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RESEARCH ARTICLE

Applying One Health and the analytic hierarchy process to malaria risk assessment in Jayapura, Indonesia

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ABSTRACT

Background and Aim: Malaria remains highly prevalent in Papua Province, Indonesia, accounting for nearly 89% of the national malaria burden. Although interventions are ongoing, most studies emphasize either human or environmental dimensions, often neglecting animal-related factors. This study aimed to apply a comprehensive One Health framework, combined with the analytic hierarchy process (AHP), to prioritize malaria risk indicators in Jayapura Regency.

Materials and Methods: A cross-sectional study was conducted in West Sentani district, Jayapura Regency, between June and August 2024. In stage one, malaria risk indicators across human, animal, and environmental domains were identified through literature review, interviews, and focus group discussions with five experts. In stage two, an AHP-based questionnaire was administered to 10 malaria and public health experts. Pairwise comparisons were analyzed using Expert Choice v.11 to generate priority weights and rankings, with a consistency ratio threshold of 0.10.

Results: Human factors (weight = 0.349) were ranked as the most significant contributors to malaria risk, followed by environmental (0.331) and animal (0.321) domains. Across all 11 indicators, completion of malaria medication (0.127), effective diagnostic screening (0.120), mosquito breeding site density (0.120), and proximity of animal enclosures to homes (0.117) emerged as top priorities. Five of the six highest-ranked indicators belonged to the human domain, highlighting the centrality of behavioral and healthcare-seeking practices.

Conclusion: The integration of One Health and AHP provided a transparent and evidence-based prioritization of malaria risk factors in Jayapura. The findings emphasize the importance of treatment adherence, improved diagnostic capacity, community-driven vector control, and livestock management to reduce transmission. Strengthening health education, enhancing rapid diagnostic test quality, and introducing geospatial tools for environmental mapping are recommended. This One Health–AHP approach demonstrates strong potential for informing multisectoral malaria elimination strategies in endemic regions.

Keywords: analytic hierarchy process, malaria, malaria risk factors, One Health, Papua, vector control

INTRODUCTION

Malaria remains highly prevalent in tropical regions, with the World Health Organization (WHO) reporting 249 million cases and 631,000 deaths across 85 countries in 2022 [1]. Indonesia recorded 443,530 malaria cases during the same period [2]. Between 2011 and 2020, Papua and West Papua provinces accounted for 89% and 11% of 2,046,833 malaria cases in Indonesia, respectively [3]. These figures underscore the urgent need to reduce malaria prevalence in Papua Province. To address this, the Indonesian Ministry of Health has launched

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several initiatives aimed at eliminating malaria by 2030. These efforts include mass drug administration, distribution of insecticide-treated nets (ITNs), strengthening of malaria cadre networks, and the identification of transmission hotspots [2]. A comprehensive and region-specific elimination strategy is therefore urgently required in Papua Province. In 2022, Papua Province alone contributed approximately 393,801 of the 443,530 malaria cases reported nationwide, representing 88.8% of the total burden [4]. Although several studies have incorporated elements of the One Health framework, most emphasized only two of the three domains. For example, Gebre *et al*. [5] and Zhao *et al*. [6] integrated environmental and human factors through spatial and demographic data but did not consider zoonotic or animal-related drivers. Other studies, such as those by Fuller *et al*. [7] and Franco *et al*. [8], examined vector exposure or livestock-based interventions but lacked integration with environmental mapping or human behavior analysis. Thus, although previous studies included aspects of the human and environmental domains, they did not explicitly adopt the One Health framework or fully integrate animal health considerations. In contrast, the present study adopts a holistic One Health perspective, systematically uniting the three domains within an analytic hierarchy process (AHP) structure to provide actionable, locally contextualized insights for malaria control. The One Health approach integrates human, animal, and environmental dimensions to achieve comprehensive disease control. Previous studies by Gebre *et al*. [5], Zhao *et al*. [6], and Fuller *et al*. [7] have seldom explicitly identified their methodology as "One Health," although some incorporated its principles through multidisciplinary data sources or diverse expert involvement. One Health provides a comprehensive framework for integrating human, animal, and environmental factors in malaria elimination strategies [8–12]. Targeted interventions are essential for evaluating regional malaria control strategies [13]. This study aimed to develop a regional malaria elimination plan using the One Health approach. Accordingly, the present study applies the One Health framework in combination with the AHP to assess malaria risk factors in Jayapura, Papua. By integrating human, animal, and environmental dimensions, this study offers a holistic perspective that has rarely been addressed in previous risk prioritization studies [14]. The application of the AHP in evaluating malaria risk factors within the human–animal–environment framework provides a holistic method that integrates diverse criteria influencing disease transmission. This approach addresses the multifactorial nature of malaria by breaking down complex interactions among human activities, animal interactions, and environmental conditions into a hierarchical decision model that allows systematic evaluation and prioritization of risk determinants. Human behavior, including agricultural practices, settlement patterns, and housing infrastructure, significantly influences malaria risk. Activities including crop cultivation have been linked to the development of mosquito breeding sites, whereas the spatial distribution of human settlements influences their proximity to these sites [15]. Each of these factors can be quantitatively compared through pairwise comparisons using AHP, which allows weights to be assigned reflecting their relative importance. The AHP method provides a clear ranking of criteria and enables decision-makers to understand the complex interdependencies among various factors [15, 16]. Malaria risk is also strongly influenced by animal-related factors. Rearing practices may either decrease or increase transmission dynamics depending on their spatial arrangement relative to human dwellings. In some cases, the presence of animals diverts mosquito blood meals away from humans (zooprophylaxis), thereby reducing human exposure. However, keeping animals close to households may inadvertently increase mosquito density and enhance transmission risk [17]. By incorporating these considerations into an AHP framework, decision-makers can evaluate the relative influence of husbandry practices compared with other factors, providing an evidence-based foundation for recommendations on animal management near residential areas [17, 18]. Environmental factors further contribute to the complexity of malaria transmission by shaping the ecology and behavior of vectors. Land cover, proximity to water bodies, and climatic conditions determine the suitability of habitats for *Anopheles* mosquitoes [16]. When integrated into the AHP model, environmental criteria are assessed simultaneously with human and animal parameters, thereby capturing the multifaceted nature of malaria risk. This comprehensive integration facilitates the development of robust risk maps and decision-support systems to guide regional interventions and resource allocation strategies [15, 16]. Moreover, the weights generated through AHP help identify critical environmental risk factors and highlight the importance of local ecological nuances in modulating disease dynamics. Overall, AHP provides a structured, replicable, and transparent framework for assessing malaria risk within the human–animal–environment context. By systematically comparing and ranking multifaceted risk factors, AHP converts subjective expert judgments into quantifiable priorities. This integrated method is particularly valuable in designing public health interventions for endemic regions, where achieving optimal malaria control requires balancing human activities, animal presence, and environmental conditions [15, 17, 18].

Despite ongoing malaria elimination initiatives in Indonesia, Papua Province continues to bear the overwhelming majority of the national malaria burden, accounting for nearly 89% of reported cases [2–4]. Although previous studies have applied spatial mapping, demographic analyses, or livestock-based interventions, most have focused on only one or two dimensions of malaria transmission. Specifically, many studies have emphasized human and environmental factors while neglecting the animal health domain, even though livestock proximity and rearing practices can significantly influence vector density and human exposure [5–8, 17]. Furthermore, while elements of the One Health approach have been implicitly applied in prior work, very few studies have explicitly operationalized this framework to systematically integrate human, animal, and environmental determinants. Another gap lies in the methodological approaches used to prioritize malaria risk factors. Traditional risk assessments often rely on descriptive epidemiology or qualitative expert opinion, which may not provide a transparent or quantifiable hierarchy of risks. The AHP offers a robust and replicable framework for converting expert judgments into measurable weights, yet its application in malaria research has been limited and seldom combined with the One Health perspective [14–16]. Importantly, no previous studies in Papua have comprehensively employed both frameworks to generate locally contextualized priorities for malaria control. This absence of integrated, evidence-based prioritization methods limits the ability of policymakers to allocate resources effectively and design multisectoral strategies tailored to the unique ecological and sociocultural dynamics of Papua. The integration of One Health and AHP demonstrates its potential for informing multisectoral interventions in malaria-endemic regions [19].

This study aims to fill these gaps by developing a regional malaria risk prioritization model for Jayapura, Papua, using a combined One Health and AHP framework. Specifically, the study seeks to:

1. Identify and validate key malaria risk indicators across the human, animal, and environmental domains through expert consultations and literature review.
2. Apply AHP methodology to systematically assign weights to these indicators based on expert judgments, thereby producing a transparent and quantifiable ranking of risk factors.
3. Generate locally contextualized insights into the relative importance of human behaviors, animal husbandry practices, and environmental determinants in shaping malaria transmission in Jayapura.

By integrating One Health principles with a structured decision-making tool, this study provides a holistic, evidence-based foundation for malaria control strategies. The outcomes are expected to guide policymakers, health authorities, and community stakeholders in designing more targeted, multisectoral interventions that accelerate malaria elimination in Papua and serve as a model for other endemic regions.

MATERIALS AND METHODS

Ethical approval

This study was approved by the Health Research Ethics Committee (Komisi Etik Penelitian Kesehatan [KEPK]) of the Faculty of Public Health, Universitas Cenderawasih, under approval number No. 119/KEPK-FKM UC/2024. The protocol titled *“Model One Health dalam Eliminasi Malaria di Kabupaten Jayapura”* was declared ethically feasible in accordance with the seven WHO 2011 standards, including social and scientific values, risk–benefit assessment, informed consent, and privacy protection, with reference to the 2016 Council for International Organizations of Medical Sciences Guidelines. The ethical approval is valid from April 23, 2024, to April 23, 2025. All participants were fully informed of the study’s objectives and procedures, and they provided written informed consent before participating.

Study period and location

Fieldwork, including expert consultations, data collection, and validation, was conducted from June to August 2024, coinciding with the dry-to-wet transition period, which is epidemiologically significant for malaria transmission patterns in Papua.

The study was conducted in Jayapura Regency, Indonesia’s easternmost province of Papua. Jayapura is classified as a malaria-endemic region with persistently high annual case burdens, particularly in rural and coastal districts. The regency encompasses both lowland and highland ecological zones and is characterized by a tropical rainforest climate with high humidity and rainfall throughout the year. According to the Indonesian Ministry of

Health, persistent malaria transmission in Jayapura is driven by the complex interactions of human activities, ecological conditions, and vector habitats.

Geographically, Jayapura Regency lies approximately between 2°S–3°S latitude and 139°E–141°E longitude, with altitudes ranging from sea level to mountainous terrain. These conditions make the region highly suitable for *Anopheles* mosquito breeding, sustaining malaria transmission across multiple seasons.

Study participants

The study employed a two-stage process of expert engagement. In the first stage, in-depth interviews and focus group discussions (FGDs) were conducted with five domain experts with extensive experience in malaria, veterinary, and environmental health. These experts were purposively selected for their interdisciplinary expertise and long-standing involvement in malaria prevention and control programs.

In the second stage, a separate panel of 10 experts, including malaria program officers and public health officials, participated in the AHP questionnaire to prioritize the previously identified indicators. All participants had at least 10 years of experience in malaria-related field programs and held operational or decision-making roles. Experts without sufficient One Health expertise or experience in community-level intervention programs were excluded.

Composition of the expert panel

The AHP panel consisted of 10 professionals with extensive experience in malaria prevention, public health, and One Health-related programs in Jayapura Regency. They were purposively selected to ensure representation from diverse but relevant disciplines, including epidemiology, environmental health, veterinary public health, and health program management.

Inclusion criteria were as follows:

1. A minimum of 10 years of field experience in malaria-related health interventions.
2. Active roles in operational or decision-making capacities within governmental or non-governmental health programs.
3. Demonstrated understanding of One Health and its application in vector-borne disease control.

Panel composition included:

- Four malaria program officers from district health offices.
- Three public health officials specializing in surveillance and community interventions.
- Two environmental health practitioners.
- One veterinary public health officer with expertise in zoonotic disease prevention.

Each expert was contacted in advance, received a written explanation of the study goals, and provided written informed consent before participation. Of the ten experts who completed the AHP questionnaire, nine provided complete matrices and were included in the final analysis. The tenth respondent submitted an incomplete matrix and was therefore excluded, following AHP standards requiring full pairwise comparisons to ensure matrix consistency.

This composition ensured methodological rigor and interdisciplinary validity, with experts bringing complementary perspectives from all three One Health domains. The sample size of 10 aligns with best practices for AHP studies by Saaty [20] and Forman and Gass [21] which typically involve 6–15 decision-makers to balance input diversity with judgment consistency.

Indicator development

The initial set of malaria risk indicators was developed through a comprehensive literature review focusing on One Health-related determinants across the human, animal, and environmental domains. Indicators were refined through expert input during interviews and FGDs, ensuring contextual relevance, conceptual clarity, and consensus on inclusion.

Human domain

1. Avoiding outdoor activities after dark.
2. Consumption of regular meals (breakfast, lunch, and dinner).
3. Maintaining consistent and sufficient sleep.
4. Use of mosquito nets while sleeping.
5. Seeking medical care when experiencing symptoms.

6. Completion of the full course of prescribed malaria medication.
7. Access to proper malaria diagnosis.

Animal domain

1. Proximity of animal pens to human dwellings.
2. Hygiene of animal enclosures.

Environmental domain

1. Number of mosquito breeding sites.
2. Proximity of breeding sites to residential areas.

The finalized indicators were incorporated into the AHP questionnaire, which was distributed to ten malaria program personnel and public health officials. Of these, nine completed questionnaires met the inclusion criteria for analysis using Expert Choice v.11 software (Expert Choice Inc., Arlington, VA, USA).

Data collection procedure

Data collection was conducted in two stages from June to August 2024 in Jayapura Regency.

- Stage 1: Five experts from public health, veterinary science, and environmental health participated in in-depth interviews and FGDs to identify and validate malaria risk indicators. Discussions were recorded and documented with participant consent. All transcribed interview data were reviewed by the research team to ensure accuracy and internal validity.
- Stage 2: The validated indicators were converted into a structured AHP questionnaire, which was hand-delivered to ten malaria program officers and public health officials. Respondents completed the pairwise comparisons independently. Any clarification needed was provided in person during distribution or follow-up visits.

All responses were collected confidentially and anonymized before analysis. Of the ten distributed questionnaires, nine were fully completed and met the consistency threshold required for inclusion in the final analysis. Outliers or inconsistent patterns were revalidated with the respective experts when necessary before final data entry.

AHP questionnaire and analysis

The completed AHP questionnaires were analyzed using Expert Choice v.11 software. This method transforms expert judgments into quantitative weights through structured pairwise comparisons based on Saaty's 1–9 fundamental scale.

Judgment matrices were constructed for each domain, and eigenvalue calculations were used to derive relative weights. The consistency ratio (CR) was calculated to assess the logical coherence of expert judgments, with $CR \leq 0.10$ considered acceptable. If the CR exceeded this threshold, responses were reviewed, and participants were asked to revise their pairwise comparisons.

Final domain-specific and overall rankings were synthesized to produce malaria risk factor prioritizations. The use of expert choice ensured transparency, reproducibility, and methodological rigor.

Outcome metrics

The AHP analysis produced priority weights for each indicator within the human, animal, and environmental domains. Outcomes included:

1. Normalized priority values for all indicators.
2. Domain-level weights comparing the overall influence of human, animal, and environmental factors.
3. An integrated ranked list of indicators, guiding malaria control priorities in Jayapura.

These outputs provide quantitative evidence to support locally contextualized, multisectoral strategies for malaria elimination in Papua, consistent with the One Health approach.

RESULTS

Overall domain prioritization

Figure 1 presents the One Health conceptual framework applied in this study, illustrating the interconnections between the human, animal, and environmental domains. This framework guided the identification and categorization of key malaria risk indicators before prioritization using the AHP.

The AHP analysis revealed that the human domain had the highest overall priority weight (0.349), followed by the environmental domain (0.331), and the animal domain (0.321). These findings underscore the predominant influence of human-related factors on malaria risk perception among local experts. The relative weights also highlight the multidimensional nature of malaria risk, consistent with the One Health framework.

Human domain prioritization

As shown in Figure 2, the prioritization of human-related indicators revealed that:

- Completion of the malaria medication regimen (Human [H]6) and
- Effective malaria diagnosis (H7)

were considered the most critical priorities. These were followed by the use of mosquito nets (H4) and seeking medical care when symptoms appeared (H5).

Lower-ranked indicators included consistent sleep (H3), avoiding outdoor activity after dark (H1), and maintaining a regular meal schedule (H2). This ranking suggests that preventive and responsive health behaviors, particularly adherence to treatment and timely diagnosis, are perceived as more influential than general lifestyle habits in shaping malaria risk.

Animal domain prioritization

Figure 3 illustrates the ranking of animal-related indicators. The proximity of animal enclosures to residences (Animal [A]1) was ranked higher than the hygiene of animal pens (A2).

This result suggests that the spatial relationship between humans and livestock is perceived as a more immediate driver of malaria transmission than enclosure sanitation. Experts associated closer proximity with increased vector–human contact, as mosquitoes are attracted to animal hosts. While hygiene remains relevant, it was considered to play a more indirect role in malaria risk.

Environmental domain prioritization

The environmental indicators assessed included the number of mosquito breeding sites (Environment [E]1) and the distance of breeding sites from dwellings (E2). As shown in Figure 4, E1 was ranked higher than E2.

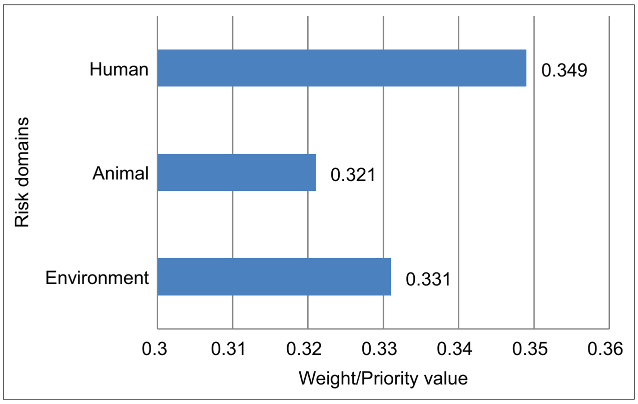

Figure 1: Overall priority weight of malaria risk domains based on One Health-analytic hierarchy process analysis.

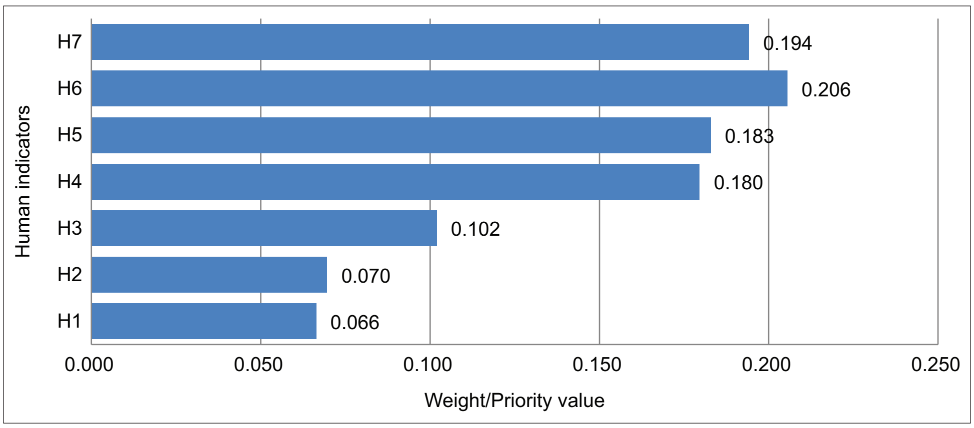

Figure 2: Priority ranking of human indicators.

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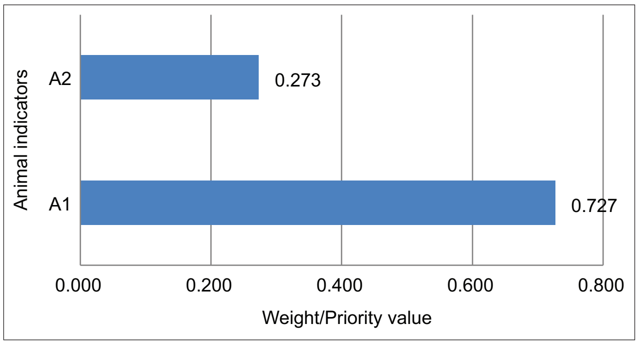

Figure 3: Priority ranking of animal indicators.

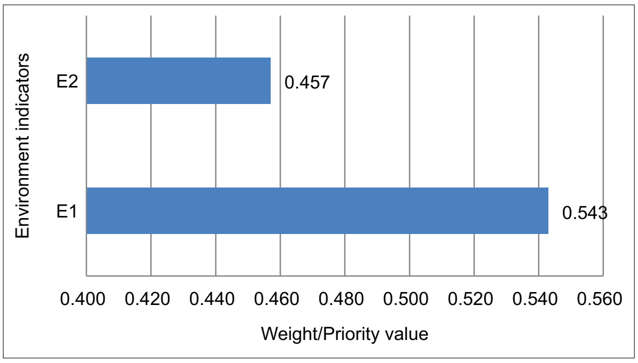

Figure 4: Priority ranking of environmental indicators.

This suggests that the density of mosquito breeding sites was viewed as a more direct determinant of malaria risk than spatial distribution alone. The findings indicate that higher densities of breeding sites, regardless of their exact proximity, can substantially increase mosquito populations and enhance community-level transmission potential.

Integrated indicator prioritization

An integrated ranking of all 11 indicators was conducted to identify the most influential malaria risk factors across the One Health spectrum, as shown in Figure 5.

The highest priorities were as follows:

1. Completion of the malaria medication regimen (H6)
2. Effective malaria diagnosis (H7)
3. Number of breeding sites (E1)
4. Proximity of animal enclosures to homes (A1)
5. Seeking medical care when symptoms appear (H5)
6. Use of mosquito nets (H4)
7. Distance to mosquito breeding sites (E2)
8. Adequate and consistent sleep (H3)
9. Hygiene of animal enclosures (A2)
10. Consistent meal schedule (H2)
11. Avoiding outdoor activities after dark (H1)

Remarkably, five of the top six indicators belonged to the human domain, underscoring the pivotal role of human-centered interventions in localized malaria control strategies.

The high ranking of medication completion (H6) reflects its central role in ensuring parasite clearance and breaking transmission cycles. Non-adherence increases risks of treatment failure, relapse, and drug resistance – critical challenges in malaria-endemic areas. Similarly, effective malaria diagnosis (H7) was prioritized due to its importance in reducing misdiagnosis, guiding timely treatment, and avoiding unnecessary drug use. These human-centered behaviors are directly linked to individual health outcomes and systemic efficiency, explaining their high prioritization in the AHP model.

DISCUSSION

Added value of the One Health–AHP framework

This study is among the first in the region to operationalize the One Health approach through AHP analysis for malaria risk prioritization. By incorporating expert insights across human, animal, and environmental sectors, it bridges disciplinary silos and provides a more inclusive and targeted strategy for malaria elimination.

Treatment adherence

The findings highlight that effective treatment adherence is the foremost strategy for malaria control in Papua. However, community hesitancy remains regarding care-seeking at health centers when symptoms appear. This aligns with the broader One Health literature, which emphasizes the interdependence of human behavior, environmental exposure, and animal–human interactions in malaria transmission [22, 23].

Although earlier studies often prioritized environmental or biomedical factors such as vector control and habitat mapping, this study underscores the importance of behaviorally grounded integration. The dominance

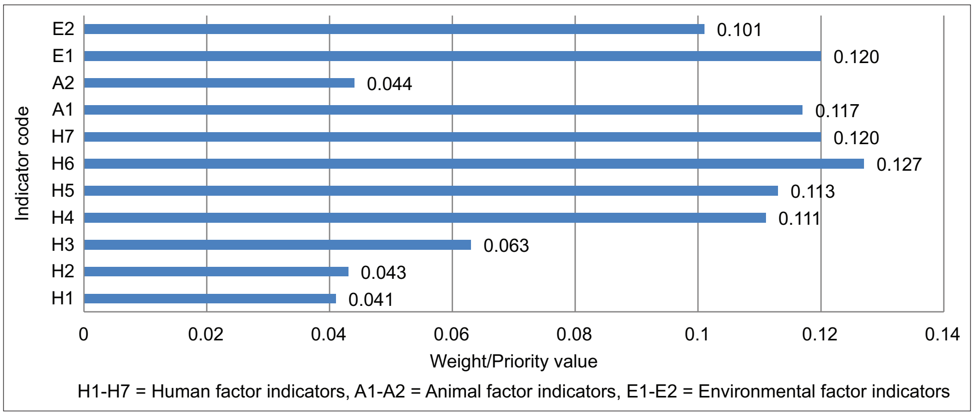

Figure 5: Weighted prioritization of malaria risk indicators based on One Health-analytic hierarchy process analysis.

of human-related indicators mirrors findings from sub-Saharan Africa, where health-seeking behavior and treatment adherence strongly influence malaria persistence [5, 24].

Strict adherence to antimalarial medication is essential in Papua and other endemic regions. Current treatment protocols target both *Plasmodium falciparum* and *Plasmodium vivax* infections. Patients with uncomplicated malaria receive a 3-day course of dihydroartemisinin–piperaquine (DHA–PIP), while *P. vivax* infections require a radical cure with a 14-day primaquine regimen to eliminate dormant liver-stage parasites (hypnozoites) [25–27].

Combining a blood schizonticide (DHA–PIP) with primaquine ensures both the acute phase and latent reservoir which are addressed. However, adherence to the 14-day primaquine regimen remains a major challenge in Papua. Sociocultural factors and patient beliefs questioning the need for continued treatment after symptom relief often compromise compliance [27]. Poor adherence contributes to relapses, worsens health outcomes, and hinders elimination goals [26, 27].

Ensuring adherence requires effective patient counseling, community-based support, and monitoring systems to reinforce the importance of completing both treatment components and to reduce relapse rates and transmission [25–27].

Diagnostic strategies

Effective screening and diagnosis are critical for malaria control in Papua. The prevalence of both *P. falciparum* and *P. vivax*, combined with difficulties in delivering timely care to vulnerable groups such as pregnant women, makes diagnostic accuracy essential [28, 29].

Robust diagnostic systems ensure appropriate treatment initiation and prevent unnecessary drug use that may contribute to resistance. Enhancing diagnostic capacity requires expanding access to rapid diagnostic tests (RDTs), improving microscopy quality, and exploring innovative diagnostic technologies.

Microscopy remains the gold standard in Papua but is limited by a shortage of trained personnel and inconsistent quality assurance. Histidine-Rich Protein 2 (HRP-2)/Plasmodium Lactate Dehydrogenase-based RDTs are increasingly used, particularly in antenatal care settings where rapid results are vital [30]. Evaluations in Indonesia confirm their reliability even in resource-limited contexts [30].

Nevertheless, challenges remain, including inconsistent RDT use, weak patient retention, and poor adherence to routine screening, especially among pregnant women [30]. Addressing these gaps requires systemic improvements, including enhanced laboratory quality assurance, regular health personnel training, and strengthened diagnostic protocols.

Vector ecology and environmental control

Mosquito breeding site control is another critical intervention area. Effective vector management in Papua is complicated by diverse and abundant breeding habitats, shaped by both environmental and human factors. High rainfall, abundant water bodies, and varied hydrological conditions create ideal environments for mosquito proliferation [31]. Natural depressions, puddles, and artificial containers further support vector survival. Warm temperatures and favorable water quality additionally enhance larval development [32].

Human behaviors exacerbate these conditions. Poor waste disposal, inadequate drainage, and accumulation of unused containers contribute to stagnant water habitats [33]. Local water storage practices in open containers also promote breeding near homes. Weak implementation of integrated vector management (IVM) has allowed both temporary and permanent breeding sites to persist [28].

Addressing these challenges requires IVM strategies such as larval source management. Community-driven initiatives, such as clean-up campaigns, better urban planning to prevent water stagnation, and improved drainage infrastructure are vital [32]. Chemical control with larvicides (e.g., temephos) has shown efficacy when paired with environmental management [31], while biological control using natural predators can complement chemical strategies in settings where insecticide use is limited or unacceptable [33].

Animal proximity and livestock management

The proximity of animal enclosures to human dwellings strongly influences malaria transmission dynamics in Papua. A study by Hasyim *et al*. [33] in Central Java has linked cow enclosures within 100 m of homes to higher malaria risk, largely due to carbon dioxide and body odors emitted by livestock that attract mosquitoes.

Although direct evidence from Papua is limited, similar patterns are likely given the ecological similarities. Poor sanitation and clustering of animal shelters near residences create microhabitats favorable to mosquito breeding [34]. Combined with Papua's abundant natural breeding sites, this increases peri-domestic and indoor transmission risk [35].

To reduce these risks, IVM strategies must include livestock management measures such as relocating pens away from homes. This reduces mosquito attraction near human dwellings and lowers human–vector contact [34]. Complementary strategies include promoting ITN use, improving household screening, and community-based environmental sanitation. Regular vector surveillance with geospatial tools can further optimize intervention targeting [35].

Community behavior and health interventions

Adopting healthy living practices plays a supportive role in malaria prevention and treatment. Communities are encouraged to maintain adequate sleep, balanced nutrition, and avoid outdoor activities at night. Adequate rest and nutrition boost immune function, strengthening resistance to infections. Research in lifestyle medicine suggests that these habits may also reduce adverse epigenetic changes associated with chronic inflammation [36].

Although these practices do not directly interrupt malaria transmission, they improve immunity and resilience, potentially reducing disease severity. In endemic settings such as Papua, these behaviors complement primary prevention strategies, including vector control, chemoprophylaxis, and prompt medical treatment [36, 37].

CONCLUSION

This study applied the One Health framework in combination with the AHP to prioritize malaria risk factors in Jayapura, Papua. The analysis revealed that human factors (weight = 0.349) exerted the strongest influence on malaria transmission, followed by environmental factors (0.331) and animal factors (0.321). Among the 11 identified indicators, completion of malaria medication (H6), effective malaria diagnosis (H7), and mosquito breeding site density (E1) emerged as the top three priorities. Notably, five of the six highest-ranked indicators belonged to the human domain, underscoring the centrality of behavioral and healthcare-related practices in malaria control.

The findings emphasize the need to strengthen treatment adherence programs, expand reliable diagnostic services, and promote community-based vector control. Specifically, patient counseling and community engagement are critical for improving compliance with the 14-day primaquine regimen to prevent *P. vivax* relapses. At the environmental level, targeted interventions to reduce mosquito breeding sites and regulate livestock enclosure practices can complement medical measures. Policymakers and health authorities should integrate these insights into malaria elimination strategies, ensuring that interventions are both multisectoral and locally contextualized.

The study's main strength lies in its holistic operationalization of the One Health approach, which systematically united human, animal, and environmental determinants into a structured decision-making model. The use of AHP provided a transparent and quantifiable method for prioritizing risk factors, enhancing the evidence base for malaria elimination in Papua. The inclusion of domain experts from diverse fields further increased the interdisciplinary validity and contextual relevance of the findings.

Despite these strengths, the study had some limitations. The expert panel sample size was modest (n = 10), which may limit generalizability. In addition, the study did not incorporate geospatial tools (e.g., GIS-based habitat mapping), which could have provided additional precision in environmental risk assessment. Furthermore, the findings reflect expert perceptions rather than direct epidemiological or entomological measurements.

Future research should expand expert participation, include community-level perspectives, and integrate mixed-method approaches combining epidemiological, entomological, and geospatial analyses. Incorporating real-time surveillance data and GIS-based modeling would enhance the robustness of environmental assessments. In addition, longitudinal studies are needed to evaluate the effectiveness of implementing One Health–AHP-based strategies in reducing malaria incidence over time. In summary, this study demonstrates that the integration of One Health and AHP provides a powerful framework for identifying and prioritizing malaria risk factors in endemic settings. The results highlight the central role of human-centered interventions, complemented by environmental management and livestock practices, in achieving malaria control. By offering a structured, evidence-based prioritization of risks, this study contributes actionable insights for policymakers, health practitioners, and communities. Operationalizing such integrated approaches will be essential for accelerating progress toward malaria elimination in Papua and may serve as a model for other malaria-endemic regions worldwide.

AUTHORS' CONTRIBUTIONS

IA, KLT, FAA, and KMP: Conceived and designed the study. IA, KLT, FAA, KMP, ARY, and DYB: Conducted interviews, administered the AHP questionnaire and drafted and reviewed the manuscript. IA and FAA: Performed data analysis. All authors have read and approved the final manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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REFERENCES

1. WHO. (2024) World Health Statistics 2024. World Health Organization, Geneva.
2. Ministry of Health of the Republic of Indonesia. (2022) 2022 Annual Report Malaria. Ministry of Health of the Republic of Indonesia, Jakarta.
3. Tobing, T.C.L., Wahrianto, E.S., Wafa, N.I., Zulfianti, P.D., Sihaloho, L.I., Husna, R.A., Salsabila, D., Silalahi, F.H.H., Sitohang, A.I., Sabrina, A., Harianja, A.D.H., Barus, S.A., Sabina, S., Rahma, A.A., Velaro, A.J., Khairunnnisa, K., Salim, E., Nurkolis, F. and Syahputra, R.A. (2024) Malaria in Indonesia: Current treatment approaches, future strategies, and potential herbal interventions. *Pharmacia*, 7: 1–14.
4. Setianingsih, T.Y., Sismadi, P., Widoyono, R., Suryaningrat, M. and Tjitra, E. (2023) Prevalence rates reduction efforts of malaria cases among health students in endemic area. *J. Commun. Dis*., 55(4): 60–65.
5. Gebre, S.L., Temam, N. and Regassa, A. (2020) Spatial analysis and mapping of malaria risk areas using multi-criteria decision making in Didessa District, South West Ethiopia. *Cogent. Environ. Sci*., 6: 1860451.
6. Zhao, X., Thanapongtharm, W., Lawawirojwong, S., Wei, C.C., Tang, Y., Zhou, Y., Sun, X., Cui, L., Sattabongkot, J. and Kaewkungwal, J. (2020) Malaria risk map using spatial multi-criteria decision analysis along Yunnan border during the pre-elimination period. *Am. J. Trop. Med. Hyg*., 103(2): 793–809.
7. Fuller, D.O., Troyo, A., Alimi, T.O. and Beier, J.C. (2014) Participatory risk mapping of malaria vector exposure in Northern South America using environmental and population data. *Appl. Geogr*., 48: 1–7.
8. Franco, A.O., Gomes, M.G.M., Rowland, M., Coleman, P.G. and Davies, C.R. (2014) Controlling malaria using livestock-based interventions: A one health approach. *PLoS One*, 9(7): e101699.
9. Adnyana, I.M., Utomo, B., Eljatin, D.S. and Sudaryati, N.L. (2023) One Health approach and zoonotic diseases in Indonesia: Urgency of implementation and challenges. *Narra J*., 3(3): e257.
10. Khairani, S. and Sagasiousman, R. (2022) Implementation of one health approach for malaria zoonotic control in Indonesia: Past, present, and future. *BIO Web Conf*., 49(4): 04003.

11. Oladipo, H.J., Tajudeen, Y.A., Oladunjoye, I.O., Yusuff, S.I., Yusuf, R.O., Oluwaseyi, E.M., AbdulBasit, M.O., Adebisi, Y.A. and El-Sherbini, M.S. (2022) Increasing challenges of malaria control in sub-Saharan Africa: Priorities for public health research and policymakers. *Ann. Med. Surg*. (*Lond*), 81: 104366.
12. Ruiz-Castillo, P., Rist, C., Rabinovich, R. and Chaccour, C. (2022) Insecticide-treated livestock: A potential One Health approach to malaria control in Africa. *Trends Parasitol*., 38(2): 112–123.
13. Fadilah, I., Djaafara, B.A., Lestari, K.D., Fajariyani, S.B., Sunandar, E., Makamur, B.G., Wopari, B., Mabui, S., Ekawati, L.L., Sagara, R., Lina, R.N., Argana, G., Ginting, D.E., Sumiwi, M.E., Laihad, F.J., Mueller, I., McVernon, J., Baird, J.K., Surendra, H. and Elyazar, I.R.F. (2022) Quantifying spatial heterogeneity of malaria in the endemic Papua region of Indonesia: Analysis of epidemiological surveillance data. *Lancet*, 5: 100051.
14. World Health Organization. (2017) Global Vector Control Response 2017–2030. WHO, Geneva. Available from: https://www.who.int/publications/i/item/9789241512978. Retrieved on 22-09-2025.
15. Mwangungulu, S.P., Deus, D., Ngereja, Z.R. and Kaindoa, E.W. (2023) Geospatial based model for malaria risk prediction in Kilombero Valley, South-Eastern Tanzania. *PLoS One*, 18(10): e0293201.
16. Istiana, I., Hadi, U., Dachlan, Y. and Arwati, H. (2021) Malaria at forest areas in South Kalimantan, Indonesia: Risk factors and strategies for elimination. *Open Access Maced. J. Med. Sci*., 9(E): 1147–1154.
17. Hasyim, H., Dhimal, M., Bauer, J., Montag, D., Groneberg, D., Kuch, U. and Muller, R. (2018) Does livestock protect from malaria or facilitate malaria prevalence? A cross-sectional study in endemic rural areas of Indonesia. *Malar J*., 17(1): 302.
18. Temu, E.A., Coleman, M., Abílio, A.P. and Kleinschmidt, I. (2012) High prevalence of malaria in Zambezia, Mozambique: The protective effect of IRS versus increased risks due to pig-keeping and house construction. *PLoS One*, 7(2): e31409.
19. Weiss, D.J., Lucas, T.C.D., Nguyen, M., Nandi, A.K., Bisanzio, D., Battle, K.E., Cameron, E., Twohig, K.A., Pfeffer, D.A., Rozier, J.A., Gibson, H.S., Rao, P.C., Casey, D., Bertozzi-Villa, A., Collins, E.L., Dalrymple, U., Gray, N., Harris, J.R., Howes, R.E., Kang, S.Y., Keddie, S.H., May, D., Rumisha, S., Thorn, M.P., Barber, R., Fullman, N., Huynh, C.K., Kulikoff, X., Kutz, M.J., Lopez, A.D., Mokdad, A.H., Naghavi, M., Nguyen, G., Shackelford, K.A., Vos, T., Wang, H., Smith, D.L., Lim, S.S., Murray, C.J.L., Bhatt, S., Hay, S.I. and Gething, P.W. (2019) Mapping the global prevalence, incidence, and mortality of *Plasmodium falciparum*, 2000–17: A spatial and temporal modelling study. *Lancet Infect. Dis.*, 19(10): 1055–1067.
20. Saaty, T.L. (2008) Decision making with the analytic hierarchy process. *Int. J. Serv. Sci*., 1(1): 83–98.
21. Forman, E.H. and Gass, S.I. (2001) The analytic hierarchy process-An exposition. *Oper. Res*., 49(4): 469–486.
22. Destoumieux-Garzón, D., Mavingui, P., Boetsch, G., Boissier, J., Darriet, F., Duboz, P., Fritsch, C., Giraudoux, P., Le Roux, F., Morand, S., Paillard, C., Pontier, D., Sueur, C. and Voituron, Y. (2018) The one health concept: 10 years old and a long road ahead. *Front. Vet. Sci*., 5: 14.
23. World Health Organization. (2022) One Health Joint Plan of Action (2022–2026): Working Together for the Health of Humans, Animals, Plants and the Environment. WHO, Geneva.
24. Zinszer, K., Verma, A.D., Charland, K., Brewer, T.F., Brownstein, J.S., Sun, Z. and Buckeridge, D.L. (2015) A scoping review of malaria forecasting: Past work and future directions. *BMJ Open*, 5(7): e007992.
25. Devine, A., Kenangalem, E., Burdam, F., Anstey, N., Poespoprodjo, J., Price, R. and Yeung, S. (2018) Treatment-seeking behavior after the implementation of a unified policy of dihydroartemisinin-piperaquine for the treatment of uncomplicated malaria in Papua, Indonesia. *Am. J. Trop. Med. Hyg*., 98(2): 543–550.
26. Davies, N.M., Poespoprodjo, J.R., Patriani, D., Malloy, M.J., Kenangalem, E., Sugiarto, P., Simpson, J.A., Soenarto, Y., Anstey, N.M. and Price, R.N. (2017) Unsupervised primaquine for the treatment of *Plasmodium vivax* malaria relapses in Southern Papua: A hospital-based cohort study. *PLoS Med*., 14(8): e1002379.
27. Rahmalia, A., Poespoprodjo, J.R., Landuwulang, C.U.R., Ronse, M., Kenangalem, E., Burdam, F.H., Thriemer, K., Devine, A., Price, R.N., Grietens, K.P., Ley, B. and Gryseels, C. (2023) Adherence to 14-day radical cure for *Plasmodium vivax* malaria in Papua, Indonesia: A mixed-methods study. *Malar J*., 22(1): 162.
28. Poespoprodjo, J.R., Fobia, W., Kenangalem, E., Lampah, D., Sugiarto, P., Tjitra, E., Anstey, N.M., Price, R.N. (2015) Treatment policy change to dihydroartemisinin-piperaquine contributes to the reduction of adverse maternal and pregnancy outcomes. *Malar J*., 14(1): 272.
29. Ahmed, R., Poespoprodjo, J., Syafruddin, D., Khairallah, C., Pace, C., Lukito, T., Maratina, S.S., Asih, P.B.S., Santana-Morales, M.A., Adams, E.R., Unwin, V.T., Williams, C.T., Chen, T., Smedley, J., Wang, D., Faragher, B., Price, R.N. and Kuile, F.O.T. (2019) Efficacy and safety of intermittent preventive treatment and intermittent screening and treatment versus single screening and treatment with dihydroartemisinin-piperaquine for the control of malaria in pregnancy in Indonesia: A cluster-randomised, open-label, superiority trial. *Lancet Infect. Dis*., 19(9): 973–987.
30. Ahmed, R., Levy, E.I., Maratina, S.S., Jong, J.J., Asih, P.B.S., Rozi, I.E., Hawley, W., Syafruddin, D. and Kuile, F.T. (2015) Performance of four HRP-2/pLDH combination rapid diagnostic tests and field microscopy as screening tests for malaria in pregnancy in Indonesia: A cross-sectional study. *Malar J*., 14(1): 420.
31. Lusiyana, N. (2024) Entomological survey and temephos susceptibility of *Aedes*, *Culex* and *Anopheles* in Naena Muktipura Mimika Papua. *J. Environ. Health*, 16(1): 10–17.
32. Pascoe, L., Clemen, T., Bradshaw, K. and Nyambo, D. (2022) Review of importance of weather and environmental variables in agent-based arbovirus models. *Int. J. Environ. Res. Public Health*, 19(23): 15578.
33. Hasyim, H., Ihram, M.A., Fakhriyatiningrum, Misnaniarti, Idris, H., Liberty, I.A., Flora, R., Zulkifli, H., Tessema, Z.T.,

Maharani, F.E., Syafrudin, D. and Dale, P. (2023) Environmental determinants and risk behaviour in the case of indigenous malaria in Muara Enim Regency, Indonesia: A case-control design. *PLoS One*, 18(8): e0289354.

34. Cahyaningrum, P. and Sulistyawati, S. (2018) Malaria risk factors in Kaligesing, Purworejo District, Central Java Province, Indonesia: A case-control study. *J. Prev. Med. Public Health*, 51(3): 148–153.
35. Rozi, I.E., Permana, D.H., Syahrani, L., Asih, P.B.S., Zubaidah, S., Risandi, R., Wangsamuda, S., Dewayanti, F.K., Demetouw, M.R., Mabui, S., Robaha, M.M.F., Sumiwi, M.E., Bangs, M.J., Lobo, N.F., Hawley, W.A. and Syafruddin, D. (2024) Rapid entomological assessment in eight high malaria endemic regencies in Papua Province revealed the presence of indoor and outdoor malaria transmissions. *Sci. Rep*., 14(1): 14603.
36. Gharipour, M., Mani, A., Baghbahadorani, M., Cardoso, C.K.S., Jahanfar, S., Sarrafzadegan, N., de Oliveira, C. and Silveira, E.A. (2021) How are epigenetic modifications related to cardiovascular disease in older adults? *Int. J. Mol. Sci*., 22(18): 9949.
37. Johnson, S.S. (2023) A rationale and framework for activating employers as agents of change in the implementation of lifestyle as medicine. *Am. J. Health Promot*., 37(7): 997–1023.

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