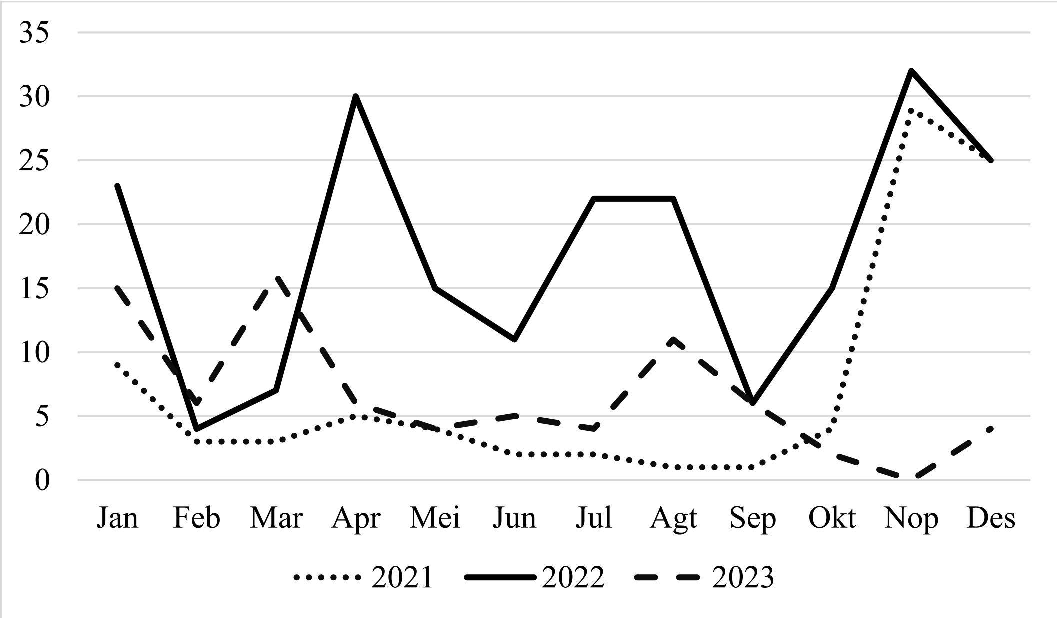

Figure 1. Distribution of Malaria Incidence in Bitung City per Month

The distribution of malaria incidence in 2021-2023 in Bitung City based on time in this case the month shows that in general it can be seen that malaria cases in 1 year have 3 peaks, namely in March-April, July-August and November. However, this pattern did not occur at the end of 2023 where in October to November it decreased since August 2023.

Malaria is one of the infectious diseases caused by *Plasmodium* sp. The disease is transmitted through the bite of a female Anopheles mosquito. The incidence of malaria is influenced by several factors, namely the agent, host and environment. In relation to environmental factors, the existence of lakes, puddles, forests, rice fields, fish ponds, and mining in an area will increase the likelihood of malaria disease because these places are breeding grounds for malaria mosquitoes (Suyono, et al 2020).

The increase in malaria incidence in 2022 can occur due to many factors. One of them is rainfall. Based on data from the Bitung City BPS, it was found that in 2021 rainfall was 184.9 mm and in 2022 it increased to 199 mm. High and low rainfall will affect the existence of malaria vector development habitat. High rainfall can increase the amount of standing water that has the potential to become a breeding habitat for malaria-vector mosquitoes. The presence of rain will increase the number and type of waterlogging. Rain can also increase relative humidity, thus extending the life of adult mosquitoes. The minimum rainfall required by mosquitoes to develop is 1.5 mm per day.

The North Sulawesi Meteorology, Climatology and Geophysics Agency shows that in 2023, the number of rainy days in Bitung City will range from 11-20 days. This shows that there is a pause in every rainfall so that when puddles are formed, mosquitoes can start their life cycle with supportive environmental conditions. Rain provides many advantages for mosquitoes to breed, but continuous heavy rains can damage mosquito breeding grounds and cause a decline in mosquito populations (Suryaningtyas et al 2019). This is what the researcher suspects to explain the decrease in the incidence of Malaria in the city of Bitung in 2023.

Malaria transmission is inseparable from the existence of a physical and biological environment that supports the occurrence of the disease. Environmental factors such as climate, temperature and rainfall are factors that trigger the re-emergence of malaria in an area. The results of the study stated that rainfall affects vector fluctuations in an area (Suryaningtyas et al, 2019).

Distribution of Malaria Incidence by Person

The distribution of malaria incidence in Bitung City by person (gender) can be seen in Figure 2.

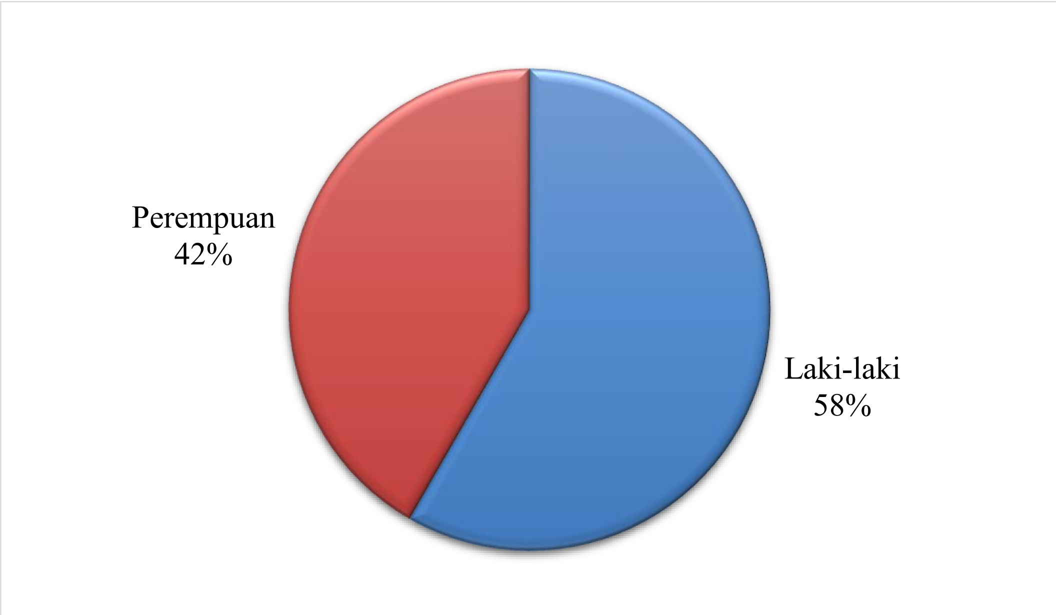

Figure 2. Distribution of Malaria Incidence in Bitung City by Gender

The distribution of malaria incidence in 2021-2023 in Bitung City by gender shows that malaria cases occurred most in men (58%) out of 379 cases during 2021-2023.

Malaria is caused by the parasite *Plasmodium* which is transmitted through the bite of a female mosquito of the species Anopheles which contains the parasite *Plasmodium* in it. After biting, Anopheles mosquitoes will infect humans with the *Plasmodium* parasite, which will then live and multiply in human blood cells (Harapan, 2020). Risk factors that cause malaria include individual factors and environmental factors, this is because individual and environmental factors can affect health status (Wardani, 2016).

Indonesia's Health Profile in 2019-2021 shows that the highest number of cases occurred in men with a total of 461,953 cases. Every year, the number of malaria patients in Indonesia increases in the male population. However, in the last 3 years, the number of malaria cases in the female population has fluctuated or fluctuated.

The results of research conducted by Khair, Noraida, and Darmiah revealed that men experience more malaria than women, this is due to the tendency of men to do outdoor activities in daily life, especially the habit of staying up late and often, as a result of which men are more often exposed to the *Anopheles* mosquito, which is a vector of malaria (Malino et al 2023).

Research from Mosso and Song at the Manokwari Regency Hospital found that malaria cases occurred in 52% of men and 48% of women. The findings are associated with vector habits that have a habit of biting humans outdoors and indoors. To identify the problem of malaria in an area, we can look at the number of malaria cases and the number of deaths due to malaria within that area (Malino et al 2023).

Some studies say that malaria infects more men than women. This is because men are more active at night. In addition, children under the age of 15 are at high risk of being infected with malaria because at this age children's immunity is still in the developmental stage (Rizki 2023).

Distribution of Malaria Incidence by Place

The distribution of malaria incidence in Bitung City by place (District) can be seen in Figure 3.

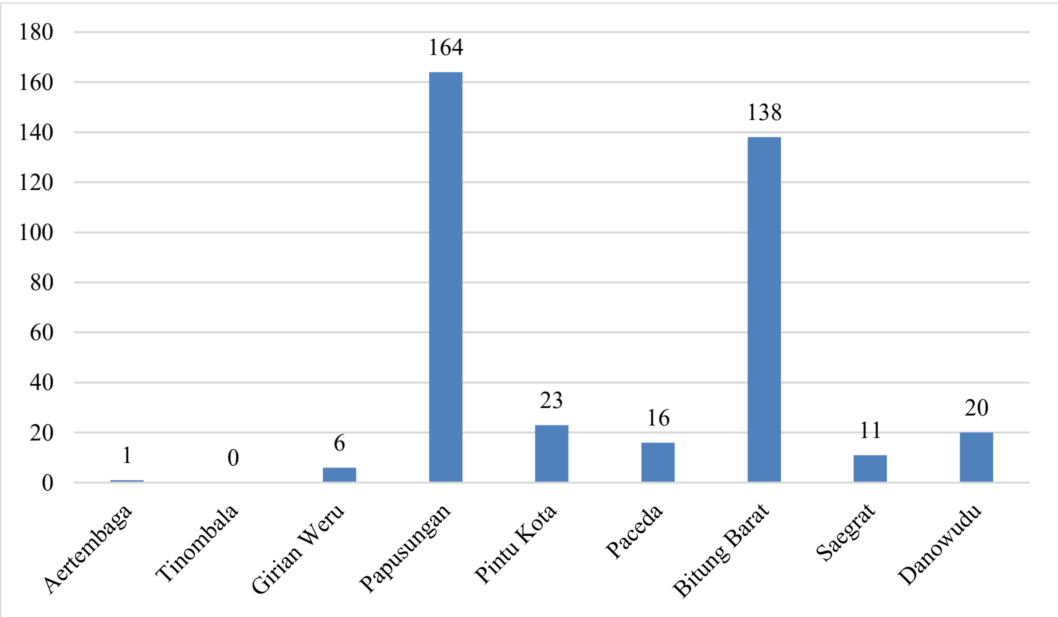

Figure 3. Distribution of Malaria Incidence in Bitung City by Sub-district

The distribution of malaria incidence in Bitung City by sub-district was seen to occur most in Papusungan sub-district with 164 cases and West Bitung with 138 cases while in Tinombala sub-district there were no cases of Malaria and Aertembaga only 1 case.

Malaria can be found throughout Indonesia, but the eastern region of Indonesia has a higher number of malaria cases. The eastern region of Indonesia is still vulnerable to malaria due to its high endemism, as well as geographical and cultural factors. Some areas in eastern Indonesia still have people living around gardens, swamps, and trees, where mosquitoes breed, this increases the risk of malaria (Malino et al 2023).

The results of the study conducted in the Menoreh Hills explained that malaria cases are more common in areas with lower population density, near river headwaters and hillsides. Climatic conditions (rainfall and humidity) and migration also have an effect on the incidence of malaria in Purworejo Regency. The height / location of the house is proven to be related to malaria the results of the study in Menoreh show that the height of the dwelling is a risk factor for malaria. *Anopheles* sp. which plays a role as a vector of malaria transmission in Indonesia also varies in type. Each of these species occupies a different topography. The habitat of this malaria vector can be found on beaches, mountains, hills, rice fields, forests and mining areas (Rejeki et al 2018; Rejeki et al 2019; Barcus et al 2002).

Demographic factors such as population density affect the process of transmission and transfer of diseases from one person to another (Achmadi, 2012). The results of Sulistyawati's (2012) research in Purworejo Regency showed that the number of malaria cases increased with the location of the village still in the low density classification because the environmental conditions were very supportive of the many potential breeding habitats for *Anopheles* mosquitoes.

Spatial Analysis of Malaria Distribution in Bitung City

In this section, the results of the spatial analysis of the city of Bitung are explained based on the height of the place and population density, the distribution of malaria cases based on API per sub-district, the average height of the sub-district and the density of the sub-district population. The description of the average height of the sub-district in Bitung City is divided into 2 categories, namely low if the average is 0-200 meters above sea level and high if > 200 meters above sea level, this can be seen in Figure 4.

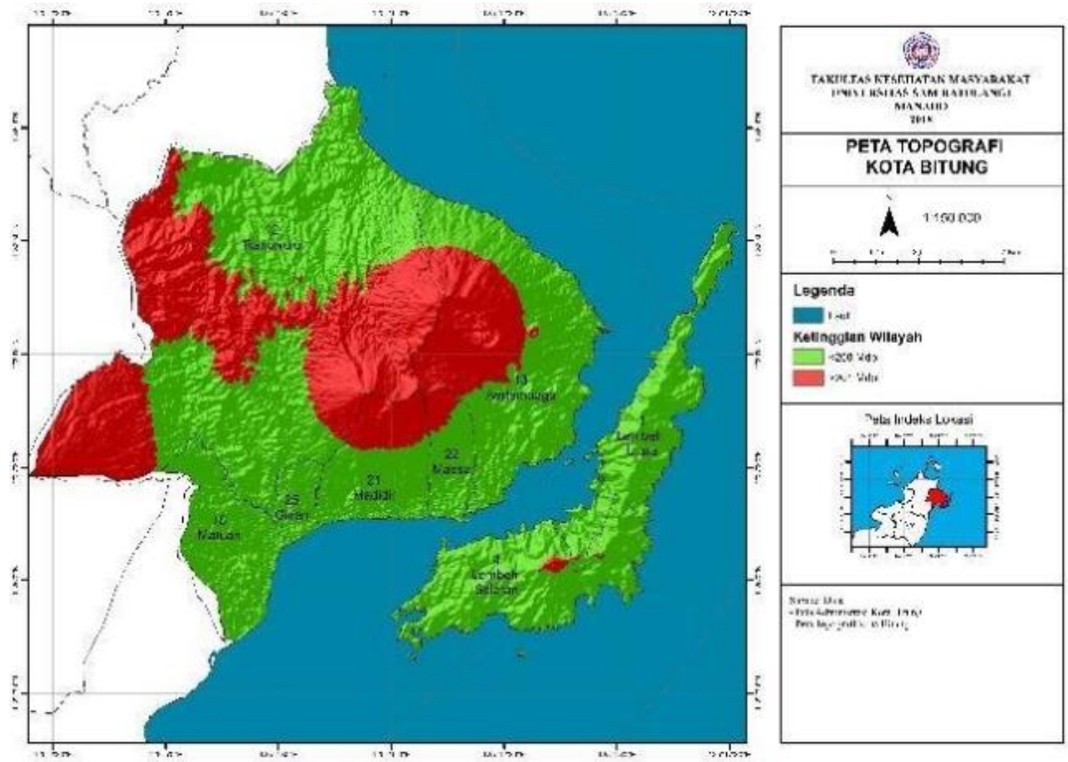

Figure 4. Height of the Place Based On District

The results of this study show that Ranowulu and South Lembeh sub-districts are sub-districts with sub-district areas whose areas are in the highland category (> 200 meters above sea level) where Ranowulu sub-district is the sub-district with the most area in the highlands. Furthermore, the sub-districts of Matuari, Girian, Madidir, Maesa, Aertembaga and North Lembeh whose areas are included in the lowland category (< 200 meters above sea level). Furthermore, the distribution of malaria is explained based on the height of the place.

CONCLUSIONS AND RECOMMENDATIONS

Table 1. Distribution of Malaria by Place Altitude

Yes	**Districts**	**Total Malaria Cases (people)**	**Category Height of Place**
1	SquirrelCopper	1	Low
2	Girian	6	Low
3	South Lembeh	164	Height
4	North Lembeh	23	Low
5	Madidir	16	Low
6	Maesa	138	Low
7	Mature	11	Low
8	Dunkin' Donuts	20	Height

Table 1 shows that the sub-districts with the "Low" Altitude Category consist of 6 sub-districts, namely Aertembaga, Girian, North Lembeh, Madidir, Maesa, and Matuari. The total number of malaria cases is 195 people, with an average of 32.5 cases per sub-district. These results show that sub-districts in the lowlands show a very wide variation in cases, from very low (Aertembaga: 1 case) to very high (Maesa: 138 cases). This suggests that although in general low-risk areas are at risk, other factors outside of altitude have a very strong influence in determining the height of cases in an area.

Furthermore, for sub-districts with the "High" height category, there are 2 sub-districts, namely South Lembeh and Ranowulu. The total number of malaria cases is 184 people with an average of 92 cases per sub-district. This data shows that even though there are only two sub-districts, the average cases are almost three times higher than the average sub-district in the lowlands. However, it should be noted that 164 cases (89%) came from South Lembeh alone, while Ranowulu "only" had 20 cases. It shows extreme inconsistency even within the same category.

These results show that height is not the only determining factor. The classical theory states that *Anopheles* mosquitoes (malaria vectors) breed more in the lowlands. The data partially supports this (6 out of 8 endemic sub-districts are lowlands). However, the existence of very high cases in South Lembeh (High category) and very low in Aertembaga (Low category) proves that altitude is only one factor. Other environmental and epidemiological factors play a more crucial role. Furthermore, it was found that there was a "Hotspot" or local outbreak. This can be seen in South Lembeh sub-district which is clearly a malaria hotspot or epicenter in this region with 164 cases (43% of all malaria cases). Maesa District is also a vulnerable area with 138 cases (36% of the total). These two sub-districts (South Lembeh and Maesa) alone account for almost 80% of the total malaria cases. This indicates that transmission is highly concentrated.

In addition, these results show the existence of specific environmental factors such as the presence of Coastal and Swamp Areas, brackish waterlogging/ponds and population density and mobility. The sub-districts of "Lembeh" (South and North) and "Girian" are often associated with coastal areas. Coastal areas with mangrove forests, ponds, or brackish swamps are ideal habitats for *certain Anopheles* mosquitoes (such as *An. sundaicus*). South Lembeh and Maesa are suspected to have brackish waterlogs/ponds that are very productive breeding grounds for vector mosquitoes. Maesa District, which is in a lowland area but has very high cases, may be an area with high population density and active mobility, making it easier to transmit from infected people to healthy people.

Furthermore, a spatial map of Bitung City based on population density is presented. Population density is divided into 3 categories, namely high (> 500 people/km2), medium (250-500 people/km2), and low (1-250 people/km2). The spatial distribution of population density by sub-district can be seen in Figure 5.

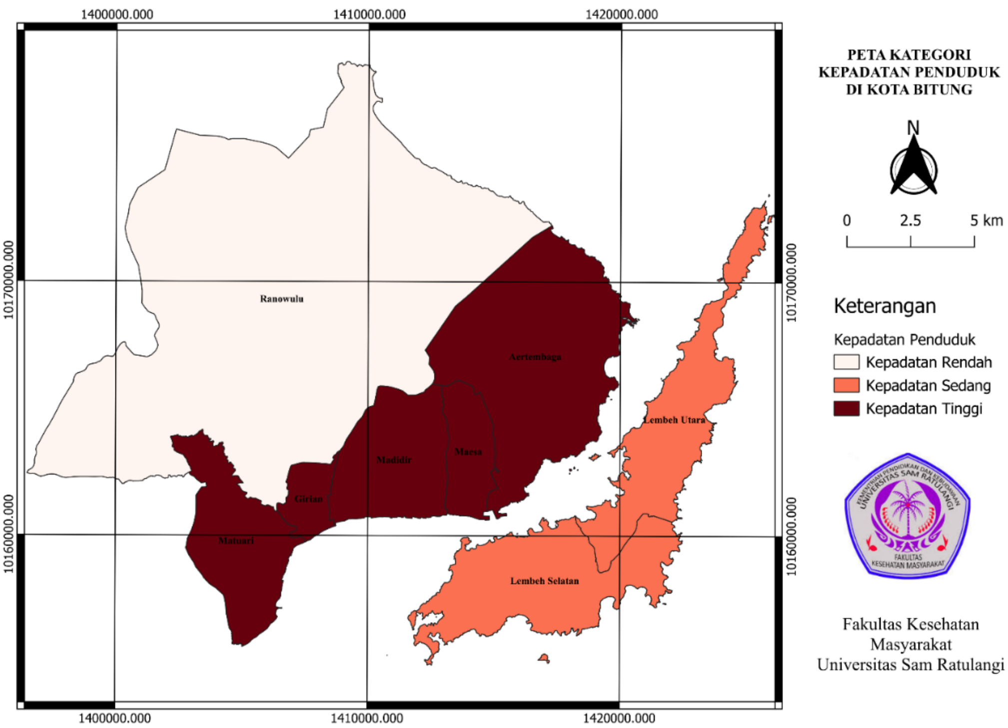

Figure 5. Population Density in Bitung City per District

The results of this study show that 5 (five) sub-districts were found to be in the high density category (> 500 people/km2), namely Aertembaga, Girian, Madidir, Maesa and Matuari sub-districts. There are 2 sub-districts in moderate density (250-500 people/km2), namely North Lembeh and South Lembeh sub-districts. Ranowulu District is in the low density category (1-249 people/km2).

Table 2. Distribution of Malaria Cases by Population Density

Yes	Districts	Total Malaria Cases	Jlh resident	Area (km2)	Population Density Category
1	SquirrelCopper	1	29980	2610,0	Height
2	Girian	6	37499	516,6	Height
3	South Lembeh	164	10621	2353,0	Medium
4	North Lembeh	23	9503	3061,5	Medium
5	Madidir	16	35559	3045,0	Height
6	Maesa	138	36894	965,4	Height
7	Mature	11	37972	3610,0	Height
8	Dunkin' Donuts	20	21035	17117,0	Low

Let's group and analyze the data by their categories:

1. "High" Density Category (5 Districts)
   - Districts: Aertembaga, Girian, Madidir, Maesa, Matuari.
   - Characteristics: Large population, relatively small area.
   - Key Findings:
     a) Very Wide Variation: The sub-districts in this category show a very large variation in malaria cases, from the lowest (Aertembaga: 1 case) to the second highest (Maesa: 138 cases).
     b) Low Cases in Dense Cities: Aertembaga, Girian, Madidir, and Matuari have relatively low cases (an average of 9.5 cases per sub-district). This may be due to more dense urban environments with fewer mosquito habitats (open waterlogs, forests), better access to health services, and more intensive vector control programs.
     c) Outlier: Maesa is an anomaly. Despite the high population density, malaria cases are very high (138). This shows that there are specific risk factors in Maesa that other densely populated districts do not have, such as the existence of swamps, rivers, or certain sanitary conditions that are breeding grounds for mosquitoes.
2. "Medium" Density Category (2 Districts)
   - Districts: South Lembeh, North Lembeh.
   - Characteristics: Smaller population, larger area.
   - Key Findings:
     a) Highest Transmission Rate: It is this sub-district, especially South Lembeh, that is the epicenter of the malaria outbreak in this data. South Lembeh alone accounted for 43% of the total cases.

b) Key Geographic Factors: Large areas with moderate population density often indicate areas that may have more forested, swamp, or coastal areas that would be ideal habitat for *Anopheles* mosquitoes. The interaction between the population and mosquito habitats in areas like this tends to be higher.

3. "Low" Density Category (1 District)
   - District: Ranowulu.
   - Characteristics: Small population, very large (dominant) area.
   - Key Findings:

   a) Relatively Low Cases: With only 20 cases, Ranowulu has a low number although not the lowest. However, this figure needs to be seen in the context of its very low population density. If calculated as a proportion to the population, this figure may be significant.

   b) Predictable Patterns: Low cases are consistent with the theory, as areas with very low densities have fewer "hosts" (humans) for the parasite to spread. However, residents living in areas like these may have a high individual risk due to living close to mosquito habitat and limited access to health facilities.

1. Population Density Is Not the Only Determining Factor: This data refutes the assumption that densely populated areas must have high malaria cases. Geographical and environmental factors seem to be more influential.
2. High-Risk "Periphery" Areas: Districts with "Medium" density (South and North Lembeh) are the most vulnerable areas. This is a transitional area where humans interact directly with the natural environment that may be the habitat of mosquitoes.
3. Localized Hotspots:
   - South Lembeh must be a top priority for public health interventions. Field investigations are needed to identify the source of transmission (breeding sites) and the population's risky behavior.
   - Maesa needs to investigate why the cases are high even though they are in dense areas. Are there any specific areas in Maesa that are the source of the problem?
4. Success in Densely Populated Areas: Densely populated sub-districts such as Aertembaga, Girian, Madidir, and Matuari can be examples of "best practices". What they do (e.g. routine fogging, environmental management, prevention programs) can be applied in vulnerable areas such as Maesa and South Lembeh.

Furthermore, a spatial map of Bitung City is presented based on the category of the number of APIs per sub-district. API categories are created in 3 categories which are high (API > 5 per mile), medium (API 1-5 per mile) and low (API < 1 per mile). *Annual Parasite Incidence* (API) where the number of positive malaria cases is divided by the number of at-risk population in a sub-district area in the same time period multiplied by 1,000. A map of the distribution of malaria cases based on API can be seen in Figure 3.

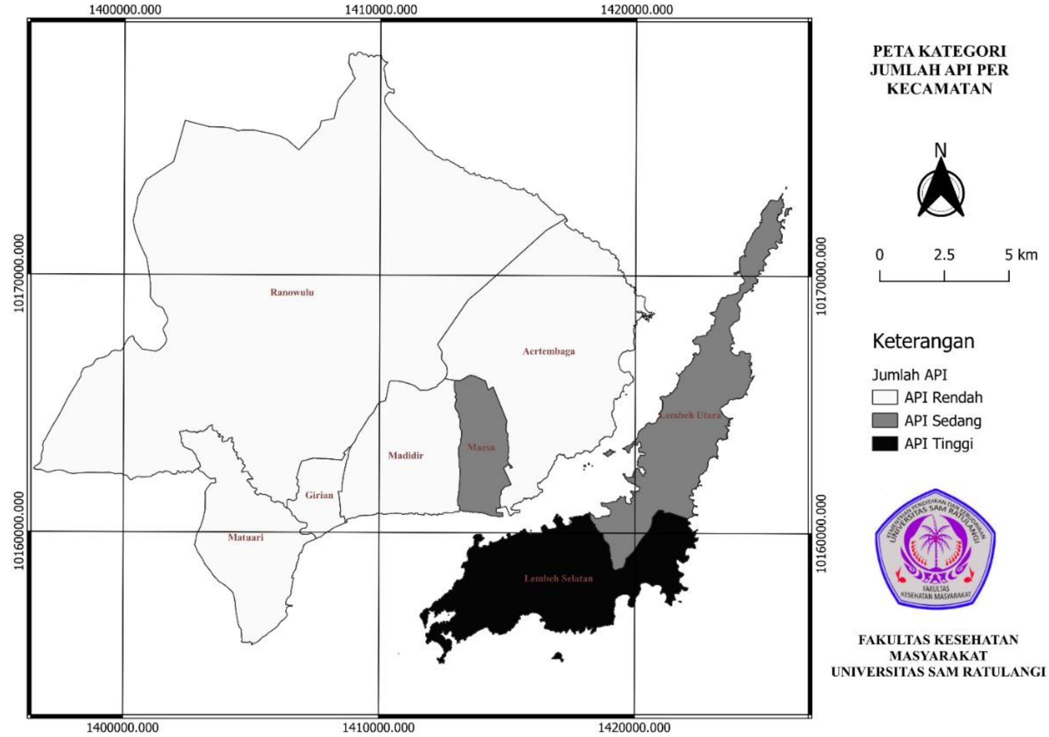

Figure 3. Number of APIs in Bitung City per District

The results of this study show that there are 2 sub-districts included in the medium API, namely North Lembeh sub-districts (2.42 per mile) and Maesa (3.74 per mile). Only 1 sub-district was found, namely South Lembeh sub-district (15.4 per mile) which was in the high category.

Altitude characteristics are closely related to the presence of malaria-vector mosquitoes. Mosquitoes will survive if the environment is optimal and altitude is one of these optimal factors. Rahajo stated that the optimal altitude for *Anopheles* mosquitoes is between 100-130 meters above sea level (Elyazar et al 2013; Rejeki et al 2014).

The results of this study show that the incidence of malaria is spread throughout Bitung City. An area with an average height of < 200 meters above sea level is a potential area for the development of *Anopheles* mosquitoes. Under optimal conditions, the development of mosquitoes will be rapid, this further increases the possibility of contact with humans so that it has an impact on the risk of transmission (Suryaningtyas et al 2019).

The results of this study show that the sub-districts of Aertembaga, Girian, Madidir, Maesa and Matuari are in the category of high density (> 500 people/km2), namely. There are 2 sub-districts in moderate density (250-500 people/km2), namely North Lembeh and South Lembeh sub-districts. Ranowulu District is in the low density category (1-249 people/km2). The results of this study show that there are 2 sub-districts included in the medium API, namely North Lembeh and Maesa sub-districts. Only 1 sub-district, namely South Lembeh sub-district, was found to be in the high category.

Research conducted by Masrizal (2017) found that the higher the population density, the higher the cases affected by mosquito vectors. Mentawai, Payambuh, and West Pasaman have high population density. Settlements have a great influence on malaria transmission cases where based on research conducted by Hakim and Sugianto, there is a meaningful relationship between population density and the density of *A. Sundaicus* (the type of *Anopheles* that causes malaria). This is supported by the fact that population density has a positive relationship with the bite intensity of the *Anopheles* mosquito. Other studies have shown a relationship between population density and fluctuations in malaria pain, so it is related to API (Nugraheni et al, 2023).

Populations living in malaria breeding habitats have a 2.5 times higher risk of malaria than people living far from malaria breeding habitats. Coupled with the condition of the underprivileged population, it will increase the number of transmission rates due to the inability of the population to carry out prevention or treatment (Nugraheni et al 2023).

Geographically, Bitung City is located at the foot of Mount Dua Sudara and Mount Klabat with a sandy soil structure and is directly adjacent to the coastline. This allows the existence of brackish water as a breeding ground for malaria vectors. As a port city, Bitung City is a meeting place for many ethnicities and tribes, with a variety of livelihoods that are the background of the people's economy. Traffic in goods and services, sea transportation, fisheries, and industry are economic fields that can distinguish this city from other cities in North Sulawesi (BPS SULUT, 2024).

The conclusion of this study is that the incidence of malaria in Bitung City fluctuates and the highest cases were found in 2022 as many as 212 cases. In general, it can be seen that malaria cases in 1 year have 3 peaks, namely in March-April, July-August and November. This study shows that malaria cases in 2021-2023 are most suffered by men. The incidence of malaria is found most in Papusungan and West Bitung sub-districts. Ranowulu and South Lembeh sub-districts are sub-districts with sub-district areas whose areas are in the highland category. There are 2 sub-districts included in the medium API, namely North Lembeh and Maesa sub-districts. Therefore, it is necessary to map the distribution points of cases to identify clusters or villages with the highest incidence in South Lembeh and Maesa as well as further research on the density and type of *Anopheles* mosquitoes and their biting habits in vulnerable areas.

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