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Malaria Mapping Based on Epidemiological Variables in Bobonaro and Covalima Districts, Timor Leste

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Abstract:

Background. Malaria is an infectious disease caused by *Plasmodium* parasites and transmitted through the bite of infected female *Anopheles* mosquitoes. According to the Ministry of Health of Timor-Leste's 2023 malaria elimination report, Covalima, Bobonaro, and Oecuse districts collectively reported 9 malaria cases in 2023, along with a notable vector density. Spatial analysis offers a comprehensive method for compiling and managing spatial data, transforming it into meaningful insights.
Aims. This study aims to describe malaria mapping based on epidemiological variables in Bobonaro and Covalima Districts, Timor-Leste.
Methods. This descriptive epidemiological research utilizes malaria case reports from Bobonaro and Covalima Districts as its population and sample.
Result. The results indicate that the Annual Malaria Incidence (AMI) and Annual Parasite Index (API) in these districts showed an increasing trend from 2019-2023, mainly attributable to imported cases from the border region between Covalima and Malaka Districts. Males and individuals over 15 years of age are more frequently affected by malaria, likely due to their higher levels of mobilization for work or other activities. *Plasmodium falciparum* is the most common species identified, primarily associated with swamp habitats.
Conclusion. Covalima District has two temporary and one permanent swamp. Additionally, lake and lagoon habitats were identified in the Covalima Regency. The two regencies share similar conditions regarding sun intensity, rainfall, temperature, humidity, and altitude.
Implication. Communities can play a crucial role in independent malaria vector control efforts, such as introducing larvivorous fish into water bodies and eliminating stagnant water puddles around homes.

Keywords: Spatial Analysis, Malaria, Mapping, Epidemiological Variables

INTRODUCTION

Malaria is an infectious disease caused by parasites from the genus Plasmodium, transmitted through the bite of infected female Anopheles mosquitoes. The term "malaria" is derived from two Italian words, mal (bad) and aria (air), literally meaning "bad air." Other names, such as swamp fever, tropical fever, cure fever, and paludism, also refer to this disease (Prabowo, 2007).

Malaria has remained a significant public health problem in Timor-Leste for the past decade. Financial support from the International agency Global Fund has been instrumental in funding malaria prevention and elimination efforts in Timor-Leste since 2006. From 2006 to 2012, the focus was on the "control stage," which involved several key activities: a) preparing the national strategy for the malaria program (2006-2015); b) writing the first edition of the malaria treatment guidelines (2007); c) distributing mosquito nets (2010); d) implementing indoor residual spraying (2010-2012); and e) conducting routine entomological surveillance. The second phase, from 2013-2017, was termed the "elimination stage," and its activities included: a) strengthening diagnosis through the use of rapid diagnostic tests and microscopy; b) mass distribution of mosquito nets, with a criterion of two people receiving one net; c) conducting focused case investigations; and d) revising the national strategy for the malaria program (2015-2020). The current "prevention or elimination stage," from 2018 to the present, involves: a) updating the national strategy for the malaria program (2021-2025); b) strengthening the epidemiological surveillance system at all levels; and c) categorizing areas into very high, moderate, low, and no risk to facilitate targeted malaria interventions.

Districts located along the border between Timor-Leste and Indonesia are endemic for malaria. This is primarily due to their coastal areas, the presence of rice fields, swamps, irrigation systems, and small rivers, all of which provide potential breeding grounds for mosquitoes. Routine entomological data from mosquito breeding sites in Covalima Regency show fluctuating vector densities of Anopheles barbirostris, Anopheles subpictus, and Anopheles sundaicus: 30/100 dips in 2021, 6.02/100 dips in 2022, and a significant increase to 498.68/100 dips in 2023. Similarly, in Bobonaro District, vector densities were recorded as 10/100 dips in 2021, 12.04/100 dips in 2022, and 104/100 dips in 2023. Oecusse also exhibited variations in vector density from mosquito breeding sites: 0.16/100 dips in 2021, 82/100 dips in 2022, and 100/100 dips in 2023.

Malaria vector breeding site mapping is crucial for identifying locations with the potential to serve as breeding grounds for Anopheles mosquitoes, the vectors of malaria. The breeding preferences of Anopheles mosquitoes vary by species and differ from those of other mosquito types, such as Aedes aegypti, which prefer clean water not in contact with the ground for breeding.

According to the Ministry of Health of Timor-Leste's 2023 malaria elimination report, Covalima, Bobonaro, and Oecusse districts recorded the highest vector densities. Specifically, the Tiliomar District reported 9 malaria cases in 2023, while the other two districts reported no cases. The availability of mosquito breeding grounds also influences the increasing incidence of malaria cases. Based on the aforementioned data, this researcher is interested in researching "Malaria Mapping Based on Epidemiological Variables in Bobonaro and Covalima Districts, Timor Leste".

LITERATURE REVIEW

Malaria mortality (i.e., deaths per 100,000 population at risk) significantly declined from approximately 29% in 2000 to 15% in 2015. This decline continued, albeit at a slower pace, reaching 14% in 2019. In 2020, mortality rates rose again to 15.2% before slightly decreasing to 14.3% in 2022. Within the WHO South-East Asia Region, malaria deaths have decreased by 77%, from 35,000 in 2000 to 8,000 in 2022. India and Indonesia collectively account for approximately 94% of all malaria deaths in this region (WHO, 2023).

According to WHO, the criterion for malaria elimination is the absence of local (indigenous) malaria morbidity for three consecutive years. Timor-Leste did not report local (indigenous) malaria morbidity from August 2020 to August 2023. Consequently, in October 2023, the government, through the Minister of Health, submitted a letter to the World Health Organization (WHO) in Switzerland via the WHO representative in Timor-Leste. They have since received confirmation that WHO will evaluate the malaria-free elimination process in 2024.

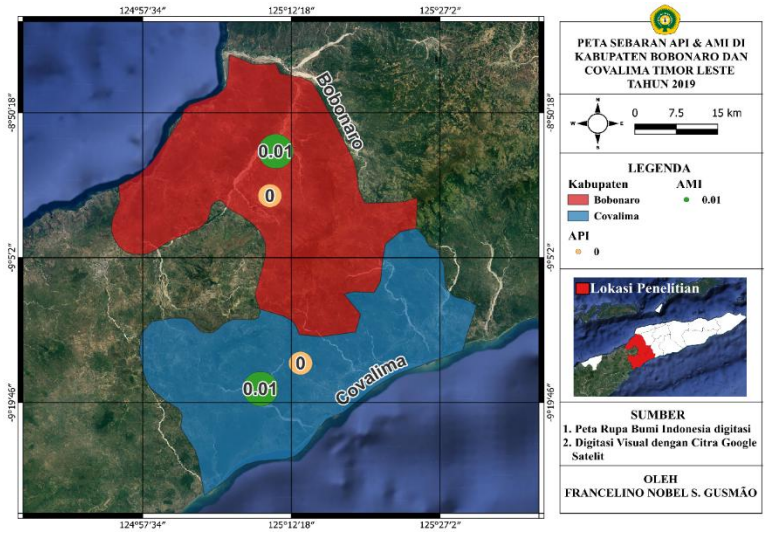
Over the past 10 years, 76% of reported malaria cases originated from 13 District Health Offices. Among these, three districts are located in the border area between Timor-Leste and Indonesia. Oecusse District contributed 51% of malaria morbidity, Dili District 13.3%, Covalima District 9.1%, and Bobonaro District 2.4% (Kemenkes Timor Leste, 2023).

METHOD

This study employed a descriptive epidemiological design to characterize malaria cases and map endemic areas. The research aimed to illustrate the distribution of malaria based on host, agent, and environmental characteristics within the Bobonaro and Covalima Districts of Timor-Leste. The population for this study consisted of monthly reports on malaria case detection and treatment from Bobonaro and Covalima Districts. The sample consisted of malaria case detection and treatment reports, specifically from these districts, for the five years from 2019 to 2023. The study was conducted in the Bobonaro and Covalima districts of Timor-Leste in February 2025.

DISCUSSION

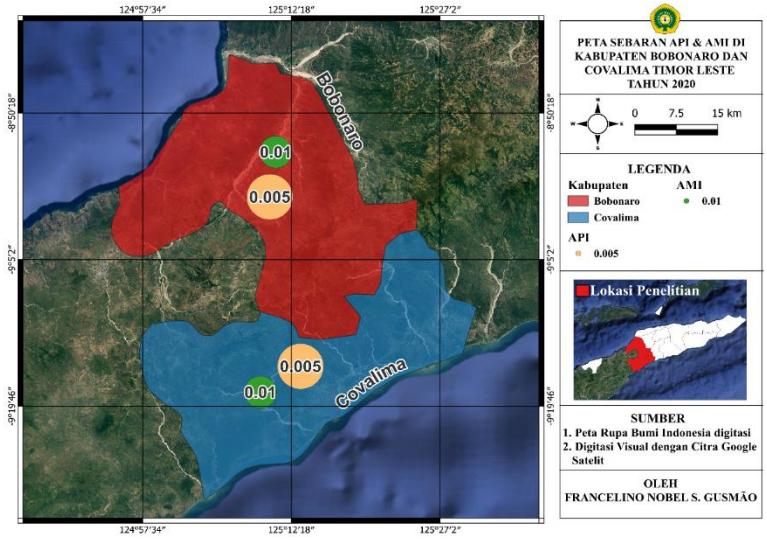
Frequency of Malaria Based on AMI and API Indicators in the Work Area of District Bobonaro and Covalima



Source: Data analysis using QGis, 2025.

Figure 1. Mapping of Distribution API and AMI in District Bobonaro and Covalima Timor Leste 2019

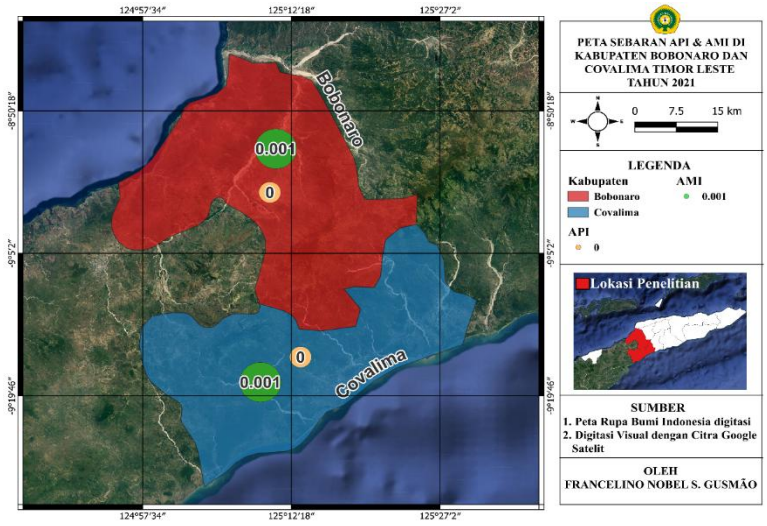
Figure 1 shows that in 2019, the API in District Bobonara and Covalima, Timor-Leste, was 0, and the AMI was 0.01.



Source: Data analysis using QGIS, 2025.

Figure 2. Mapping of Distribution API and AMI in District Bobonaro and Covalima, Timor Leste 2020

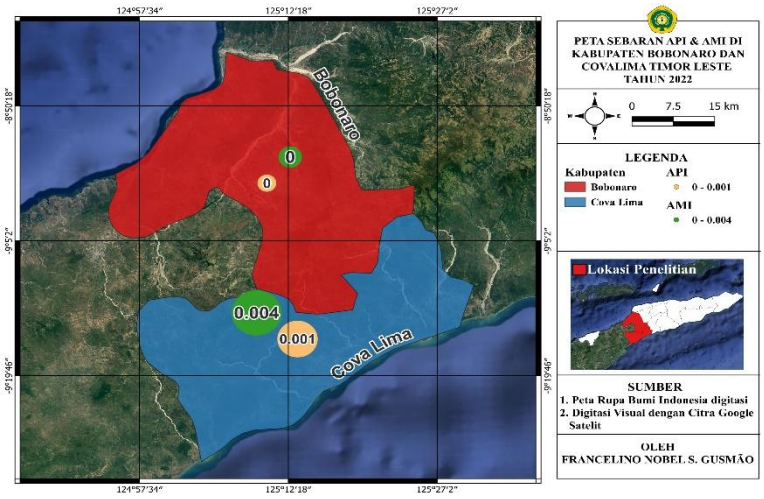
Figure 2 shows that in 2020, the API in District Bobonara and Covalima, Timor-Leste, was 0.005, and the AMI was 0.01.



Source: Data analysis using QGis, 2025.

Figure 3. Mapping of Distribution API and AMI in District Bobonaro and Covalima Timor Leste 2021

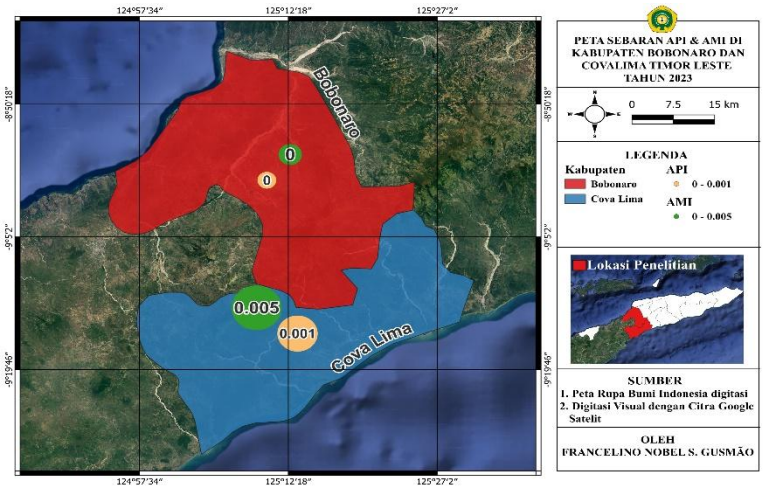
Figure 3 shows that in 2021, the API and AMI in Bobonaro and Covalima Regency were 0.



Source: Data analysis using QGis, 2025.

Figure 4. Mapping of Distribution API and AMI in District Bobonaro and Covalima, Timor Leste 2022

Figure 3 shows that in 2021, the API and AMI in Bobonaro Regency were both 0, and in Covalima Regency, Timor-Leste, the AMI was 0.004 and the API was 0.001.



Source: Data analysis using QGis, 2025.

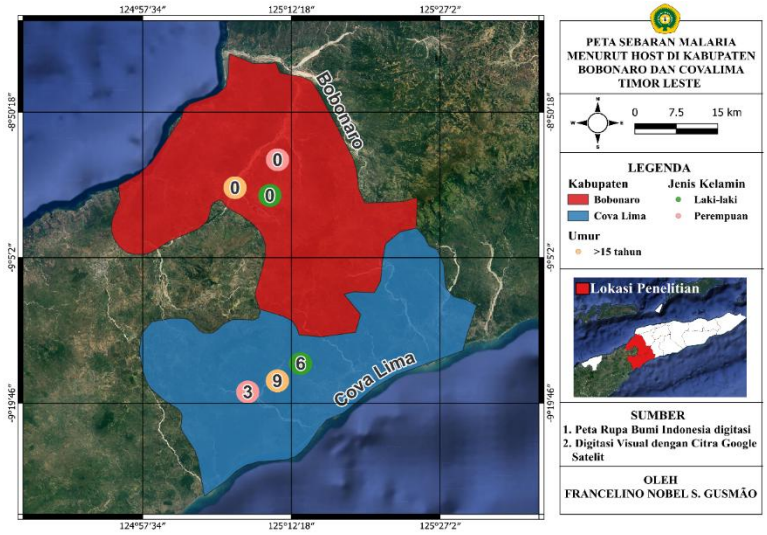
Figure 5. Mapping of Distribution API and AMI in District Bobonaro and Covalima Timor Leste 2023

Figure 5 shows that in 2021, the API and AMI in Bobonaro Regency were both 0, and in Covalima Regency, Timor-Leste, the AMI was 0.005 and the API was 0.001.

The Annual Parasite Incidence (API) figures indicate that Covalima and Bobonaru Regencies have achieved a Low Cumulative Incidence (API <1‰). However, Covalima Regency showed an increasing trend of cases during the 2019-2023 period. This rise is attributed to imported cases, likely from immigrants crossing the border who present with clinical symptoms of malaria. The primary entry route for these cases into Covalima Regency is through Malaka Regency, an area known for its endemicity of malaria. In contrast, the entry route to Bobonaru Regency is via Belu Regency, which has a low AMI and API category. Despite a low API, access to blood smear examination regimens in Bobonaru's mountainous and difficult-to-reach border areas is limited. Consequently, individuals exhibiting clinical malaria symptoms are immediately administered Artemisinin-Based Combination Therapy (ACT) until they are declared cured. This practice also eliminates the need for blood tests once a patient has taken medication and recovered.

A slum environment and poor sanitation characterize Covalima Regency. Residential structures, typically constructed from hard-dried bamboo, planks, or leaves, provide ideal resting places for mosquitoes. Gaps in these structures allow mosquitoes easy entry and access to residents, enabling them to bite. Furthermore, the design of traditional thatched houses, often with leaves extending to the ground/floor and lacking windows, creates numerous hiding spots for mosquitoes. These include the base of the walls, stored items (such as buckets, cardboard, and basins), and the kitchen. Kitchens are often located outside the main house, in open and dimly lit conditions, and frequently have puddles of water from washing dishes or food preparation. Similarly, stagnant wastewater in the dark corners of bathrooms also provides suitable breeding grounds. Mosquitoes require consistent puddles of water for egg-laying and prefer dark, humid rooms for concealment.

Description of Variable Host According to Type, Sex, and Age from Malaria Incidence in Districts Covalima and Bobonaro



Source: Data analysis using QGIS, 2025.

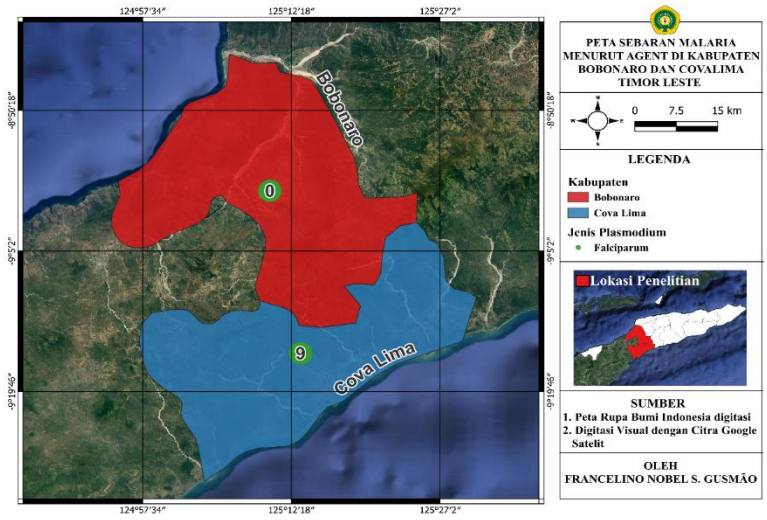
Figure 6. Malaria Distribution Map Based on Host Variables in Bobonaro and Covalima Districts, Timor Leste

Figure 6 illustrates the distribution of malaria cases in Covalima Regency by host characteristics. Regarding gender, male individuals accounted for the majority of cases (6 cases) compared to females (3 cases). In terms of age, all nine malaria cases in Covalima Regency occurred in individuals aged 15 years or older.

While malaria can affect both men and women, these two regencies show a higher prevalence among male sufferers than female sufferers. This disparity can be attributed to men's higher mobility during the peak hours when Anopheles mosquitoes bite. Their nighttime activities often include social gatherings for conversation and socializing over drinks. Additionally, a local Pencak Silat school conducts practices at night, with participants often wearing only shorts. This nocturnal timing for Pencak Silat, misappropriated from its original purpose as a traditional martial art, is utilized by the local community to develop physical combat skills. Men generally prefer and feel more comfortable engaging in activities at night. Furthermore, hot ambient temperatures lead to a habit of removing clothing during leisure activities and while sleeping at night. This behavior, often without the use of protective measures like mosquito repellent lotion, significantly increases the frequency of mosquito bites.

Malaria sufferers are predominantly individuals over 15 years old. This age group marks the transition from adolescence to adulthood, influencing individuals' independence and freedom in making life choices that support their survival. At this stage, individuals are often granted autonomy by their parents to pursue independent learning, such as engaging in small-scale businesses in border areas. These businesses typically involve buying and selling goods, such as cigarettes, necessities, and fuel, at the border for resale within the Covalima Regency.

Description of Variable Agent According to Type of Plasmodium Incidence Malaria in Districts Covalima and Bobonaro



Source: Data analysis using QGIS, 2025.

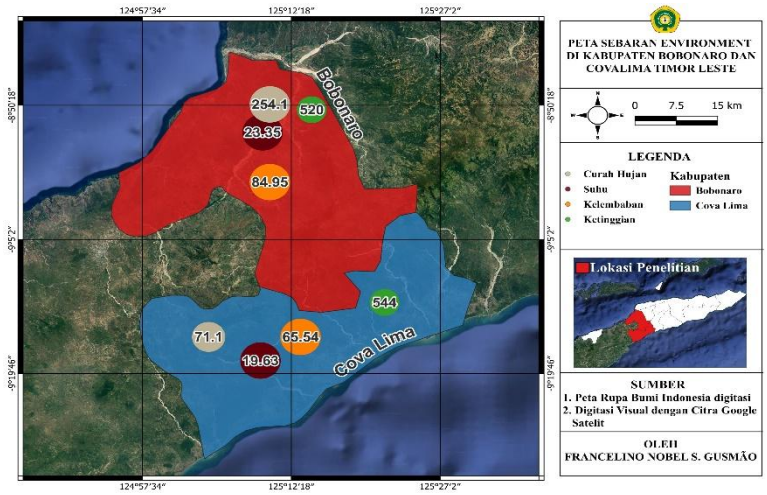
Figure 7. Malaria Distribution Map Based on Agent Variables in Bobonaro and Covalima District, Timor Leste

Figure 7 shows that, according to the agent, the type of Plasmodium is the most common malaria case, with Plasmodium falciparum accounting for as many as 9 cases in Covalima Regency.

Plasmodium falciparum dominates malaria cases there. The species Barbirostris, Subpictus, and sundaicus are widely found in the Covalima Regency area, particularly in the Suai District. This species inhabits a habitat consisting of 2 temporary swamps and 1 permanent swamp. Temperature and altitude factors also affect its survival. The resistance of P. falciparum to survive, reproduce, and cause symptoms, even when treated with the aminoquinoline class 4 malaria treatment, is a factor that enables this parasite to infect more people. The habit of the Covalima and Bobonaro people is that whenever they shiver, they immediately consume chloroquine or quinine without consulting medical personnel.

Eventually, this habit makes the parasites that live and are dormant in the body increasingly resistant.

Description of Environmental Variables Based on Rainfall, Temperature, Humidity, Altitude, and Malaria Breeding Areas in Covalima and Bobonaro Districts



Source: Data analysis using QGIS, 2025.

Figure 8. Environment Distribution Map in Bobonaro and Covalima Districts, Timor Leste

Figure 8 details several environmental factors in these regencies. Specifically, Bobonaro Regency exhibits higher rainfall intensity (254.1) compared to Covalima Regency (71.1). Similarly, Bobonaro Regency records a higher temperature (23.35) than Covalima Regency (19.63), and its humidity (84.95) surpasses that of Covalima Regency (65.54). Conversely, Covalima Regency has a slightly higher altitude (544 meters) than Bobonaro Regency (520 meters).

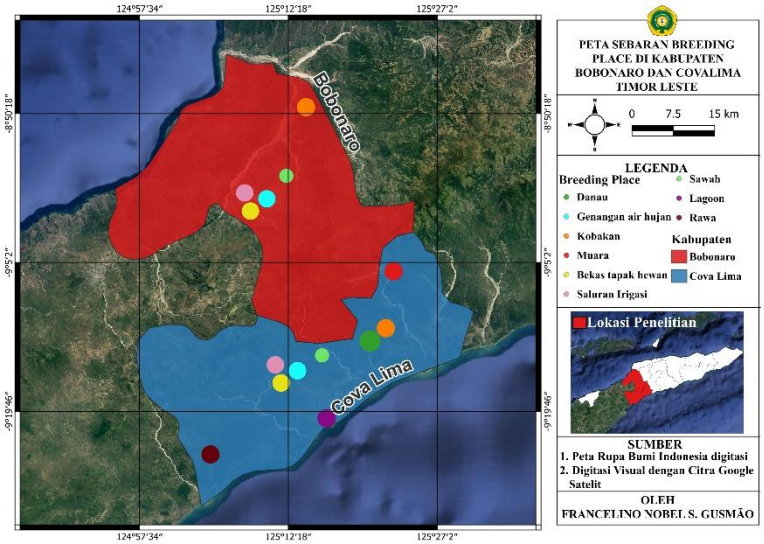
The geographical and meteorological factors present in Covalima and Bobonaro Districts are highly conducive to malaria transmission. Rainfall, for instance, leads to an increase in mosquito breeding sites and elevates relative humidity, which in turn prolongs the lifespan of the vector. This combination facilitates mosquito development and increases the likelihood of malaria epidemics. In both districts, the rainfall is often interspersed with periods of heat, further enhancing the potential for Anopheles mosquito breeding.

The average temperatures in Covalima District (19.63°C) and Bobonaro District (23.35°C) are particularly relevant. Within this temperature range, the extrinsic incubation period of P. falciparum (sporogony) is supported for 10-12 days. The optimum temperature for parasite development ranges from 20 °C to 30 °C. As temperature increases, the extrinsic

incubation period shortens, and conversely, a lower temperature prolongs it (Harijanto, 2000). Parasite development ceases at an average temperature of 16°C and parasites will die if the temperature exceeds 30°C.

While low humidity shortens the lifespan of mosquitoes, it does not directly affect the parasite itself. A humidity level of 60% represents the minimum threshold for mosquito survival. At higher humidity levels, mosquitoes exhibit increased activity and bite more frequently, consequently accelerating malaria transmission. The humidity levels in Covalima District (65.54%) and Bobonaro (84.95%) are highly supportive of mosquito survival.

Generally, malaria incidence decreases with increasing altitude, a phenomenon linked to the corresponding decrease in average temperature. Malaria transmission is very rare at altitudes above 2000 meters above sea level. Covalima District's altitude is 71.1 meters above sea level, and Bobonaro's is 254.1 meters above sea level. These environmental conditions collectively provide strong support for the increasingly easy and intense transmission of malaria by the Anopheles vector.



Source: Data analysis using QGis, 2025.

Figure 9. Map of Breeding Place Distribution in Bobonaro and Covalima Districts, Timor Leste

Figure 9 illustrates the distribution of Anopheles mosquito larvae habitats, indicating 8 (eight) permanent and only 2 (two) temporary habitats. The prevalence of permanent habitats is attributed to their direct adjacency to the coast, ensuring a perennial water supply conducive to Anopheles larval breeding.

Habitat types such as swamps, lakes, lagoons, and estuaries are abundant in many areas of Covalima and Bobonaro Regencies that directly border the East Sea. This geographical feature contributes to the formation of numerous permanent larval habitats. The presence of these permanent habitat types significantly supports the proliferation of Anopheles larvae, leading to continuous annual reproduction and, consequently, high malaria incidence in villages. Within both districts, Anopheles larval habitats are extensively found in various forms, including puddles, swamps, estuaries, lakes, irrigation channels, rice fields, and former livestock tracks. Notably, most puddle habitats lack larval predators, whereas other habitat types still exhibit the presence of predators, such as tadpoles and frogs. It is observed that malaria case locations are often more than 5 km from known Anopheles larval habitat points. This suggests that direct Anopheles mosquito bites from these specific distant habitats are unlikely to be the cause of infection, given that the typical flight range of Anopheles mosquitoes is approximately 2-3 km, even when influenced by wind intensity and population mobility. (Suyono et al., 2021). Areas close to swamps, rivers, and lakes are most susceptible to Anopheles mosquitoes, as these environments provide ideal breeding grounds for malaria vectors.

CONCLUSION

1. Malaria Incidence (AMI and API): The frequency of malaria cases, as indicated by Annual Malaria Incidence (AMI) and Annual Parasite Incidence (API), in the working areas of the Covalima and Bobonaro Regencies showed an increasing trend from 2019 to 2023. This rise is primarily attributed to imported cases entering the Covalima Regency from border areas.
2. Host Variables (Gender and Age): Analysis of host variables revealed that malaria incidence in Covalima and Bobonaro Regencies disproportionately affects men and individuals over 15 years of age. This demographic pattern is likely due to their higher mobility for work and nocturnal activities, coupled with a tendency not to wear protective clothing during these times..
3. Agent Variables (Plasmodium Types): Plasmodium falciparum was identified as the predominant Plasmodium species responsible for malaria cases in Covalima and Bobonaro Regencies. This prevalence is linked to the abundance of Anopheles mosquito species, particularly Barbirostris, Subpictus, and Sundaicus, which originate from swamp habitats. Specifically, Covalima Regency contains two temporary and one

permanent swamp, as well as lake and lagoon habitats, which serve as breeding grounds for various species.

4. Environmental Variables (Rainfall, Temperature, Humidity, Altitude, and Breeding Places): The environmental variables, including rainfall, temperature, humidity, and altitude, in both Covalima and Bobonaro Districts exhibit similar conditions conducive to malaria transmission. The presence of significant Anopheles mosquito breeding habitats, such as lakes and lagoons found specifically in Covalima Regency, further exacerbates this risk.

IMPLICATION

The findings of this study have several implications for both the community and relevant institutions in Covalima and Bobonaro Regencies:

1. For the Community
    a) Promote Protective Measures: The community is strongly encouraged to use insecticide-treated mosquito nets (ITNs) while sleeping consistently. For individuals active at night, wearing long-sleeved clothing and long trousers is recommended to minimize exposure to Anopheles mosquito bites.
    b) Reduce Mobility to High-Risk Areas: Residents should be advised to limit non-essential travel or mobility to villages identified as having a high incidence of malaria.
    c) Encourage Community-Based Vector Control: Communities can play a crucial role in independent malaria vector control efforts, such as introducing larvivorous fish into water bodies and eliminating stagnant water puddles around homes.
2. For Related Institutions
    a) Strengthen Surveillance and Monitoring: Relevant institutions should conduct regular and systematic monitoring of areas that attract malaria vectors to identify and address breeding sites.
    b) Monitor ITN Utilization: Continuous monitoring of the proper use and distribution of anti-malaria mosquito nets is essential to ensure their effectiveness.
    c) Enhance Community Engagement in Vector Control: Institutions should actively involve and empower communities in malaria vector control programs, fostering a sense of ownership and sustainability.

d) Improve Patient Follow-Up: It is critical to conduct thorough monitoring and follow-up for all malaria patients undergoing treatment to ensure complete recovery and prevent the development of drug resistance

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