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RESEARCH ARTICLE

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Livelihoods as a key social determinant of malaria: Qualitative evidence from Uganda

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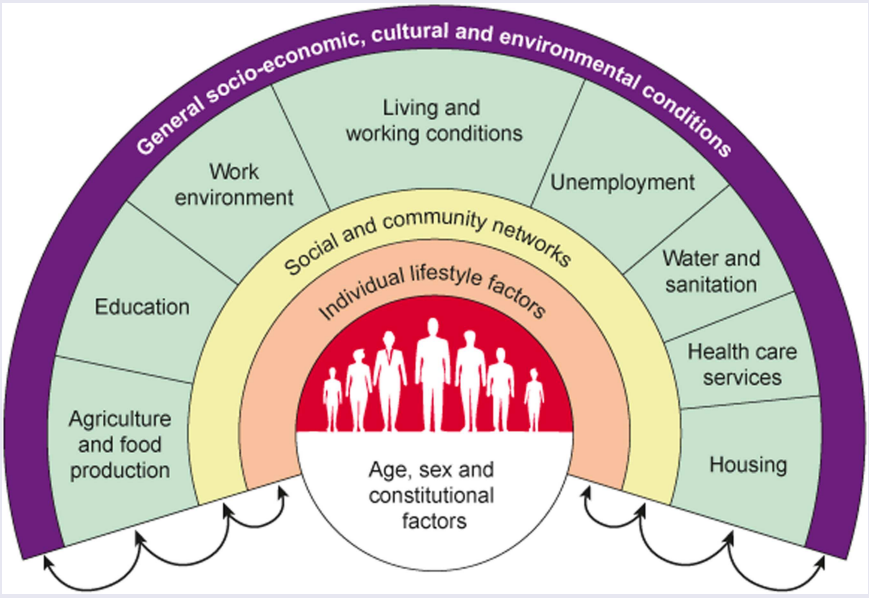
ABSTRACT

Malaria continues to be one of the leading causes of morbidity and mortality in Africa. Recent progress towards eliminating malarias has stagnated and, in some cases began to reverse. One key dimension which remains poorly understood in malaria research is the social determinants of the disease, which direct attention to the conditions in which people live and work. We present findings from a qualitative study that explored perceptions and understanding of the social determinants of malaria in Uganda, one of the main endemic countries. We conducted 14 key informant interviews, 10 focus group discussions with community members, and 11 in-depth interviews with households recently impacted by malaria. Our participants identified livelihoods and related practices as important social determinants. These included engaging in crop production with a focus on maize cultivation, livestock husbandry, construction, a range of activities conducted at dusk/night, and the gendered nature of specific livelihoods. The precise mechanisms noted through which these livelihood activities were related to malaria include increasing exposure to mosquitoes at dusk/night, the creation of new mosquito breeding sites, attracting mosquitoes to housing, providing feeding sites for mosquitoes, working near mosquito breeding sites, and the role that gendered care responsibilities play in exposing children to mosquitoes. Our findings emphasize the importance of engaging in these livelihood activities, given that they are widespread in Uganda and other African countries. We recommend that malaria prevention be incorporated into socio-economic development strategies, and urge researchers, policy makers, practitioners and other stakeholders to engage with the social determinants of malaria.



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Introduction

Malaria continues to be one of the main causes of morbidity and mortality in Africa, with an estimated 569,000 deaths due to the disease in 2023 (WHO, 2024b). Alongside high levels of morbidity and mortality with the human pain and suffering this entails, malaria also has significant consequences for development. These consequences include lost labour days due to illness and caregiving responsibilities, reduced labour productivity, diversion of household resources from productive investment, slower uptake of new technologies, and impacts on the types of crops grown and area of land that can be cultivated (Asenso-Okyere et al., 2011). At the macro level, malaria reduces economic growth and income per capita in affected countries (Sarma et al., 2019).

Although significant progress regarding malaria control has been achieved, in recent years this has begun to stagnate. The most recent World Malaria Report (2024b) highlights the following trends in the WHO African region. Firstly, in 2023 there were an estimated 246 million cases, a number that has increased steadily from 210 million in 2015 (WHO, 2024b). Secondly, in terms of incidence there has been a significant decline since 2000, from 355 cases per 1000 people to 227 cases per 1000 in 2023. However, incidence has not declined from 2019 to 2023, emphasising that progress has begun to stagnate. Thirdly, a similar trend can be observed for malaria-related deaths. The rate per 100,000 people at risk has declined from 140 in 2000 to 52 in 2023. However, the mortality rate was 57 in 2019, also showing a slowdown in progress. Unsurprisingly, this means that all but three countries in the WHO African region are unlikely to meet the case incidence and mortality targets outlined in the Global Technical Strategy for Malaria 2016–2030 (WHO, 2015). Based on current trajectories, efforts to achieve malaria elimination are not on track (Wenhui et al., 2023).

The situation in Uganda reflects these regional trends. Uganda is one of the main malaria endemic countries, with the third highest number of malaria cases and accounting for 4.8% of all cases in the WHO African region (WHO, 2024b). The estimated number of cases in 2023 was 12.6 million, a figure that has steadily increased from under 10 million in 2015 (WHO, 2024a). Incidence has declined from 460 per 1000 people in 2013 to 281 per 1000 people in 2019 (Ministry of Health, 2023). Over the last 5 years, this rate of reduction has slowed, with an incidence of 258 per 1000 people in 2023 (WHO, 2024b). The reduction in incidence and the number of cases has not met government targets, making the goal of malaria-free Uganda in 2040 challenging.

African countries face a growing number of challenges, including anti-malarial drug resistance, resistance of malaria vector mosquitoes to insecticides, and changes in mosquito behaviours, including increased outdoor biting, supply chain shortages for essential drugs, weak health systems, low levels of testing and misdiagnosis, and a lack of funding (Balikagala et al., 2021; Suh et al., 2023). Furthermore, the symbiotic relationships among malaria parasites, mosquitoes and humans, where the parasite is transmitted from mosquitoes to humans and from humans to mosquitoes, presents a complex dynamic. Whilst core prevention strategies in Uganda have predominantly focused on expanding access to and use of Insecticide Treated Nets (ITNs), the use of Indoor Residual Spraying (IRS), and prompt testing and treatment (Ministry of Health, 2023) have played a key role in reducing malaria morbidity and mortality amongst children and other vulnerable populations, it is clear that other strategies are needed to achieve malaria elimination (Nalinya et al., 2022).

One overlooked factor is the role of the social determinants of malaria in the prevention and control of the disease. The social determinants of health more generally have been defined by the WHO as 'the circumstances in which people are born, grow up, live, work and age, and the systems put in place to deal with illness. These circumstances are in turn shaped by a wider set of forces: Economics, social policies and politics' (WHO, 2006). Despite calls for more engagement with the social determinants of malaria (Cardona-Arias et al., 2019; Stratton et al., 2008), biomedical and behavioural approaches to malaria prevention continue to dominate. However, failure to incorporate the social determinants of malaria into the research, practice and policy-making agenda ensures that the underlying causes remain unaddressed (Atusingwize et al., 2025).

One central component of the social determinants approach is the conditions in which we live and work, directing attention towards the role of livelihoods and their relationship with malaria. In general, the framing of the relationship between malaria and livelihoods has been through a focus on occupations that may have higher malaria risk. For example, a recent review highlighted key occupations that involved

outdoor work such as forest workers, migrant workers, soldiers, miners, farmers and rubber tappers as experiencing increased malaria incidence due to higher exposure to mosquitoes as a results of working in the evenings and at night, as well as working in environments that were conducive to hosting mosquito populations (Msellemu et al., 2024). Outdoor night-time livelihood activities have also been associated with malaria in low-transmission settings (Jacobson et al., 2019). Alongside this focus on occupations, core livelihood activities such as agriculture have been linked with malaria. For example, evidence from the Democratic Republic of Congo shows significant increases in malaria infection and indoor biting related to increases in agricultural cover (Janko et al., 2018). Other work also suggests that malaria transmission is high in areas where there is agricultural development (Dugassa et al., 2021), and especially among workers on plantations (Getachew et al., 2023) and areas with intensive rice farming (Chan et al., 2022). Whilst much of the literature focuses on exposure to mosquitoes, some livelihood activities also create contexts in which mosquitoes can thrive through providing new and expanded breeding sites. These include rice farming, agricultural development which involves irrigation systems, and artisanal mining (Dao et al., 2021; Getachew et al., 2023). However, most studies that focus on a specific livelihood activity aim to quantify the relationship with malaria and whichever activity is under investigation. For example, a study conducted using data from Uganda employed an econometric approach to assess the between a range of agroecological variables such as crop production and precipitation, and malaria risk (Wielgosz et al., 2014). This study reported statistically significant relationships between beans, sweet potatoes, millet, sorghum tree crops and 'other crops' and increased household malaria prevalence (Wielgosz et al., 2014).

Whilst there is an emerging literature that focuses on some livelihood aspects of malaria, few studies have systematically applied a livelihoods approach to understand the drivers of malaria transmission. To our knowledge, there has not been a comprehensive application of a livelihood lens applied to the issue of malaria, especially in the Ugandan context. This study addresses this significant gap by reporting findings from qualitative research conducted in Uganda that explored stakeholder perceptions and understanding of the social determinants of malaria. The qualitative approach was chosen to enable a deeper exploration of why and how different social determinants influence malaria risk. Given that the 'circumstances in which people live and work' are highlighted by the WHO definition of the social determinants of health (WHO, 2006) and that livelihoods are of great importance for the general population in Uganda, the relationship between livelihoods and malaria was a primary focus of the study.

Methods

Study area and setting

This study was conducted in Busiro South Health Sub District (HSD) in Wakiso district, one of the districts that neighbours Kampala, Uganda's capital. Wakiso is one of the districts in Uganda where malaria is endemic with poor health-seeking behaviours (Musoke et al., 2021) and high rates of misdiagnosis (Yegorov et al., 2016). For instance, in the weekly malaria case updates, during the weeks of 12–18 February 2024, 26 February–2 March 2024 and 18–20 December 2024, Wakiso district was among the top 10 districts out of the total of 146 districts in Uganda for confirmed malaria cases with 2996, 3387 and 2518 cases, respectively. Busiro South HSD has a population of approximately 243,420 people in three town councils (Kajjansi, Kasanje and Katabi), and one sub county (Bussi) (Uganda Bureau of Statistics, 2016). The area is experiencing significant population growth at around 4% per annum. Wakiso was selected as the study site as it is comprised of urban, peri-urban and more rural areas, allowing a broad exploration of a wide range of social determinants of malaria from populations engaged in different livelihood activities.

Study design

This study took a qualitative approach to explore perceptions and understand the social determinants of malaria. It was comprised of three main strands: (i) Key informant interviews (KIIs) with a range of stakeholders, including the Ministry of Health and district health officials, community health workers (also known as Village Health Teams(VHTs)), development officers, local leaders (such as the local council chairpersons and religious

leaders), non-governmental organisations (NGOs) and other organisations involved in the prevention of malaria in Uganda; (ii) focus group discussions (FGD) with community members in the study area; and (iii) in-depth interviews with households that had been significantly impacted by malaria.

Sampling approach and characteristics of participants

Sampling of participants for this study was purposive and aimed at selecting stakeholders who were able to provide information to answer the study objectives. The three groups (KIIs, FGDs and IDIs) of participants were identified and recruited in different ways. For KIIs, this entailed an initial stakeholder mapping exercise as a starting point for identifying individuals and organisations to approach. For the FGDs, we liaised with one of the VHT coordinators, who acted as the area gatekeeper and worked with local leaders and community health workers to recruit participants who reflected a range of ages, genders and educations. Community members were included in the FGDs regardless of whether they had suffered from malaria or not. For the IDIs, households that had recently been impacted by malaria were identified by the VHTs. Household heads (including male and female headed) were identified to ensure a representation of households that had an experience of losing a member to malaria, as well as those that had other malaria-related experiences. Only people aged at least 18 years were engaged in the study. Overall, we recruited a diverse sample of participants (see Table 1). In terms of sex, 52% of our participants were female, and 48% were male. We also recruited participants from different age ranges, education levels and occupations to ensure that a range of voices were included.

Data collection

Data collection was conducted during June 2024. In total, we conducted 14 KIIs, 10 FGDs (each consisting of 6–8 participants) with community members and CHWs, and 11 IDIs with households recently impacted by malaria. Overall, this involved 100 participants. These activities were facilitated by four experienced postgraduate research assistants. The research assistants were trained for 2 days on the study objectives and research ethics and reoriented on the social determinants of health using the Dahlgren-Whitehead framework (Dahlgren & Whitehead, 2007) (see supplementary file S3). This framework was selected as it is an excellent visual map (often referred to as the rainbow model) that communicates the idea of the social determinants well. Activities were conducted in- person in either English or *Luganda* (the local language most used in central Uganda), depending on the preferences of the participants and language proficiency. Typically, interviews lasted between 30 minutes to an hour, with FGDs lasting 1.5–2 hours. FGDs were conducted across rural and urban areas for men and women separately, VHTs, and for young people to ensure a range of views. For all interviews and FGDs, a research guide (see supplementary file S2) was produced and piloted. Across the different data collection methods, we explored similar issues, including general perspectives on malaria, understanding and examples of the social determinants of malaria, how malaria was being addressed in prevention work, and the barriers to and facilitators of engaging with the social determinants of malaria. To ensure that participants had a clear understanding of the social determinants of health, we translated 'the social determinants of health' into Luganda ('ebintu ebivirako omusujja gw'ensiri nga biva ku mbeera y'abantu ey'abulijjo ebetoloodde'[1]), which provided a clearer description to participants in their local language. We also circulated the Dahlgren and Whitehead conceptual map (Dahlgren & Whitehead, 2007) to participants who were invited by e-mail, and the research assistants used this conceptual map as a visual aid to explain the social determinants of health to study participants and to prompt follow-up questions. All activities were audio recorded and then transcribed verbatim and, for those conducted in *Luganda*, translated to English by the research assistants.

Data analysis

The transcripts were analysed thematically following best practice principles (Braun & Clarke, 2006). Following initial familiarisation with the data, the team agreed on a coding framework to guide analysis. The coding

Table 1. Demographic characteristics of the study sample.

	Sex		Age range				Education				Occupation			
Activity	Male	Female	18–29	30–39	40–49	50+	No formal	Primary	Secondary	Tertiary	Employed	Self-employed	Farmer	Student
IDIs	5	6	0	2	7	2	0	4	6	1	0	7	4	0
KIIs	9	5	0	2	11	1	0	0	4	10	8	6	0	0
FGDs														
Mixed rural	4	4	1	1	6	0	1	4	2	1	0	5	3	0
Mixed urban	3	3	2	1	0	3	0	0	5	1	3	3	0	0
Female rural	0	8	2	2	2	2	0	7	1	0	0	3	5	0
Female urban	0	8	2	2	2	2	1	1	4	2	1	7	0	0
Male rural	8	0	0	2	4	2	0	3	4	1	0	6	2	0
Male urban	6	0	0	0	1	5	0	0	4	2	1	3	2	0
Youth rural	3	3	3	3	0	0	0	2	4	0	1	5	0	0
Youth urban	5	3	4	4	0	0	0	0	5	3	1	6	0	1
VHT rural	3	6	1	3	0	5	0	5	3	1	1	1	7	0
VHT urban	2	6	1	1	5	1	0	1	3	4	0	1	7	0
Total (FGDs)	**34**	**41**	**16**	**19**	**20**	**20**	**2**	**23**	**35**	**15**	**8**	**40**	**26**	**1**
%	**45%**	**55%**	**21%**	**25%**	**27%**	**27%**	**3%**	**31%**	**47%**	**20%**	**11%**	**53%**	**35%**	**1%**
Total (FGD, IDI, KII)	**48**	**52**	**16**	**23**	**38**	**23**	**2**	**27**	**45**	**26**	**16**	**53**	**30**	**1**
%	**48%**	**52%**	**16%**	**23%**	**38%**	**23%**	**2%**	**27%**	**45%**	**26%**	**16%**	**53%**	**30%**	**1.00%**

Note: Values in bold signify that they are totals.

reflected emerging themes, the Dahlgren and Whitehead conceptual map and core research questions. EA and KD then coded the data independently using the coding framework. Transcripts were coded using Atlas ti (version 6) (EA) and Nvivo (version 14) (KD). Finally, EA, KD and DM compared and discussed the codes to agree on the key themes. The research team also presented the initial findings at a stakeholder workshop with 30 participants in Kampala in August 2024 which was attended by many of the participants as well as other stakeholders and invited experts such as colleagues from Makerere and the ministry of health officials, local community leaders and representatives from malaria-related NOGs not interviewed as part of the project. This gave us an opportunity to validate and gain feedback on our analysis.

Ethical considerations

Ethical approval was granted by the Makerere University School of Public Health Research and Ethics Committee (# SPH–2024–578), and the Uganda National Council for Science and Technology (# HS4271ES). The Open University Human Research Ethics Committee also gave the project a favourable opinion (# 2024–0503–2). Consent was also granted by Wakiso district authorities. All participants provided (and were able to provide) written informed consent. On invitation, participants were provided with a participant information sheet that contained details of the study, what participation entailed, and how they could withdraw. At the beginning of each data collection activity, participants were talked through the main points on the information sheet (in English or *Luganda* depending on the preferred language) and were given the opportunity to read it themselves and ask questions. If they agreed to participate, they signed a consent form. The participant consent forms were available in both English and *Luganda*. All participants received a small cash amount of 20,000 Ugandan shillings (approximately $5) as compensation for their time and travel expenses. This is in line with local research regulations and not viewed as a coercive inducement.

Reflexivity statement[2]

The authors employed a reflective approach to the entire project process and its positioning, both as a team and individuals. EA and DM reflected through their experiences with malaria as Ugandan citizens but also considered their research experience with the disease. KD has prior experience of working with DM across multiple projects which ensured that this project was conducted as a partnership, led by DM, EA and the Ugandan team. Additionally, the interdisciplinary nature of the research team enhanced trustworthiness of the results. The authors have expertise and experience across disciplines including social science, development economics, political economy, global health, environmental health, public health, as well as community-based participatory research. Their engagement with research in malaria as a disease for many years was an advantage. During data collection, RAs with experience in qualitative methods were involved, and FGDs were organised including gender- and age-specific categories that reduced paternalistic-influenced responses. The fact that the Makerere University School of Public Health is a known active partner in various public health issues, including malaria, in the study area could have influenced how participants consented and responded to the questions in a way that may overly suggest a call for action. However, DM and EA, being Ugandans, understand the culture, including the language, and other expressions, which are important in understanding the perspectives raised in the FGDs and interviews. Additionally, the RAs understood the language, gender and other cultural dynamics that were essential in managing the FGD and interviews, especially with community members. KD, as an academic from the UK, was not involved in any data collection, which helped to minimise any potential coercion or other influence over what participants felt comfortable to share. During data analysis, the authors had frequent meetings to discuss and compare the developing themes in an iterative process that reduced the introduction of potential bias from their previous experiences. Furthermore, the stakeholder workshop was designed as a way of not only giving feedback to the community but also providing study participants the opportunity to comment on the results, further contributing to the credibility of our findings. In terms of transferability, the results show themes that highlight mechanisms underlying the livelihood – malaria link, described with quotes from participants to enable alternative interpretations and judgement regarding applicability to other contexts.

Results

The key livelihood activities that were highlighted by participants were agricultural practices related to crop production and animal husbandry, construction and livelihood activities conducted at night. Our participants also provided information on how gender intersects with livelihood activities to increase women and children's vulnerability to malaria. The quotes provided are illustrative of common themes reported multiple times across the different data collection activities.

Agriculture

Agriculture was linked to malaria in several different ways. Alongside the fact that many agricultural activities occur during the wet season when there is a seasonal increase in the mosquito population, participants noted that cultivation in proximity to households also contributed to mosquito presence and exposure. Whilst a wide range of crops such as beans, bananas, coffee, yams and potatoes were mentioned, maize was by far the most frequently cited crop:

> *'Agricultural activities have a way they contribute to malaria because if you look at the season when maize is growing or when beans are flowering, mosquitoes tend to be many during that time especially in the evening. This implies that these mosquitoes have a correlation with the crops that are surrounding us. And after harvesting in the dry season, normally in the evenings, there are fewer mosquitoes, but during wet season when maize is growing, mosquitoes are really many'. (FGD Men Urban).*

One reason for the link between maize and mosquitoes was that participants viewed the plants as providing places for mosquitoes to rest during the day and as breeding sites.

> *'Let me explain. Like during the times of maize (maize seasons), once June comes around and the mosquitoes are there, people in the past would say "it's the maize that brings about mosquitoes". The mosquitoes come from that maize because that is where they lay their eggs and then they come and bite us to give us malaria'. (IDI male rural1)*

The practice of cultivating maize and other crops in the areas around households was reported as being widespread and an important livelihood strategy in rural areas:

> *'People in the villages like digging (meaning growing crops). Someone can dig and plant some crops that bring mosquitoes, especially maize. People surround their homes with crops because they want them either for food or for sale to get money' (FGD Youth Rural).*

Many participants noted that whilst they were aware that maize and other plants attracted mosquitoes, they had no choice but to plant crops around their homes due to having small plot sizes:

> *'Then, I am aware that maize harbours mosquitoes, but we have nothing much we can do because if you stop planting maize, where will you get food from? So, some mosquitoes will continue biting us as we also eat our food. [Laughs]… we need good health but again we need food, so that is why I am saying, let mosquitoes bite us as we also eat food'. (IDI Female Rural2).*

Furthermore, participants noted that agricultural practices linked with malaria were also prevalent in urban areas, following recent growth in urban agriculture:

> *'Yes, they do. We love farming but it is all dependent on where you do it from. Now, we are in an urban area, you are growing sugar canes, maize and beans on your house's veranda; and those crops are becoming a breeding place for mosquitoes'. (FGD Male rural).*

Alongside the role of cultivation around homes, participants also noted that for people who had to travel a long distance to work on their gardens, this entailed leaving home early and returning late in the evening, exposing them to mosquitoes:

> *'The linkage between agriculture and Malaria occurrence is like this. Some people tend to go very early in the garden and believe that me, mosquitoes by that time are still in the garden since those crops like cassava or*

nakati have some water droppings on them, mosquitoes are there… they move so early to the gardens or even leave the garden late. It is very easy for a mosquito to bite you while you are outside' (FGD VHT Urban).

Finally, it was also noted that agricultural practices, including irrigation and other means of water storage created breeding sites for mosquitoes:

'We are tilling the land, we are maybe opening some ditches and within there, you will find that we are even harbouring some of the drains, and you will find that there is a lot of water maybe around there, so you will find that some areas might accumulate water and within there, those are breeding points for mosquitoes'. (KII MOH).

Animal husbandry

The second main livelihood activity that participants linked to malaria was animal husbandry, and specifically livestock. The participants reported that mosquitoes are attracted to and live on cattle, and so various practices related to tending cattle increased mosquito exposure for those involved, their families, and the wider community. For example, mosquitoes were brought back by cattle to the compounds where they were kept overnight, and then were attracted to nearby houses:

'Now, for animals like cows the mosquitoes love biting them, so by the time we are bringing them back from grazing in the evening at around 5 pm, the mosquitoes are already all over them biting. However, the cows don't get affected by mosquitoes like us humans, so when you bring back the cows, the mosquitoes follow them, and they enter the house. So, they enter the house because most of the cows are near the house in the compound'. (FGD mixed, rural)

One reason that kraals are kept close to farmers' houses is that they are concerned about the animals being stolen.

'Those cows, which we most especially tie on the pegs so close to our houses for monitoring purposes, always have so many mosquitoes that also bite us. As we do home chores, those mosquitoes keep biting us even before we go to bed to sleep. We tie those cows close to our houses to be able to monitor them all the time from thieves'. (FGD CHWs rural)

The role of cattle production in contributing to increased mosquito density was also related to zero grazing practices, where cattle are permanently kept and fed in stalls:

'Or, you are doing zero grazing of a cow and you are not regularly cleaning its kraal, that later develops into pot holes with stagnant water, and that also contributes to an ever-growing mosquito infestation in your house'. (FGD male, rural)

Participants also noted that it was important to keep stalls for zero grazing, which also included the rearing of chicken, pigs and goats, clean and free from holes where water and urine could collect:

'It all depends on your sanitation level. For example those who rear pigs, the houses need to be cleaned. Then when the cows have urinated, the cow dung joins that urine hence breeding mosquitoes, so you need to clean the home all the time, you need to create a proper drainage where urine can flow. So, these days, wherever we go, you hear people talking about malaria all the time'. (IDI Female urban1)

Construction

The third livelihood highlighted by participants was construction activities, including brick laying and brick making. Brick makers were noted to conduct activities during the night, especially when they were burning bricks:

'Then even brick layers who work in swamps, they work in environments that are not favourable, they are bitten by mosquitoes. For example, on the days when they are burning bricks, they do it the entire night and mosquitoes bite them throughout'. (FGD CHWs urban)

However, the main link between construction and malaria was the process of making bricks. This involves using clay that is found in swampy areas. Brick makers dug up this clay, leaving behind large

holes that collected water that was used for cooling the bricks once they had been burned. These holes were often not covered or treated, creating new breeding sites for mosquitoes:

'Then the other issue that I can talk about is the environment, you find that we have so many people, brick layers around. So, they make [bricks], they dig this clay to make the bricks, but afterwards, they leave these sites – where water can collect and create breeding site for mosquitoes. So, instead of leaving open holes when they have finished with that, if they could instead cover those holes, I think it can help us a lot, but we have so many pools of water now where mosquitoes can breed'. (KII health facility incharge)

In addition, it was noted that water holes dug on construction sites also act as breeding sites for mosquitoes:

'Now, if there is a pond of water, mosquitoes produce from there. They dig water ponds at building sites from which they source water to aid in the building'. (IDI male rural 2)

Key interventions for dealing with these ponds created during the brick-making process were either by covering or putting oil in them, although in many cases, it was reported that this did not happen:

'The health inspectors usually visit those brick layers and in most times, they usually tell them that when for example they have abandoned a site, let me say a site where they have been extracting the clay, that they are advised to either empty or put some oil because when you pour oil in the that open place, then it helps mosquitoes not to breed in that area'. (KII health facility incharge)

Livelihood activities conducted at night

Participants also highlighted livelihood activities that were conducted either at dusk or during the night. The participants reported that women who traded either trading on public streets, markets or from kiosks during the early evening and into the night were significantly impacted. Aside from trading during times when mosquitoes are active, it was also noted that key sites for these informal businesses where customers were found were located along main roads near the drainage channels, which can become blocked and therefore created mosquito breeding sites, further exacerbating the situation:

'It leads to occurrence of malaria because you find that someone sits from 5 pm up to 11 pm in the night, they are not covered, they don't use mosquito repellent. Some of them are working along those drainage channels. And if you realise, most of the people who are selling in the evening, they do their work near the drainage channel because that is the space that is free, and between me and you, drainage water is there, so mosquitoes are there. They are real breeding grounds, some of those environments'. (KII Senior Development Officer)

These street activities included food vendors who also worked during the night when demand for their food was high:

'For example, if I am a night food vendor, I would want to sell all my food until it is finished, that way, whether you punish me or not, my food has to be finished. So, I cannot leave my duty station when food is not finished. I cannot even leave when I still have customers. Some of us are daily income earners, so you ask yourself; if I don't work, where will I get food for tomorrow?' (FGD female rural)

Another livelihood activity that was mentioned by participants was those working as guards in conditions where mosquito nets could not be used, as they primarily work outside all night:

'And we also have these night watchmen … they don't use the nets, you ask them, and they will say; Dr, for me, I sleep outside, I'm an askari, so also those ones, for those reasons, they are getting exposed to mosquitoes' (KII, health facility in charge).

Men unloading trucks bringing agricultural and commercial products from other countries, cities or rural areas were also highlighted as a key group that conducted these activities at night:

'For the men, yah well, if you look at the loaders for cargo, those lorries that bring in stuff from rural areas, those agricultural products, or even trade, say from Mombasa, Nairobi, those that offload are men, and you know

offloading is usually done in those hours. If you came to Wakiso say at that big hardware supermarket, there are men offloading by 8 pm in the night… in the process of offloading, they are being bitten by mosquitoes' (KII Senior development officer).

Other important occupations that are conducted during the night mentioned by participants were bar owners, bar/hotel workers, sex workers, pump attendants, fisherman and truck drivers.

'That's what I was saying that sometimes we take long to sleep because of our nature of work. Now like me, I own a bar, I sit there, and the mosquitoes bite me from there because I have to work. I work up to 1 am, they bite me until they get tired. I beat them, they go away, go on someone else, they come back to me'. (FGD mixed rural)
'Then those who are working at night, they are not protected. You can't use a net when you are fishing. So, somebody on the boat looking for a fish and these fishermen who work at night' (KII NGO).

As has been noted above, returning from the garden and herding cattle back home also occurs during times when mosquitoes are active. Overall, participants emphasised a wide range of livelihood activities that involved exposure to mosquitoes.

Gender and livelihoods

A final theme highlighted by the participants when asked about the gendered nature of malaria transmission was that some livelihood activities were predominantly engaged in by women. For example, selling goods alongside drainage channels and conducting agricultural tasks in the gardens were viewed as occupations that women predominantly did:

'Like us who wake up early in the morning to go and dig. In the mornings, there are so many mosquitoes, that bite us, on top of that fact, our gardens are in or surrounded by bushes. That puts us at high risk of getting malaria'. (IDI female urban 003)

Furthermore, owing to gendered expectations regarding childcare, women were often forced to take their children with them while they worked, thus exposing them (including under-fives) to mosquitoes at times when they were not at home in bed under a net:

'You find that somebody is working near a neighbouring drainage channel, and it is in these drainage channels where mosquitoes come and bite us. You may find a woman having a kiosk near a drainage channel that has stagnant water in place. At times, these women work with their children in these kiosks, so even the working environment contributes to malaria' (KII Religious leader).

Other gendered occupations were also linked with malaria, for example, female sex workers, who also often congregated along drainage channels:

'They are those ones who work at night for instance in Wakiso, we have prostitutes, in fact when you walk around, if God gives you a chance and you walk at night, you will find them. They are in walkways near the drainage channels and that is where mosquitoes mostly breed from'. (KII health inspector).

Discussion

The evidence presented in our study demonstrates how a wide range of livelihood activities and related practices both expose individuals to mosquitoes and contribute to providing and creating breeding sites. The findings provide a comprehensive assessment of the relationship between multiple livelihoods and malaria, and how these can sustain malaria transmission and undermine the effectiveness of standard interventions and efforts to eliminate the disease. Previous work has also acknowledged the role of agriculture, animal husbandry, brick building and night-time work (Jacobson et al., 2019; Janko et al., 2018; Loha, 2023; Msellemu et al., 2024; Paul et al., 2018; Yared et al., 2023). However, our analysis revealed many diverse livelihood activities that can increase malaria risk in one setting. Whilst our study focused on a specific study site, our findings have implications for most malaria endemic settings given that many of these livelihoods are commonly observed

across Africa. This presents a significant challenge for policy makers given how widespread these livelihood practices are in Uganda and other sub-Saharan African countries.

There are several issues raised by the study participants that require further consideration. First, our findings highlight that maize is a crop that presents significant challenges for malaria prevention. Maize is a staple food crop, with more than 50% of all households engaging in some form of cultivation to grow maize (UBOS, 2022). Furthermore, agriculture, including urban farming, has been an important sector for food production in Uganda for many years (Sabiiti et al., 2014). Maize cultivation is also central to government efforts to promote food security and thus an important pillar of rural and urban agricultural policy (Kronsted, 2024; Sabiiti et al., 2014). However, evidence has demonstrated that maize cultivation is positively correlated with malaria risk (Kebede et al., 2005; Wielgosz et al., 2014). Beyond the fact that maize is cultivated at times of the year where mosquito populations naturally increase, some studies indicate that mosquitoes are attracted to maize pollen (Wondwosen et al., 2017). Maize pollen is a key food source for mosquitoes and has a range of impacts, including increases in larvae survival rates, the size of female mosquitoes, longevity of life and likelihood of being infected with the malaria parasite (Ayele et al., 2023; Ye-Ebiyo et al., 2000). Therefore, one of the most common crops cultivated in Uganda, which many rely on as staple foods, creates environments in which mosquitoes are attracted to and thrive, often in settings where maize is grown near homes in rural areas and urban areas. This increases mosquito density around homes and contributes to increased outdoor biting and the number of mosquitoes entering houses. This creates a challenge for policy makers, as there are no straightforward ways to address this given the importance of maize for food security. One approach that has been suggested is to prevent farmers from growing maize near their dwellings, but as our participants noted, many have no choice given that they either have small plots or are cultivating in urban areas and are fully aware of the malaria-related risks of doing so. It does highlight the need to control breeding sites during times when maize plants are flowering, but this may not be enough on its own given mosquitoes can travel reasonable distances. With respect to maize plants providing breeding sites, there is some old evidence to suggest that mosquitoes do not breed in water collected in the axils (Watts & Bransby-Williams, 1978), but more research is required to confirm this.

The evidence regarding livestock production and malaria transmission is more mixed. For example, the presence of cattle may provide an alternative feeding source for mosquitoes and thus divert them away from humans (Mburu et al., 2021). However, in line with reports from our participants, keeping livestock may also attract mosquitoes and increase their density in and around households with the result that transmission is increased (Hasyim et al., 2018; Mwalugelo et al., 2024; Zeru et al., 2020). The extent to which keeping livestock diverts or attracts mosquitoes is impacted by a range of factors, including the types and volume of livestock a household owns, how far livestock are kept away from the house, differences in practices between rural and urban areas such as zero grazing, whether livestock are kept inside the household, and the feeding preferences of specific mosquito subspecies that are more prevalent in different settings (Degefa et al., 2017; Loha, 2023; Okunlola et al., 2024; Seyoum et al., 2002). More research is needed to understand the relationship between livestock production and malaria, given that this is another common livelihood activity in Uganda. This evidence is vital for informing policy makers, especially with respect to potential guidance around livestock production practices, alongside the consideration of biomedical approaches that can reduce mosquito biting by livestock (Heinrich et al., 2024). An additional concern relates to the presence of livestock urine. Whilst there is little literature related to pools of urine being viable breeding sites, evidence suggests that cattle urine can act as a supplementary source of nutrients for mosquitoes, increasing survival rates and mosquito density (Dawit et al., 2022). This emphasises the importance of good maintenance and drainage of livestock areas, especially around households, which was highlighted by our participants.

The livelihood lens also highlights the gendered nature of malaria. The primary explanations for why women are more impacted by malaria than men are usually centred on gendered inequalities in terms of access to ITNs or affordability of and access to testing and treatment services (Madindé et al., 2023). However, our findings illustrate how the gendered nature of livelihoods can expose women to mosquitoes, in settings such as alongside drainage channels or agricultural contexts where mosquitoes thrive (Woldu & Haile, 2015). Other groups of workers identified by our participants were female sex workers and women working in bars and hotels. This has potentially significant implications, given that malaria and HIV, which disproportionately impacts female sex workers (Shannon et al., 2015), are interrelated. Working as a sex

worker can increase both the likelihood of mosquito exposure and malaria transmission, and illness can be more severe among those co-infected with HIV and malaria (Figueroa-Romero et al., 2024). Furthermore, the gendered childcare responsibilities reported by our participants intersect with livelihood activities that also exposed young children to mosquitoes. The lack of childcare options for many mothers means that they are forced to take them to fields or trading centres at times of the day when mosquitoes are active. This is one explanation for ongoing malaria morbidity and mortality amongst children who are under 5 years. Therefore, malaria programming needs to address these gendered dynamics, given the disproportionate burden that women in Uganda experience (Okiring et al., 2022) and the implications that these have for ongoing transmission amongst children outside of the household.

Finally, our findings demonstrate a complex relationship between malaria and development. Improving living standards were an important factor in the elimination of malaria in Europe and North America, with reductions in malaria to some extent a by-product of development (Tusting et al., 2013). However, our findings illustrate that processes of socio-economic change can create conditions for mosquitos to thrive. Alongside the cases of maize cultivation and animal husbandry that are central pillars of food security strategies in Uganda, the increase in brick making and construction activities associated with rapid urbanisation and improving living standards impacts the malaria risk environment through the creation of numerous new breeding sites for mosquitoes. Other development projects, including irrigation and infrastructure projects such as dams have also been linked with increased malaria transmission (Kibret, 2018; Zhou et al., 2022). This illustrates the unintended consequences of development strategies and rapid change. Whilst we do not doubt that poverty reduction will bring reduced malaria transmission, we advocate the need to incorporate malaria considerations into all national and sub-national socio-economic development strategies, large scale development interventions, and environmental and land use guidance.

Our study has several strengths and limitations. Given this was a cross-sectional qualitative study, we do not provide a quantitative assessment of the relationship between different livelihood activities and malaria. We are also not able to account for differences between the biting behaviours of mosquitoes and the extent to which this mediates these relationships. Whilst our findings derive from a specific study area with unique characteristics, the livelihood activities identified by our participants are widespread in many malaria-endemic countries across the region. Therefore, our findings are of relevance for policy makers and practitioners working on malaria prevention and control in different contexts. We included a wide range of participants from different backgrounds, though over a third of them reported working in the agricultural sector and over half reported being self-employed. This may have resulted in an over-emphasis on the role of agricultural livelihoods and other informal sector activities in malaria transmission. However, these economic activities are reflective of the general employment profile in Uganda and the daily livelihood realities of the community in the study area. Our methods also elicited a wide range of responses from participants on the role of livelihoods, stimulated by the use of the Dahlgren and White conceptual map in data collection activities (Dahlgren & Whitehead, 2007), in contrast to previous research on the social determinants of malaria (Shayo et al., 2015).

Conclusion

Our findings highlight a range of livelihood activities that influence malaria transmission and risk. The precise mechanisms include increasing exposure to mosquitoes at dusk/night, creation of new mosquito breeding sites, attracting mosquitoes to housing, providing feeding sites for mosquitoes, working near mosquito breeding sites, and the role that gendered caring responsibilities play in exposing children to mosquitoes. Given how widespread many of these livelihood practices are in Uganda and the wider region, this should be a cause for concern for those aiming to eliminate malaria. The evidence we present also illustrates the unintended health consequences of development strategies intended to promote key livelihood activities, food security and poverty reduction. There are no straightforward solutions given the complexity of these relationships and the importance of these livelihoods for many households. Innovative, cross-sectoral initiatives will be needed to address the role of livelihoods and working conditions, and their impact on the local environment and breeding sites, in malaria prevention and control. This

suggests the need to ensure that considerations about malaria transmission and prevention are incorporated into all socio-economic development initiatives. We urge policy makers, practitioners, researchers and other stakeholders to engage with the social determinants of malaria. Failure to do so will hinder malaria elimination efforts in endemic settings.

Endnotes

1. The literal translation of this can be broken down as ebintu ebivirako (things that are the source of) omusujja gw'ensiri (fever caused by mosquitoes (malaria)) nga biva ku mbeera y'abantu ey'abulijjo (related to the daily living conditions that surround people (culture, context, economic situation, environment). The word ebetoloodde literally means surrounding, but it relates to the word 'mbeera'(situation) in this statement, hence pointing to context more generally when describing 'daily living conditions'.
2. The COREQ checklist is provided (see supplementary file S1).

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