

From Rural to Urban Malaria: Reviewing the Shifting Distribution of *Anopheles* Mosquitoes under Changing Land Use and Urban Development in Sub-Saharan Africa

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ABSTRACT

Malaria in Sub-Saharan Africa, historically concentrated in rural ecosystems, is increasingly emerging in urban and peri-urban settings due to rapid urbanization, land-use changes, and heightened human mobility. This review examines the shifting distribution of *Anopheles* mosquitoes, highlighting how deforestation, agricultural intensification, irrigation, informal settlements, and urban-rural interfaces modify vector habitats and transmission dynamics. Evidence indicates that key vectors, including *Anopheles gambiae* and *Anopheles arabiensis*, exhibit remarkable ecological adaptability, thriving in artificial and polluted urban environments. The review underscores the limitations of traditional rural-focused control measures, such as insecticide-treated nets (ITNs) and indoor residual spraying (IRS), and emphasizes the need for urban-tailored strategies, including larval source management, environmental modifications, strengthened surveillance, and integration with urban planning. Critical research gaps persist in understanding vector behavior, socioeconomic determinants, and climate change impacts on urban malaria. Addressing these gaps through multidisciplinary, context-specific interventions is essential to sustain malaria control efforts and mitigate the growing threat of urban malaria across Sub-Saharan Africa.

Keywords: Malaria, *Anopheles* mosquitoes, urbanization, peri-urban malaria, land-use change, Sub-Saharan Africa.

INTRODUCTION

Malaria continues to be one of the most significant public health challenges in Sub-Saharan Africa, accounting for the highest burden of morbidity and mortality worldwide [1]. According to the World Health Organization (WHO) [2], the region contributes more than 90% of global malaria cases and deaths, with children under five and pregnant women being disproportionately affected. Historically, malaria transmission has been strongly associated with rural environments, where natural and agricultural landscapes create favorable conditions for *Anopheles* mosquitoes, the primary vectors of malaria. These habitats include swamps, irrigated rice fields, ponds, and other stagnant water bodies that provide suitable breeding grounds. Consequently, malaria epidemiology in Sub-Saharan Africa has traditionally been studied and addressed through a rural lens, with control strategies focusing on rural households, villages, and farming communities [3].

However, the last few decades have witnessed unprecedented urbanization across Sub-Saharan Africa. Projections indicate that by 2050, more than half of the region's population will reside in urban areas, compared to just over 30% in 2010. This rapid demographic shift is accompanied by widespread land-use transformations, including deforestation, agricultural intensification, irrigation schemes, infrastructural expansion, and the establishment of informal urban settlements [4]. As a result, malaria is no longer confined to rural areas; it is increasingly becoming a concern in peri-urban and urban settings.

Urbanization alters the ecological landscape in ways that can both suppress and enhance malaria transmission. On one hand, well-planned urban areas with improved drainage, waste management, and better housing infrastructure often reduce breeding habitats for mosquitoes, thus lowering malaria risks [5]. On the other hand, unplanned urban growth, especially in low-income settlements, creates new breeding opportunities through poorly managed drainage systems, clogged gutters, construction sites, water storage containers, and peri-urban agricultural practices [6]. Additionally, increased human mobility between rural and urban areas facilitates the introduction of malaria

parasites into cities, sustaining transmission cycles even in environments where vector populations are relatively low [7].

Anopheles mosquitoes, particularly species such as *Anopheles gambiae sensu lato* and *Anopheles funestus*, have shown remarkable ecological adaptability, thriving not only in rural environments but also in human-modified urban ecosystems. Their ability to exploit artificial and temporary water collections challenges the long-held assumption that malaria is predominantly rural. The changing distribution of Anopheles mosquitoes raises critical questions about the dynamics of malaria transmission in rapidly urbanizing Sub-Saharan Africa and calls for a reassessment of vector control strategies that have traditionally been rural-centric [8].

Despite considerable progress in malaria control through interventions such as insecticide-treated nets (ITNs), indoor residual spraying (IRS), and improved case management, Sub-Saharan Africa continues to shoulder a disproportionate share of the global malaria burden. The persistence of malaria can be partly attributed to ecological and socio-economic changes associated with rapid urbanization and land-use transformations [9]. The expansion of cities, deforestation, agricultural intensification, and irrigation schemes have created complex ecological interfaces that sustain Anopheles populations in new environments.

Most existing malaria control strategies are designed with rural transmission dynamics in mind and often overlook the emerging threat of urban malaria. For instance, while interventions such as ITNs remain effective in many rural households, their coverage and consistent use are lower in overcrowded informal settlements [10]. Moreover, drainage systems and water management in cities are often poorly designed, leading to water stagnation that serves as breeding grounds for mosquitoes. Consequently, control programs face challenges in adapting interventions to suit urban-specific contexts.

Additionally, there is limited understanding of how Anopheles mosquitoes are adapting to urban ecosystems and how these adaptations affect transmission intensity. The ecological resilience of malaria vectors, coupled with increasing rural-to-urban migration, creates the possibility of persistent malaria transmission in urban centers that were previously considered low-risk. This situation threatens to undermine decades of progress in malaria control, as urban malaria presents unique challenges that differ from rural transmission patterns [11].

Therefore, there is an urgent need to examine the shifting distribution of Anopheles mosquitoes under conditions of rapid urbanization and land-use change. Without such an understanding, malaria elimination efforts in Sub-Saharan Africa risk being compromised, and public health systems may become overwhelmed by the dual challenge of rural and urban malaria [12]. This review aims to investigate the impact of land-use changes and rapid urbanization on malaria transmission in Sub-Saharan Africa, with a particular focus on Anopheles mosquito ecology and the emergence of urban malaria. The objectives include examining how deforestation, irrigation, and agricultural intensification influence mosquito habitats and distribution, analyzing the role of informal settlements in sustaining urban malaria, and assessing the ecological adaptability of key Anopheles species to urban and peri-urban environments. The study also explores the implications of changing malaria epidemiology for vector control strategies and proposes integrated, sustainable approaches for malaria prevention in the context of urban development. Research questions focus on identifying habitat alterations due to land-use transformations, understanding transmission dynamics in urbanized areas, determining species adaptability, evaluating challenges for existing control measures, and identifying strategies for integrated vector management and sustainable urban planning. The study is significant because it shifts attention from traditional rural malaria research to the growing threat of urban malaria, provides insights into vector ecology for targeted interventions, informs policy and urban planning to minimize breeding sites, supports global malaria elimination goals by tailoring strategies to diverse ecological contexts, and addresses the socio-economic burden of malaria by improving health, productivity, and sustainable development outcomes across Sub-Saharan Africa.

Rural Malaria and Traditional Vector Ecology

Rural areas remain critical hotspots for malaria transmission, primarily due to the abundant presence of major vector species such as *Anopheles gambiae sensu lato* and *Anopheles funestus sensu lato*. These mosquitoes thrive in environments commonly found in rural settings, including rain-fed agricultural fields, wetlands, and forest edges, which provide ideal breeding and resting habitats [13]. The ecological characteristics of these areas, combined with seasonal rainfall patterns, create conditions that sustain high vector densities and continuous malaria transmission cycles. Rural populations often experience disproportionately higher malaria burdens compared to urban counterparts, driven by multiple factors. Limited access to healthcare services hinders timely diagnosis and treatment, while coverage of preventive interventions such as insecticide-treated nets (ITNs) and indoor residual spraying (IRS) is frequently suboptimal. Additionally, human behaviors and livelihoods in rural settings, including outdoor activities during peak mosquito biting times and proximity to vector breeding sites, increase human-vector contact. Understanding the interplay between traditional vector ecology and rural community dynamics is essential for designing targeted malaria control strategies that address both environmental and socio-behavioral determinants of transmission [14].

Migration and Human Mobility

Human migration and mobility significantly influence malaria transmission dynamics by altering exposure patterns and facilitating parasite spread. Seasonal agricultural workers, rural-to-urban migrants, and displaced populations frequently move between endemic and non-endemic areas, often carrying malaria parasites into urban or peri-urban settings. This movement can introduce parasites to local mosquito populations, creating new transmission foci in areas previously considered low-risk [15]. Similarly, urban residents traveling to malaria-endemic rural regions may acquire infections and return to cities, sustaining urban transmission cycles where competent vectors exist. Migration-driven malaria spread is further complicated by socio-economic factors, including limited access to healthcare, poor housing, and inadequate vector control measures among mobile populations. Seasonal or temporary migration may also coincide with peak vector abundance, amplifying transmission risk. Displacement due to conflict or environmental changes can concentrate vulnerable populations in high-risk areas, increasing infection rates. Understanding patterns of human mobility is therefore critical for malaria control, informing targeted surveillance, prevention strategies, and public health interventions to limit the introduction and spread of parasites across diverse geographic and demographic contexts [16].

Land Conversion and Habitat Transformation

Land conversion and habitat transformation are major drivers altering the ecological niches of *Anopheles* mosquitoes, with significant implications for malaria transmission. Activities such as deforestation, agricultural intensification, irrigation schemes, and settlement expansion modify local environments, creating new or enhanced breeding sites [17]. Deforestation, for example, often produces sunlit pools ideal for *Anopheles gambiae* proliferation, while irrigated rice fields provide persistent aquatic habitats suitable for *Anopheles arabiensis*. Infrastructure development, including roads and construction projects, generates artificial water bodies that support mosquito breeding in urban and peri-urban areas. These environmental modifications reduce the traditional separation between rural and urban malaria transmission patterns, leading to more complex and widespread vector distributions. Consequently, human-driven landscape changes are reshaping malaria ecology, facilitating mosquito adaptation to diverse habitats, and complicating vector control efforts. Understanding the impacts of land-use changes on *Anopheles* populations is critical for designing effective, context-specific interventions that account for evolving breeding patterns and transmission risks across both rural and urban African settings [18].

Urbanization and the Urban-Rural Interface

Historically, urban malaria in Sub-Saharan Africa was considered minimal due to factors such as pollution, limited mosquito breeding sites, and relatively better infrastructure. However, rapid and often unplanned urbanization has significantly altered this scenario, creating environments conducive to malaria transmission. Informal settlements with poor drainage, inadequate sanitation, and limited access to piped water lead residents to store water in containers, inadvertently providing breeding habitats for *Anopheles* mosquitoes [19]. Peri-urban agriculture further contributes to standing water sources, supporting the proliferation of key malaria vectors, particularly *Anopheles arabiensis* and *Anopheles gambiae*. The urban-rural interface—zones where expanding cities meet agricultural landscapes—has emerged as a critical area for vector adaptation, enabling mosquitoes to exploit both urban and rural resources. This interface facilitates sustained malaria transmission, as vectors can thrive in heterogeneous environments and move between urban and peri-urban areas. Consequently, the evolving patterns of urbanization in Sub-Saharan Africa have transformed previously low-risk urban areas into potential malaria hotspots, underscoring the need for targeted vector control strategies, urban planning interventions, and integrated public health approaches to mitigate malaria transmission in these dynamic landscapes [20].

Vector Adaptability and Emerging Urban Malaria

Recent evidence indicates that several *Anopheles* mosquito species are exhibiting significant adaptability to urban environments, reshaping the epidemiology of malaria in African cities. *Anopheles gambiae*, traditionally associated with rural habitats, has been observed breeding in polluted water bodies, while *Anopheles arabiensis* persists in irrigated urban gardens, reflecting their ecological flexibility [21]. The growth of urban agriculture, including backyard irrigation and community gardens, along with widespread household water storage practices, provides additional breeding sites that facilitate mosquito survival and reproduction in densely populated areas. These shifts challenge the long-held notion that malaria is primarily a rural disease, as urban settings now offer suitable conditions for sustained vector populations and ongoing malaria transmission. The adaptability of these vectors underscores the need for tailored urban malaria control strategies that account for altered breeding habitats, human-vector interactions, and the complexities of city landscapes. Failure to address these emerging urban dynamics may hinder malaria elimination efforts and contribute to persistent disease burdens in rapidly expanding African cities [22].

Implications for Malaria Epidemiology

The shifting distribution of malaria vectors in urban and peri-urban areas has significant implications for malaria epidemiology. Transmission risk is highly heterogeneous, often concentrated in peri-urban zones where

environmental conditions, such as stagnant water and poor drainage, create suitable breeding habitats. This localized clustering challenges conventional assumptions about urban malaria, which was previously considered low risk, and necessitates targeted vector control strategies [23]. Changing transmission patterns are also emerging, as urbanization introduces artificial water bodies that support year-round mosquito breeding, disrupting traditional seasonal malaria cycles and potentially sustaining continuous transmission. Furthermore, urban malaria vectors are increasingly exposed to both insecticides used in vector control programs and antimalarial drugs in human populations, creating strong selection pressures that accelerate the evolution of resistance. This dynamic complicates control efforts, as resistant vector populations reduce the effectiveness of conventional interventions, while drug-resistant parasites threaten treatment success. Overall, these shifts underscore the need for fine-scale surveillance, adaptive vector management, and integrated strategies that account for heterogeneous risk, altered seasonality, and the growing challenge of resistance in urban malaria settings [24].

Control Challenges, Opportunities, and Research Gaps

Urban malaria presents unique challenges that limit the effectiveness of traditional control strategies such as insecticide-treated nets (ITNs) and indoor residual spraying (IRS), which were primarily designed for rural contexts. High population density, diverse housing structures, and numerous artificial water-holding containers create complex breeding environments that reduce the efficacy of conventional interventions [25]. Addressing these challenges requires innovative, context-specific approaches including environmental management through improved drainage and waste disposal, larval source management via biological control and targeted larviciding, and strengthened urban surveillance and early warning systems. Integrating malaria control with urban planning and housing development enhances sustainability and ensures that urban growth does not exacerbate transmission. Despite these strategies, critical research gaps persist, including comprehensive mapping of urban vector breeding habitats, understanding vector behavioral adaptations to polluted and artificial environments, elucidating socioeconomic and cultural determinants of vulnerability, and assessing climate change impacts on urban malaria distribution [25]. Filling these gaps is essential for developing evidence-based, adaptive interventions and sustainable urban malaria control programs in African cities.

CONCLUSION

The shifting distribution of *Anopheles* mosquitoes from rural to urban settings in Sub-Saharan Africa underscores the evolving complexity of malaria transmission in the context of rapid urbanization and land-use change. Traditional assumptions of malaria as a predominantly rural disease are increasingly challenged, as vectors such as *Anopheles gambiae* and *Anopheles arabiensis* exhibit remarkable ecological adaptability, exploiting artificial water bodies, peri-urban agriculture, and informal settlements. These dynamics have created heterogeneous transmission patterns, concentrated in peri-urban zones and urban-rural interfaces, complicating control efforts and heightening the risk of sustained urban malaria. Conventional interventions like insecticide-treated nets and indoor residual spraying require adaptation to urban contexts, complemented by innovative strategies such as larval source management, environmental modifications, strengthened surveillance, and integration with urban planning. Addressing critical research gaps—including vector ecology in polluted environments, socioeconomic determinants, and climate change impacts—is essential for evidence-based interventions. Ultimately, a multidisciplinary, context-specific approach is imperative to mitigate the emerging threat of urban malaria and sustain progress toward malaria control and elimination in Sub-Saharan Africa.

REFERENCES

1. Ugwu O. P. C, Alum E. U, Egba S. I, Uti D. E, Alum B. N. Climate Variability and Malaria Transmission: Unraveling the Complex Relationship. *INOSR Scientific Research*, 2024; 11(2):16-22. <https://doi.org/10.59298/INOSRSR/2024/1.1.21622>
2. Fact sheet about malaria, <https://www.who.int/news-room/fact-sheets/detail/malaria>
Emmanuel I. N., Ani. O. C., Ugwu F. J., Egba S. I., Aguzie I. O., Okeke O. P., et al (2020) Malaria Prevalence in Rice Farm Settlements South East Nigeria. *IJTDH*, 41(9): 64-74
3. Kamana, A.A., Radoine, H., Nyasulu, C.: Urban challenges and strategies in African cities – A systematic literature review. *City and Environment Interactions*. 21, 100132 (2024). <https://doi.org/10.1016/j.cacint.2023.100132>
4. Obeagu E. I, Obeagu G, U, Egba S. I, Emeka-Obi O. R, (2023) Combatting Anaemia in Paediatric Malaria: Effective management strategies *Int. J. Curr. Res. Med. Sci.* (2023). 9(11): 1-7
5. Jemberie, M.A., Melesse, A.M., Abate, B.: Urban Drainage: The Challenges and Failure Assessment Using AHP, Addis Ababa, Ethiopia. *Water*. 15, 957 (2023). <https://doi.org/10.3390/w15050957>
6. Egwu, C. O., Alope, C., Chukwu, J., Agwu, A., Alum, E., Tsamesidis, I, et al. A world free of malaria: It is time for Africa to actively champion and take leadership of elimination and eradication strategies. *Afr Health Sci.* 2022 Dec;22(4):627-640. doi: 10.4314/ahs.v22i4.68.

7. Koffi, A.A., Camara, S., Ahoua Alou, L.P., Oumbouke, W.A., Wolie, R.Z., Tia, I.Z., Sternberg, E.D., et al: Anopheles vector distribution and malaria transmission dynamics in Gbékê region, central Côte d'Ivoire. *Malaria Journal*. 22, 192 (2023). <https://doi.org/10.1186/s12936-023-04623-1>
8. Ugwu, O. P. C., Alum, E. U. and Uhama, K. C. (2024). Dual Burden of Diabetes Mellitus and Malaria: Exploring the Role of Phytochemicals and Vitamins in Disease Management. *Research Invention Journal of Research in Medical Sciences*. 3(2):38-49.
9. Cathorall, M.L., Peachey, A., Najjuma, S.: Knowledge, attitudes, and practices regarding malaria in rural Uganda: a cross-sectional study. *Malariaworld J*. 16, 14 (2025). <https://doi.org/10.5281/zenodo.15776707>
10. lum, E. U. (2024). Phytochemicals in Malaria Treatment: Mechanisms of Action and Clinical Efficacy. *KIU J. Health Sci*, 4(2):71-84. <https://doi.org/10.59568/KJHS-2024-4-2-06>.
11. De Silva, P.M., Marshall, J.M.: Factors Contributing to Urban Malaria Transmission in Sub-Saharan Africa: A Systematic Review. *J Trop Med*. 2012, 819563 (2012). <https://doi.org/10.1155/2012/819563>
12. Armin R., Michele R. R., (2013). Malaria during pregnancy with parasite sequestration in the villous chamber. *Blood, the Journal of the American Society of Hematology*, 121, (12), 2173-2173. <https://doi.org/10.1182/blood-2012-10-465096>
13. Olubunmi A., Faoziyat A. S, Abdulummeen A. H, Azeezat A., Abraham C A., Oloriegbe S, et al (2021). In pursuit of new anti-malarial candidates: novel synthesized and characterized pyrano-benzodioxepin analogues attenuated Plasmodium berghei replication in malaria-infected mice. *Heliyon*, 7, (12), 8523. DOI: <https://doi.org/10.1016/j.heliyon.2021.e08517>
14. Tilaye, T., Tessema, B., Alemu, K., Yallew, W.W.: Perceived causes and solutions for malaria prevalence among seasonal migrant workers in Northwest Ethiopia: a qualitative study. *Malaria Journal*. 24, 47 (2025). <https://doi.org/10.1186/s12936-024-05231-3>
15. Abdulazeez M A, Adebisi S S, Musa S A, Abdullahi M S, Mudassir L (2021). Histological Study of Ethanol Leaf Extract of Vernonia amgydalina in Cerebellum of Young Mice Malaria Model. *International Journal of Research and Reports in Hematology*, 4, (1), 20-29.
16. Estifanos, T.K., Fisher, B., Ricketts, T.H.: Deforestation changes the effectiveness of bed nets for malaria control. *People and Nature*. 7, 180–193 (2025). <https://doi.org/10.1002/pan3.10753>
17. Nakisuyi J, Bernis M, Ndamira A, Theophilus P, Agwu E, Lule H, et al (2023). Prevalence and factors associated with malaria, typhoid, and co-infection among febrile children aged six months to twelve years at kampala international university teaching ... *Heliyon*, 9, (9), e19588.
18. Merga, B.B., Moisa, M.B., Gameda, D.O.: Spatial analysis of malaria risk using geospatial techniques in Wabi Shebele river sub-basin, Southeastern Ethiopia. Taylor & Francis. (2024)
19. Agwu E, Nyakerario E, Moazzam M (2015). Updates on Malaria parasites distribution among HIV infected and AIDS patients in Comboni Hospital, Uganda. *Special Parasites Pathogens Journal (SPPJ)*, 1, 29-35.
20. Mzilahowa, T., Luka-Banda, M., Uzalili, V., Mathanga, D.P., Campbell, C.H., Mukaka, M., Gimnig, J.E.: Risk factors for Anopheles mosquitoes in rural and urban areas of Blantyre District, southern Malawi. *Malawi Med J*. 28, 154–158 (2016). <https://doi.org/10.4314/mmj.v28i4.2>
21. Simon I, Ejemot-Nwadiaro R, Inah J, Eko J., (2017). Prevalence of malaria among pregnant women and children under five years in Abi Local Government Area, Cross River State, Nigeria. *Asian Journal of Medicine and Health*, 7, (1), 1-7. <https://doi.org/10.9734/AJMAH/2017/35911>.
22. Georges S, Ananias E, John K, Laurent R, Anne-Charlotte G, Sabrina K (2011). Malaria in hominids. *Bulletin de l'Academie nationale de medecine*, 195, (8), 1945-1954. [https://doi.org/10.1016/s0001-4079\(19\)31931-4](https://doi.org/10.1016/s0001-4079(19)31931-4).
23. Lobo, N.F., Achee, N.L., Greico, J., Collins, F.H.: Modern Vector Control. *Cold Spring Harb Perspect Med*. 8, a025643 (2018). <https://doi.org/10.1101/cshperspect.a025643>
24. Gebeyaw M, Theodros G, Atkure D, Tigist S, Girum T, Misrak G, et al (2019). Determinant of malaria service readiness at health facility: Evidence from 2018 Service Availability and Readiness Assessment: Cross sectional study. 2019/11/28. <https://doi.org/10.21203/rs.2.17893/v1>.
25. Ortiz, D.I., Piche-Ovares, M., Romero-Vega, L.M., Wagman, J., Troyo, A.: The Impact of Deforestation, Urbanization, and Changing Land Use Patterns on the Ecology of Mosquito and Tick-Borne Diseases in Central America. *Insects*. 13, 20 (2021). <https://doi.org/10.3390/insects13010020>

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