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Urban Agriculture, Water Management, and Mosquito Breeding in Peri-Urban Sub-Saharan Africa: Implications for Malaria Control

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ABSTRACT

Malaria remains a significant public health issue in Sub-Saharan Africa (SSA), with increasing transmission rates in urban and peri-urban areas due to rapid urbanization and inadequate infrastructure. Urban agriculture, a vital livelihood strategy in peri-urban SSA, often intersects with poor water management practices, creating favorable breeding grounds for malaria vectors, particularly Anopheles mosquitoes. This review explores the complex relationship between urban agriculture, water management, and mosquito breeding in peri-urban areas, emphasizing how irrigation systems, water storage, and waste management contribute to malaria transmission. It discusses the implications of these practices for malaria control and highlights the need for integrated strategies that simultaneously address food security, environmental management, and public health. The review also examines emerging technologies such as remote sensing, GIS, and mobile health platforms, which can enhance mosquito surveillance and community involvement in malaria prevention. By proposing a multi-sectoral approach that includes urban planning, vector control, and community-based interventions, the review calls for sustainable urban agricultural practices to mitigate malaria risks while fostering resilient, healthy urban environments in SSA.

Keywords: Water management, mosquito breeding, peri-urban areas, malaria control, Anopheles mosquitoes.

INTRODUCTION

Malaria continues to pose a substantial public health burden in Sub-Saharan Africa (SSA), accounting for over 90% of global malaria cases and deaths (World Health Organization [1]. It disproportionately affects children under five, pregnant women, and other vulnerable populations, contributing significantly to morbidity, mortality, and economic losses in the region. Historically, malaria has been predominantly associated with rural areas, where vector breeding habitats are abundant and transmission conditions are favorable [2]. However, rapid urbanization, population growth, and environmental transformations have altered malaria epidemiology, leading to an increased risk of transmission in urban and peri-urban environments. This shift is particularly concerning, as urban centers in SSA are growing at unprecedented rates, often outpacing the development of adequate infrastructure and sanitation systems [3].

Peri-urban areas, which represent the transitional zones between dense urban centers and rural landscapes, are especially vulnerable to malaria transmission. These zones typically exhibit characteristics of both urban and rural settings: unplanned settlements, insufficient drainage, poor waste management, and inadequate access to clean water. Such conditions create ideal environments for the proliferation of malaria vectors, particularly *Anopheles gambiae s.l.*, *Anopheles funestus s.l.*, and *Anopheles arabiensis* [4]. These mosquitoes thrive in small collections of stagnant water, which are common in peri-urban areas due to poor infrastructure and environmental mismanagement. Consequently, the growing urban and peri-urban populations of SSA face an emerging public health challenge, as malaria transmission intensifies in areas previously considered low-risk [5].

One of the key drivers of malaria transmission in peri-urban areas is urban agriculture. Urban and peri-urban agriculture (UPA) encompasses the cultivation of crops and rearing of livestock within or near city limits. Across SSA, urban agriculture has become an essential component of food systems, providing fresh vegetables, fruits, and animal products to rapidly expanding urban populations. UPA not only contributes to food security but also offers employment opportunities, income generation, and poverty alleviation [6]. Despite these benefits, the expansion of urban agriculture can inadvertently exacerbate malaria risk. Irrigation canals, water storage containers, poorly managed drainage, and other water-retaining features commonly associated with urban farms provide ideal habitats for mosquito larvae. For instance, vegetable gardens with standing water after irrigation or rainfall become breeding grounds for *Anopheles* species, facilitating the continuation of malaria transmission cycles in densely populated areas [7].

The intersection between urban agriculture and malaria transmission highlights the complex interactions between human activities, environmental management, and vector ecology. In many SSA cities, farmers lack access to effective guidance on water management or vector control, and urban planning often overlooks the health implications of agricultural expansion. Furthermore, socio-economic pressures force residents to engage in agriculture in high-risk areas, prioritizing food production and livelihood over vector control [8]. This scenario underscores the need for integrated interventions that simultaneously support urban food security while reducing vector breeding opportunities.

Despite growing recognition of the health risks posed by urban agriculture, the literature on its role in malaria transmission remains fragmented. Existing studies often focus either on agricultural practices or on vector ecology, but rarely integrate the two perspectives to inform comprehensive public health interventions. There is, therefore, a pressing need to review and synthesize evidence on the links between urban agriculture, water management, and malaria risk in peri-urban SSA. Such an understanding can inform the design of sustainable interventions that address both food security and public health objectives [9].

Malaria transmission in peri-urban areas of SSA has emerged as a significant public health problem, driven in part by the expansion of urban agriculture. While UPA provides essential economic and nutritional benefits, its water-intensive practices often create suitable habitats for malaria vectors. Poor irrigation techniques, inadequate drainage, and improper waste management in urban farms contribute to mosquito proliferation, increasing the risk of malaria outbreaks among vulnerable urban populations [10]. The lack of integrated policies that simultaneously address urban agriculture, environmental management, and vector control further compounds the problem. Consequently, peri-urban residents remain at high risk of malaria, which undermines public health, economic productivity, and social well-being. Understanding the complex interactions between urban agriculture and malaria transmission is therefore critical for devising interventions that promote both sustainable urban development and effective disease control [11]. This review aims to examine the complex relationship between urban agriculture and malaria transmission in peri-urban regions of Sub-Saharan Africa (SSA). Specifically, it will explore how urban agriculture practices, particularly water management strategies, contribute to mosquito breeding and malaria risk. By analyzing the ecological and socio-economic factors in urban agricultural settings, the review seeks to identify key elements that exacerbate malaria transmission. It will also assess integrated strategies for malaria control that can balance the benefits of urban agriculture with the imperative of safeguarding public health. The review is guided by research questions focusing on the role of urban agriculture in malaria transmission, water management practices that foster mosquito breeding, and factors that increase malaria risk in these settings. The significance of the study lies in its potential to enhance understanding of urban malaria epidemiology, inform urban planning, and guide public health interventions. Furthermore, it provides practical recommendations for urban farmers, extension workers, and community organizations to implement changes in water and land management to reduce mosquito breeding. This review ultimately advocates for sustainable urban agriculture practices that support food security while minimizing malaria transmission, fostering healthier, more resilient urban communities in SSA.

Urban Agriculture in Peri-Urban Sub-Saharan Africa

Urban agriculture in peri-urban Sub-Saharan Africa plays a significant role in the socio-economic fabric of the region, contributing to food security, income generation, and employment, especially for low-income households. This practice involves the cultivation of crops and the rearing of livestock in urban and peri-urban areas, where up to 70% of urban households engage in some form of farming. Peri-urban zones are particularly conducive to urban agriculture due to their mixed land use and proximity to urban markets, which offer a direct route for selling produce [12]. These areas also provide open land, making them favorable spaces for farming. However, the success of urban agriculture is often limited by inadequate infrastructure, such as the lack of piped water and drainage systems. As a result, many urban farmers resort to informal irrigation practices using wastewater, stagnant pools, or rainwater for crop cultivation, which inadvertently creates environmental challenges. The use of open containers and poorly managed irrigation systems fosters ideal breeding grounds for mosquitoes, as stagnant water accumulates in these settings [13]. Consequently, this practice not only raises concerns regarding pest control but also extends the duration of mosquito breeding, facilitating the spread of vector-borne diseases like malaria, especially during the dry season when other breeding sites are less common.

Water Management and Mosquito Breeding

Water management plays a crucial role in the dynamics of mosquito breeding, particularly in peri-urban and urban farming areas. Irrigation systems, such as small canals, ditches, and furrows, are often poorly maintained, leading to water stagnation due to blockages or leaks. This stagnant water creates ideal breeding grounds for Anopheles mosquitoes, which are responsible for malaria transmission. Similarly, water storage containers like barrels, tanks, and buckets, essential for urban farmers coping with irregular water supply, are often left uncovered, allowing mosquitoes to lay their eggs [14]. Inadequate drainage systems exacerbate the problem, especially in areas lacking formal infrastructure. Stagnant water accumulates in open drains, roadside ditches, and untreated wastewater from households and farms, which further perpetuates breeding sites in wetlands or low-lying areas. Moreover, poor waste disposal practices in peri-urban environments contribute significantly to mosquito proliferation. Discarded plastic containers, tires, and cans collect rainwater, creating larval habitats for both Anopheles and Aedes mosquitoes, the latter being vectors for diseases like dengue and Zika. The lack of proper sanitation and coordinated waste management in informal settlements and urban agricultural zones worsens the situation, enabling mosquitoes to thrive year-round. Effective water management, proper drainage, and waste disposal systems are vital for controlling mosquito populations and reducing the transmission of vector-borne diseases [15].

Vector Ecology and Breeding Habitat Dynamics

Malaria vectors, particularly Anopheles gambiae s.l., have demonstrated remarkable adaptability to urban and peri-urban environments, which has significantly influenced the dynamics of malaria transmission in these regions. In cities such as Accra (Ghana), Dar es Salaam (Tanzania), and Lagos (Nigeria), studies have shown that these vectors can successfully breed in man-made, polluted water bodies, often created by human activities like poor waste management and construction [16]. This adaptability allows malaria transmission to persist even in densely populated urban areas, where the availability of natural breeding sites such as stagnant ponds and swamps is limited. Furthermore, the scattered and often small breeding sites found in peri-urban zones complicate vector control efforts. These sites are frequently linked to urban agriculture, which utilizes irrigation systems, and poorly maintained drainage systems, which provide ideal conditions for larval development. The high number and variability of these breeding sites pose a significant challenge to larval source management (LSM) strategies, such as environmental modification and larviciding. Efforts to control mosquito populations become increasingly difficult due to the constantly changing and diverse nature of these breeding environments. As urbanization continues to expand, understanding and addressing the complexities of vector ecology in these environments will be crucial for effective malaria control programs [17].

Implications for Malaria Control

Malaria control in peri-urban areas presents unique challenges that require a multi-faceted approach. Traditional methods such as insecticide-treated nets (ITNs) and indoor residual spraying (IRS) are designed to target indoor resting mosquitoes, but they are often less effective in peri-urban environments where mosquitoes may breed outdoors and exhibit early biting behaviors. The shift in vector ecology in these areas highlights the need for an integrated approach that considers both agricultural practices and malaria prevention [18]. In peri-urban settings, the overlap between agricultural water management and malaria vector ecology necessitates innovative solutions that address both aspects simultaneously. A critical step in this process is integrating urban planning with malaria control efforts. Sustainable urban agriculture policies should include strategies for water and waste management that limit mosquito breeding sites. For instance, constructing covered water storage facilities, improving drainage systems, and promoting environmental sanitation can significantly reduce mosquito populations. Furthermore, addressing malaria in peri-urban areas requires collaboration across sectors. Public health authorities, agricultural departments, and environmental agencies should work together to embed vector control measures within broader urban development plans. Empowering local communities with knowledge about vector ecology and safe agricultural practices can also play a vital role in enhancing malaria prevention efforts [19]. By fostering community-based, cross-sectoral interventions, malaria control can be more effective in these dynamic and rapidly changing urban environments, ultimately contributing to the long-term goal of malaria elimination.

Emerging Technologies and Innovative Approaches

Emerging technologies and innovative approaches have revolutionized the management and control of mosquito breeding sites, playing a critical role in the fight against vector-borne diseases. Advanced remote sensing technologies, geographic information systems (GIS), and drone-based habitat mapping have significantly enhanced the ability to monitor and identify mosquito breeding hotspots with unprecedented accuracy and efficiency [20]. These technologies allow for real-time data collection and the mapping of breeding sites, providing valuable insights into patterns of mosquito activity and environmental factors that contribute to their proliferation. In addition to these monitoring technologies, integrating eco-friendly strategies such as bio-larvicides and water recycling systems can effectively reduce the availability of breeding sites [21]. Bio-larvicides offer a sustainable alternative to chemical treatments, targeting mosquito larvae without harming other wildlife. Furthermore, innovative urban designs, such as the creation of constructed wetlands, can help manage stormwater runoff while reducing the chances of stagnant water where mosquitoes thrive. The integration of mobile health (mHealth) platforms further enhances community involvement by providing a means for the public to report breeding site locations and receive real-time alerts on mosquito control efforts. This combination of advanced technology, eco-friendly interventions, and community engagement offers a comprehensive and sustainable approach to combating mosquito-borne diseases [22].

CONCLUSION

In conclusion, urban agriculture, water management, and mosquito breeding in peri-urban Sub-Saharan Africa represent a complex intersection of environmental, socio-economic, and health challenges. While urban agriculture plays a crucial role in improving food security and livelihoods, its unintended contribution to mosquito breeding presents significant risks for malaria transmission. Poor water management practices, such as inefficient irrigation systems and inadequate drainage, create ideal breeding sites for malaria vectors, particularly in the absence of proper waste management. Addressing these challenges requires integrated solutions that balance the benefits of urban agriculture with effective malaria control strategies. This includes improving water management infrastructure, promoting eco-friendly farming practices, and incorporating vector control measures into urban planning and development. Additionally, leveraging emerging technologies like remote sensing, GIS, and mobile health platforms can enhance monitoring and community engagement in malaria control efforts. Ultimately, a multi-sectoral approach that involves health authorities, urban planners, and local communities is essential for reducing malaria transmission and fostering sustainable, healthy peri-urban environments.

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