Trans R Soc Trop Med Hyg 2025; **119**: 85–96
https://doi.org/10.1093/trstmh/trae084 Advance Access publication 4 November 2024

ORIGINAL ARTICLE

Household satisfaction with health services and response strategies to malaria in mountain communities of Uganda

Siya Aggrey [a,b,*], Anthony Egeru[a], John Bosco Kalule[c], Akim Tafadzwa Lukwa[d,e], Noah Mutai[f], and Sonja Hartnack[g]

[a]Department of Environmental Management, Makerere University. P. O. Box 7062 Kampala Uganda; [b]Uganda Wildlife Research and Training Institute. P. O. Box 173 Kasese Uganda; [c]College of Veterinary Medicine, Animal Resources and Biosecurity, Makerere University, P.O. Box 7062 Kampala, Uganda; [d]Health Economics Unit, School of Public Health and Family Medicine, Faculty of Health Sciences, University of Cape Town, Anzio Road, Observatory 7925, South Africa; [e]DSI-NRF Centre of Excellence in Epidemiological Modelling and Analysis (SACEMA), Stellenbosch University, Private Bag X1, Matieland, Stellenbosch 7602, South Africa; [f]Faculty of Business and Economics, Berlin School of Business and Innovation, Berlin, Germany; [g]Section of Epidemiology, Vetsuisse Faculty, University of Zurich, Winterthurerstrasse 270, 8057 Zurich, Switzerland

*Corresponding author: E-mail: siyaggrey@gmail.com

Received 27 April 2024; revised 21 May 2024; editorial decision 5 June 2024; accepted 30 September 2024

Background: Measuring satisfaction with health service delivery in fragile communities provides an opportunity to improve the resilience of health systems to threats including climate change. Additionally, understanding factors associated with the choice of response strategies to certain public health threats provides an opportunity to design context-specific interventions.

Methods: We used polytomous latent class analyses to group participants' responses and an additive Bayesian modelling network to explore satisfaction with health service delivery as well as factors associated with response strategies of households to malaria. We did this with a focus on the rural parts of Uganda in Mount Elgon.

Results: We found that approaches to malaria control and management at household level include the use of traditional (54.5%), private (20.5%) and publicly available services (25%). Regarding satisfaction with health services, 66.6% of respondents were satisfied with health service components of information flow, drug/vaccine access and accessibility. Type of housing, livelihood sources, previous malaria experience and health services were strongly associated with responses to malaria occurrence at household level. The rest of the factors were weakly associated with malaria responses.

Conclusions: The indigenous interventions utilised by households to manage and control malaria were largely dependent on their satisfaction with health service delivery components. Interventions thus ought to leverage local existing knowledge to optimise outcomes and ensure sustainable health.

Keywords: climate change, malaria, malaria treatment, mountain communities, rural communities

Introduction

Malaria continues to affect millions of people globally, with the highest morbidity and mortality in Africa.[1] It is estimated that up to 241 million cases of malaria occurred worldwide in 2020, 95% of which occurred in Africa and 96% of them died. Through the bites of infected mosquitoes, disease-causing parasites are transmitted to humans and can be life-threatening and sometimes fatal. Accelerated interventions over the past decade have significantly reduced the burden of malaria in sub-Saharan Africa.[1] However, it remains a major public health threat. Changing climate has led to an expanding belt of malaria vectors that transmit malaria to humans.[2] Notably, increased warming in high altitude areas provides ambient conditions suitable for mosquito growth and development, increasing the transmission of malaria parasites to humans.[3,4] Rainfall availability complements such occurrences by providing breeding grounds, although temperature plays a more role.[3,5] These events have been observed, for example, in high mountain areas where cases of malaria have occurred.[6] Unfortunately, the limited experience with malaria in such areas limits the robustness of responses at the household and community level.

Uganda continues to report cases from different parts of the country, despite various malaria-control measures being in place.[6-8] This is attributed to a range of factors, including climate change,[6,9] low coverage of insecticide-treated nets,[10] human movement,[11] limited information access[10] and low levels of education,[10] among others. These factors are often common in rural areas where people have limited access to social services. As a consequence, the hotspots for malaria that would be used to design interventions for its management are highly variable.[6] It is even worse in mountain communities where access to social services is limited.[12] Indeed, the hotspots for malaria in mountain communities such as Elgon have been shown to be highly variable[6] and yet the area has limited surveillance and response capacities for such diseases.[13]

Because of the limited access to modern health services, strategies to manage malaria in such hard-to-reach areas have integrated indigenous knowledge-driven interventions, including the use of local herbs, self-medication and visiting health facilities, among others.[14-16] These interventions are highly variable across different communities and cultures and their understanding is vital in designing interventions for malaria control.[17] Understanding the nature of such management practices provides important opportunities for designing relevant interventions to fully contribute to the eradication of malaria. Interventions such as malaria home management would benefit from data on existing practices related to malaria at the malaria-responsive household level.[18] Notably, it will provide opportunities for enhancing testing and the use of modern antimalarial drugs. This is important because the health systems in hard-to-reach areas are highly fragile and are threatened by climate change.[19,20] This is because of their limited resilience capacity.[21]

Understanding the causes of malaria and response strategies in a changing climate requires robust approaches to identify relationships between variables. Observational studies usually include many potentially relevant risk factors. Classical regression modelling originally evolved in an experimental setting where researchers could control all factors, but this is not possible in observational studies. Therefore, several statistical aspects lead to unbalanced groups, orthogonality or Simpson's paradox, which are not suitable for many observational studies. A possible alternative is the additive Bayesian network (ABN) modelling approach, which originated in machine learning. This approach may provide important opportunities for analysing multivariate data on malaria in changing climate and household-level response dynamics.[22]

It can be useful in analysing system level aspects regarding a disease. For instance, it has been applied in understanding child diarrhoea as a disease system in Pakistan.[23] It has also been applied in understanding antimicrobial resistance and associated factors, as well as the knowledge, attitudes and practices regarding the use of antibiotics.[24] Additionally, ABN has been applied in veterinary medicine to understand feline calicivirus infection among cats in Switzerland.[25] Regarding malaria, attempts have been made to apply ABN modelling approaches in understanding the effects of climate change on malaria, as well as the risk of malaria across different scales. For instance, Nkurunziza et al.[26] and Chirombo et al.[27] utilised a Bayesian approach to understand the effects of climate change on malaria. Similarly, Semakul et al.[28] utilised a Bayesian network modelling approach, although not in a data-driven approach, as in the current study. Despite these efforts, ABN has yet to be applied in understanding the association between malaria and different factors at household level. ABN results are presented in the form of networks, consisting of nodes, representing the variables and links, designating the conditional probabilities between the variables of interest. ABN modelling is specifically designed to deal with highly correlated and complex data. The aim of this study was to analyse the response strategies of households to malaria and also analyse their satisfaction with health services delivery, possibly impacted by sociodemographic factors. We performed this analysis using the lens of climate change in remote areas of Mount Elgon in Uganda.

Methods

Study site

This study was undertaken in Kween district in eastern Uganda, located at 01 25N, 34 31E (Figure 1).

The district is located on the northern slopes of Mount Elgon, at an average altitude of about 1900 m above sea level. Kween borders several other districts, namely, Nakapiripirit to the north, Amudat to the northeast, Bukwo to the east, Kapchorwa to the west and Bulambuli to the northwest (Figure 1). In the south, it borders the Republic of Kenya. The district headquarters are located at Binyiny, approximately 69 km by road from Mbale, one of the largest towns in eastern Uganda.

Study design and data collection

This study took a cross-sectional study design using semistructured interview questionnaires. The questionnaire was developed following the procedures described in.[29] The target population involved 200 randomly selected household heads within the subcounties of Kween district. The sample size was arrrived at using Cochran's sample size determination formula.[30] This is because the target population was finite. The subcounties of Benet, Binyiny, Kwanyiy and Ngenge were purposively selected for this study as they constitute the highest population sizes within the district. Households were selected using systematic random techniques from the subcounties. The targeted households were enrolled into the study upon confirmation of having a malaria case in the last 3 mo prior to the study. Semistructured questionnaires covered aspects of health-seeking behaviours in the event of malaria, satisfaction with health services, as well as the health system components. In total, 200 respondents were interviewed in Kween district. The questionnaire was in English, and it was tested before the actual survey. Questions were translated to Kupsabiny (the local language) during the survey. Those individuals engaged during the pretesting of the questionnaire were not included in the final study. The final questionnaire included five sections: (i) sociodemographic characteristics, (ii) perceptions on climate variability, (iii) perceptions on malaria trends, (iv) household responses to malaria and (v) health services (see Supplementary 1).

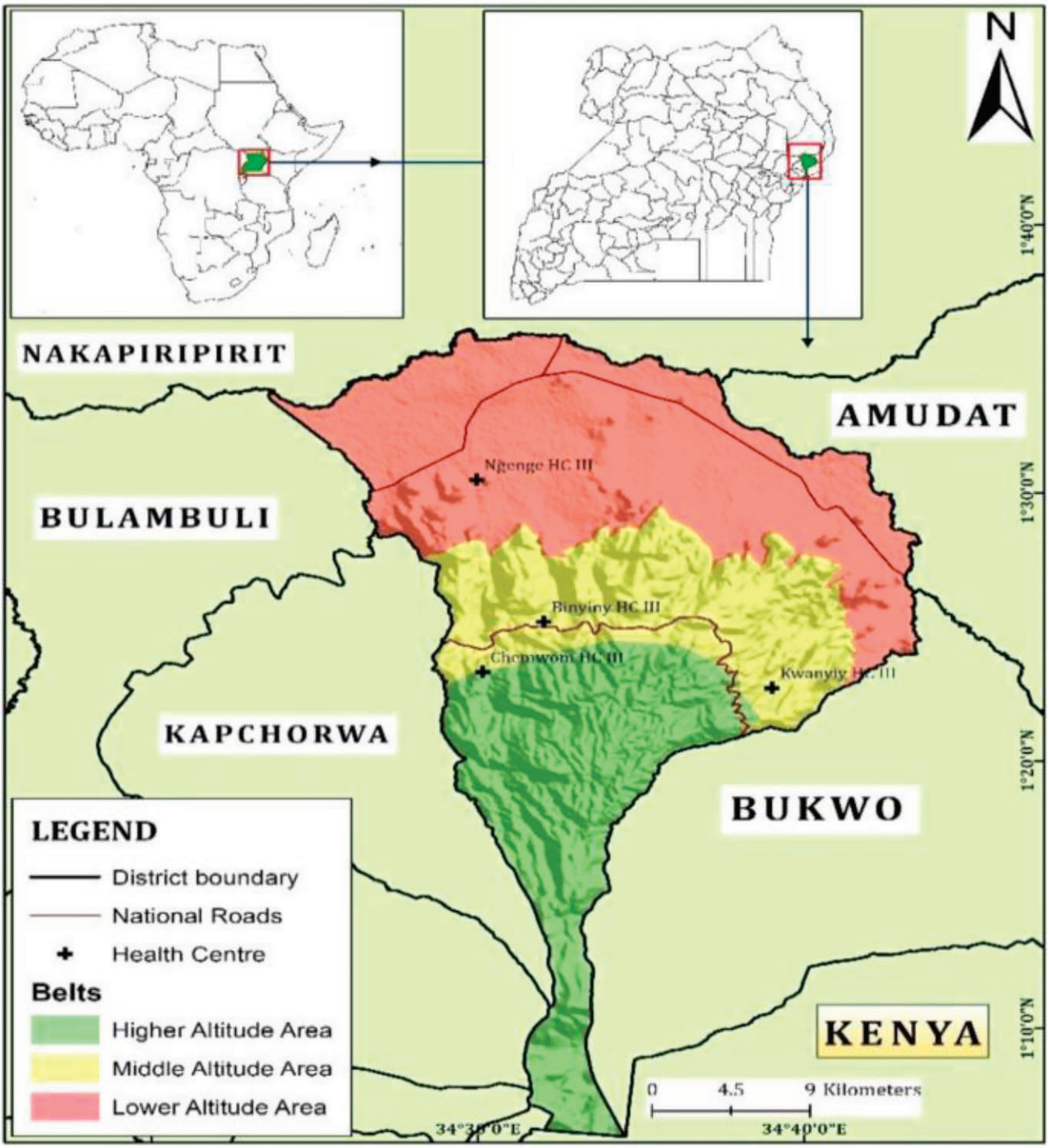

Figure 1. Location of study area (adapted from[6]).

Data analysis

Data were entered into Microsoft Excel for cleaning before analysis. Thereafter, data were imported into *R* software version 4.2.0 for analysis.[31] Descriptive statistics were computed at 95% CI for binomial with the commands BinomCI() with Jeffreys approach, for multinomial with MultinomCI() and for continuous data with MeanCI() using the R package DescTools.[32] Polytomous latent class analyses were used to group respondents based on their responses. The aim was to (a) reduce the number of variables, that is, one latent class variable instead of six questions related to satisfaction with health service delivery (class.hsv), instead

of 15 questions related to satisfaction with health information and drugs or vaccines (class.hsg), and instead of six questions related to perception of the relationship between climate change and human health (class.coping); and (b) assess graphically if all questions related to the three elements of satisfaction and perception were answered in a similar way.

Polytomous latent class analysis was undertaken using the *poLCA* package,[33] from one to five classes with 20 repetitions and 50 000 iterations. The selection of the final model (i.e. number of predicted latent classes) was based on Bayesian Information Criterion (BIC) and having at least 10% of the participants in each predicted class. To determine the relationship between 18 variables, ABN modelling using the *abn* package was applied.[22,34] The 18 variables included sociodemographic characteristics of the respondents, that is, age (Age.c), gender (Gender), household size (No.HH.members), marital category (Marital.Category), employment (Employment), income (Income.c), livelihood sources (livelihood.sources) and housing type (Type.housing). These variables also included expenditure on malaria (expenditure.malaria.c), strategies to overcome malaria (overcome), health service delivery (class.hsv), drugs and vaccines (class.hsg), coping strategies (class.coping), likelihood to recommend health services (lik.recommend), climate variability and change (variability.climate), experience with malaria (experience.malaria), causes of malaria (causes) and prevention strategies for malaria (prevention). The continuous variables age, expenditure of malaria and monthly income were normalised.

For the ABN analysis, first the optimal complexity level was determined by increasing the number of children directly connected to the parent from one to seven. Second, the model was tested for robustness and possible overfitting using a Markov chain Monte Carlo (MCMC) simulation over the structure using the R package mcmcabn[35] and evaluating the posterior distributions. For the MCMC simulation, we used a thinning factor of 10 and a burn-in phase of 100 MCMC iterations. The final Direct Acyclic Graph (DAG) was determined by removing all arcs supported by <50% of the 1000 DAGs generated. The Markov blanket of the variable of interest (i.e. in a Bayesian network, its parents, children and the other parents of all its children) is presented. To complement the analysis, principal component analysis was utilised to cluster the most important factors in the provision of health services.[36] This was done for satisfaction with health services, as well as specific components including drugs and health information.

Visualising responses to malaria across different factors

The results of the optimal DAG yielded 27 arcs, while the final DAG yielded 26 arcs. The variable of interest is highlighted in red and includes coping with malaria (Fig. 5). It was decided that this becomes the central focus as it is the overall objective of the health systems that target malaria. In green are all those variables of the Markov blanket, and in blue are the rest of the variables. Regarding the shape of the nodes, a circle represents Gaussian, a square is for binomial, a diamond for poison and an octagon is multinomial. The thickness of the arcs refers to the link strength and dashed or dotted for a positive or negative association, while solid is for multinomial. These arcs were directed across different variables.

Table 1. Sociodemographic characteristics of respondents.

Variable	1st quartile	Median	Mean	3rd quartile
Age, y	30	38	40.01	46.25
Number of household members	4	6	5.91	7
Income (UgX)	650 000	2 500 000	3 804 800	5 000 000
Expenditure on malaria (UgX)	25 000	47 500	100 633	80 000

Table 2. More information on sociodemographic characteristics of respondents.

Variable	Subcategory (n)	Estimate % (95% CI)
Gender	Males (105)	52.5 (45.6; 59.3)
	Females (95)	47.5 (40.7; 54.4)
Livelihood sources	Subsistence farming (143)	71.4 (65.3; 77.6)
	Informal job (12)	0.6 (0; 12.3)
	Business (45)	22.6 (16.6; 28.9)
Marital status	Single (30)	15 (19.6; 20.4)
	Married (170)	85 (79.6; 89.4)
Type of housing	Permanent (30)	15 (8.5; 22.1)
	Semipermanent (47)	23.5 (17; 30.6)
	Temporary (123)	61.5 (55; 68.6)
Go first to overcome malaria	Traditional (109)	54.5 (47.5; 61.8)
	Private (41)	20.5 (13.5; 27.8)
	Public (50)	25 (18; 32.3)

Results

Sociodemographic characteristics of respondents

Of the 200 respondents, the minimum age of respondents was 20 y, and the maximum age was 92 y (Table 1). The average number of household members was six, which is slightly higher than the five as per the 2014 census.[37] The maximum expenditure on malaria at household level was up to UgX 2 000 000 (US$529.96) per year (Table 1).

In terms of gender, 52.5% of respondents were males (Table 2). A majority of respondents (61.5%) were living in temporary housing, while only 15% had permanent houses. In terms of

Table 3. Satisfaction with health service delivery (*class.hsv*).

Variable	Very satisfied (N=200) % (95% CI)	Satisfied (N=200) % (95% CI)	Somewhat satisfied (N=200) % (95% CI)	Not satisfied (N=200) % (95% CI)
Q1: Information flow	19.5 (12.5; 27.1)	33.5 (26.5; 41.1)	32 (25; 39.6)	15 (8; 22.6)
Q2: Hospital staff relations	24.5 (17.5; 32.2)	34.5 (27.5; 42.3)	29.5 (22.5; 37.2)	11.5 (4.5; 19.2)
Q3: Delivery of drugs	29.5 (22.5; 37.3)	38.5 (31.5; 46.3)	25 (18; 32.8)	70 (0; 14.8)
Q4: Waiting time	45.5 (38.5; 53.1)	29.5 (22.5; 37.1)	19 (12; 26.6)	6 (0; 13.6)
Q5: Accessibility to health services	28.5 (21.5; 36.2)	36 (29; 43.7)	26 (19; 33;7)	9.5 (2.5; 17.2)
Q6: Lab-testing procedures	27 (20; 34.7)	33 (26; 40.7)	28 (21; 35.7)	12 (5; 19.7)

Manifest variables
Q1: Information flow
Q2: Hospital staff relations
Q3: Delivery of drugs
Q4: Waiting time
Q5: Accessibility to health services
Q6: Lab-testing procedures
Outcome variables
1: Very satisfied
2: Satisfied
3: Somewhat satisfied
4: Not satisfied

responses to malaria, a majority of respondents (54.5%) noted using traditional approaches to respond to malaria, while only 25% indicated using official public services (Table 2).

Satisfaction with health services within the community

Health service delivery (class.hsv)

In terms of health service delivery, respondents were generally satisfied with information flow, hospital staff relations, drug delivery, health service access and laboratory-testing procedures, as well as waiting time (Table 3 and Figure 2). A model with three latent classes was chosen to describe patterns of satisfaction index according to our latent class analysis criteria (Figure 2). Class 1 (19.6%) were somewhat satisfied with the health services (Figure 2), while Class 2 (47%) had a mix of opinions regarding their satisfaction with health services. Finally, Class 3 (33.4%) were not happy with the health services (Figure 2).

Similarly, results for the principal component analysis indicated information flow, hospital staff relations, delivery of drugs, waiting time and accessibility of health centre to be important factors in predicting the satisfaction of respondents with health service delivery (Figure F1 and Tables S1 and S2 in Supplementary 2).

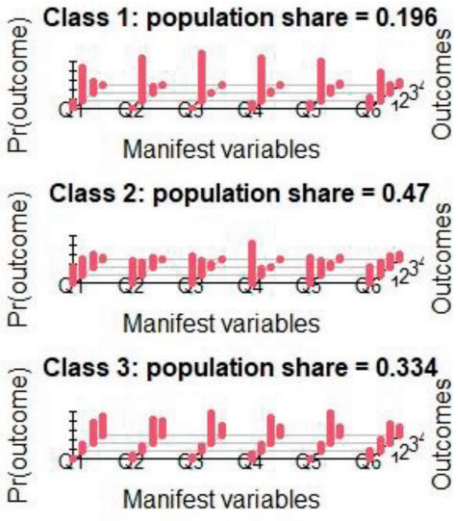

Figure 2. Satisfaction with health service delivery (*class.hsv*).

Health information

On analysing information flow, a majority of respondents somewhat trusted (44%), interpreted (38%) and understood (41%) the information. Regarding price and timeliness, respondents were very satisfied (Table 4 and Figure 3). A three-class model describing patterns of satisfaction with health information revealed Class 1 (30.2%) to be happier than Class 2 (41.8%). However, Class 3 (28%) were not satisfied with the health information (Figure 3).

From the principal component analysis, believability of the information and interpretability, understandability, as well as the price of the information, were critical in determining satisfaction with health information (Figure F1 and Tables S1 and S2 in Supplementary 2).

Table 4. Satisfaction with health information.

Variable	Very satisfied (N=200) % (95% CI)	Satisfied (N=200) % (95% CI)	Somewhat satisfied (N=200) % (95% CI)	Not satisfied (N=200) % (95% CI)
Q7: Believability/trust	11 (4; 18.5)	24.5 (17.5; 32)	44 (37; 51.5)	20.5 (13.5; 28)
Q8: Interpretability	8 (1; 15.7)	33 (26; 40.7)	38 (31; 45.7)	21 (14; 28.7)
Q9: Understandability	9.5 (2.5; 17.1)	30 (23; 37.6)	41 (34; 48.6)	19.5 (12.5; 27.1)
Q10: Price	45.5 (38.5; 52.9)	28.5 (21.5; 35.9)	16 (9; 23.4)	10 (3; 17.4)
Q11: Timeliness	53.5 (47; 61)	25 (18.5; 32.5)	13.5 (7; 21)	8 (1.5; 15.5)

Manifest variables
Q7: Believability/trust
Q8: Interpretability
Q9: Understandability
Q10: Price
Q11: Timeliness
Outcome variables
1: Very satisfied
2: Satisfied
3: Somewhat satisfied
4: Not satisfied

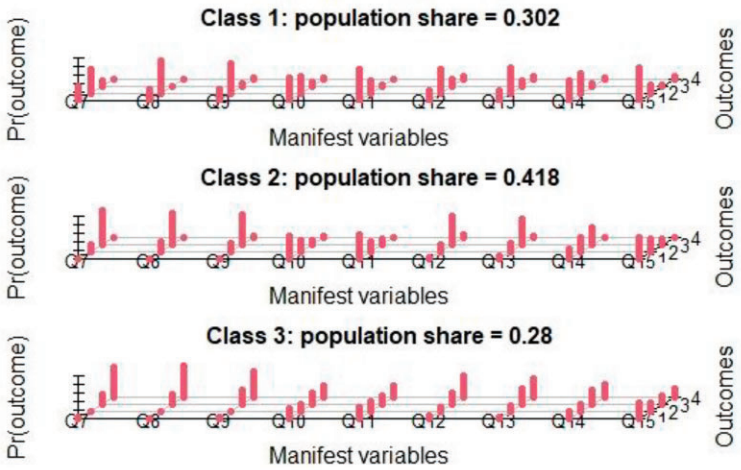

Figure 3. Satisfaction with health information.

Drugs/vaccines

Regarding drugs/vaccines, a majority of respondents were somewhat satisfied with their effectiveness (40.5%). A majority were satisfied with the accessibility of these drugs (33%). In terms of the prices of drugs/vaccines, a majority (55%) of respondents were very satisfied (Table 5).

From the principal component analysis, believability and trust were important factors that determined satisfaction regarding drugs/vaccines (Figure F1 and Tables S1 and S2 in Supplementary 2). Their accessibility and price were also important factors in determining satisfaction regarding drugs/vaccines (Figure F1 and Tables S1 and S2 in Supplementary 2).

Perception of the relationship between climate-related shocks and human health

Climate-related shocks were strongly associated with diseases like malaria (45.5%), destruction of infrastructure (44.5%) and food production shortages (40.2%). This was followed by water accessibility and strange/new diseases (Table 6). Analysis of the several ways climate change undermines human health revealed that an overall 64.8% (Class 1) of respondents agreed that climate change was affecting their health (Figure 4). Meanwhile, the other 35.2% (Class 2) did not perceive climate change as affecting their health (Figure 4). Climate change was noted to affect human health through diseases (increased incidence and

Table 5. Satisfaction with drugs/vaccines.

Variable	Very satisfied (N=200) % (95% CI)	Satisfied (N=200) % (95% CI)	Somewhat satisfied (N=200) % (95% CI)	Not satisfied (N=200) % (95% CI)
Q12: Believability	11 (4; 18.6)	27 (20; 34.6)	41.5 (34.5; 49.1)	20.5 (13.5; 28.1)
Q13: Effectiveness	12 (5; 19.6)	31 (24; 38.6)	40.5 (33.5; 48.1)	16.5 (9.5; 24.1)
Q14: Accessibility	28.5 (21.5; 36.3)	33 (26; 40.8)	29 (22; 36.8)	9.5 (2.5; 17.3)
Q15: Price	55 (48.5; 62.4)	25.5 (19; 32.9)	12.5 (6; 19.9)	7 (0.5; 14.4)

Table 6. Perception of the relationship between climate change and human health.

Variable	Very low (N=200) % (95% CI)	Low (N=200) % (95% CI)	Moderate (N=200) % (95% CI)	High (N=200) % (95% CI)	Very high (N=200) % (95% CI)
C1: Diseases	9.5 (2.5; 16.7)	5.5 (0; 12.7)	17.5 (10.5; 24.7)	2.2 (15; 29.2)	45.5 (38.5; 52.7)
C2: Strange/new diseases	24.5 (18; 32)	19 (12.5; 26.5)	15 (8.5; 22.5)	21.5 (15; 27)	20 (13.5; 27.5)
C3: Infrastructure (e.g. roads)	10 (3; 17.3)	3.5 (0; 10.8)	14.5 (7.5; 21.8)	27.5 (20.5; 34.8)	44.5 (37.5; 51.8)
C4: Food production	8 (1; 15.4)	9 (2; 16.4)	13.1 (6; 20.4)	29.6 (22.6; 37)	40.2 (33.2; 47.5)
C5: Access to water	11 (4; 18.2)	11 (4; 18.2)	21.5 (14.5; 28.7)	31.5 (24.5; 38.7)	25 (18; 32.2)
C6: Education	34 (27; 41.3)	32.5 (25.5; 39.8)	12.5 (5.5; 19.8)	12.5 (5.5; 19.8)	8.5 (1.5; 15.8)

Manifest variables
C1: Diseases
C2: Strange/new diseases
C3: Infrastructure (e.g. roads)
C4: Food production
C5: Access to water
C6: Education
Outcome variables
1: Very low
2: Low
3: Moderate
4: High
5: Very high

prevalence), occurrence of strange/new diseases, infrastructural damage, limiting food production, limited water access and undermining access to education.

Factors associated with the choice of responses to malaria occurrence within households

Type of housing, livelihood sources and previous experience with malaria were directly linked to prevention strategies implemented to manage malaria (Figure 5 and Supplementaries 3 and 4). These management strategies for malaria included formal and informal interventions. Other indirect factors included the nature of employment and household size, as well as climate variability.

The type of livelihood sources, type of housing and health services delivery were strongly related to the choice of response strategies to malaria (Figure 5). Meanwhile, previous experiences with malaria and knowledge of the causes of malaria, as well as prevention strategies, were weakly associated with response strategies to malaria. While the nature of livelihood sources was directly associated with responses to malaria, it showed a very weak relationship (Figure 5).

Discussion

Satisfaction with health services delivery

The results of the current study indicate the satisfaction of the community with health service delivery including information flow, hospital staff relations, laboratory testing and access to the health facility. This general satisfaction within communities could be because of the government's initiative to scale up health

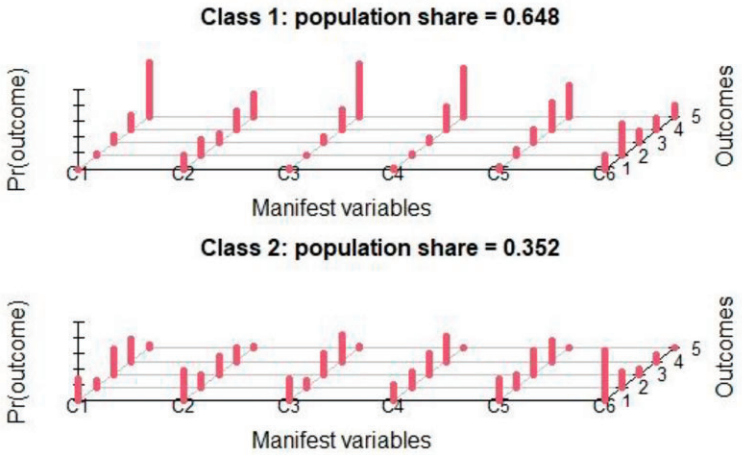

Figure 4. Perception of the relationship between climate change and human health.

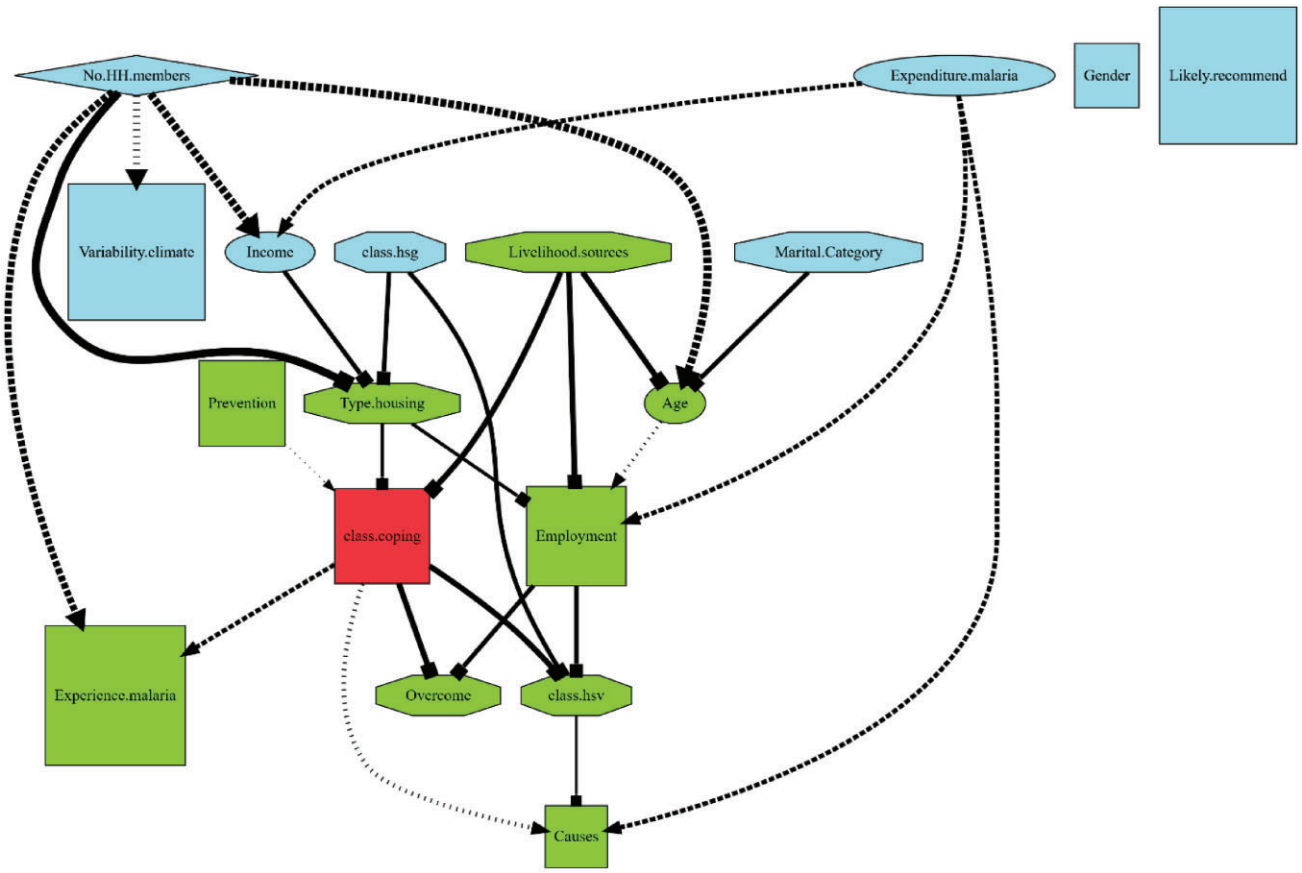

Figure 5. Coping with malaria at household level in the changing climate.

service access in recent decades.[38] This suggests that the quality of health services at the time of the interviews was good. Improved quality of health service delivery through establishment of health facilities that are equipped enhanced satisfaction by the community members. This was demonstrated in one of the studies in the western part of Uganda that indicated the increased satisfaction of community members with health services after the extension of service delivery.[39] This result is similar to that obtained from a survey across the country that targeted faith-based health facilities.[40] Although these two studies

targeted health facilities with different management structures, the factors that determine satisfaction with health services can be deduced. Notably, increased government interventions to improve health service delivery, as well as a majority of the respondents being informally employed, could have influenced people's attitudes regarding health services.

Notably, people with informal employment and low education are likely to be satisfied with improved health services.[40] This can be related to the current study as more than one-half of the respondents were informally employed. Although few studies have been undertaken to understand the level of satisfaction regarding health service delivery, satisfaction of community members has been mainly associated with high stockouts of medicines in some health facilities.[41] On the contrary, the current study indicates a majority of respondents being dissatisfied with delivery of drugs. This could be one of the major setbacks to ensuring health service delivery in health facilities within the Mount Elgon areas of Uganda. Although this result may not be generalisable to the entire region and across the years, it provides an important opportunity for ensuring overall satisfaction with health services. In a study conducted in western Uganda, access to HIV/AIDS care services was rated as low by respondents.[42] It was indicated that access to tangibles was difficult and sometimes drugs would run out in health facilities.[42] This result can be linked to the results of the current study as the study area is a hard-to-reach area with limited opportunities for ensuring sustained health systems. This has been demonstrated in other studies that indicate limited surveillance capacity, partly because of the terrain, as well as limited infrastructure and communication channels.[13]

Elsewhere, in countries like Nigeria, community members have been noted to be satisfied with health services, a result similar to that in the current study.[43] However, respondents were dissatisfied with waiting times and the cost of treatment.[43] This difference in results could be associated with population density within the catchment area of the health facility. Some health facilities in locations with high population density can experience an increased number of patients, undermining delivery of health services. This implies that interventions to ensure effective and efficient health service delivery should also take into consideration the population density of the catchment area.

Perception of climate change and diseases

Climate change was noted to result in shocks that were strongly associated with diseases like malaria. They were also noted to undermine infrastructure, including housing, roads and other communication networks. Regarding food production, climate change was noted to undermine production. These are important factors that relate to access to health services. This result is similar to those from other studies that have shown that community healthcare workers within this area perceive climate change as undermining their activities.[13] Although the target populations are different, similar results were reported in a study undertaken among Centers for Disease Control and Prevention (CDC) staff who agreed that climate change has negative consequences on health services.[44] Previous studies have indeed shown climate change to influence malaria within this region, with hotspots that are variable and that include high altitude areas.[6] This result is critical in designing strategies for controlling malaria in the changing climate. This is particularly useful in ensuring that health systems are resilient to the changing climate.

Factors associated with household responses to malaria in the changing climate

The results of the current study indicated that the type of housing, livelihood sources, previous experience with malaria within a household and health services delivery were directly linked to coping strategies implemented to prevent the occurrence of malaria. Interventions for managing malaria were both formal and informal. Type of housing has been linked to the transmission rates of malaria.[45-47] Improved housing has been demonstrated to have the potential to reduce the risk of malaria by limiting the entry of mosquito vectors. Notably, the nature of the wall and roof can influence the transmission of malaria by mosquitoes.[46] Results in some studies have indicated that mud-walled buildings and bedrooms without ceilings present more opportunities for malaria transmission.[48,49]

The primary malaria vector in Africa, *Anopheles gambiae*, typically bites indoors at night-time, so simple features such as screened windows and doors, metal roofs and closed eaves can reduce exposure to malaria infection.[50] This result could be related with that in the current study as the houses were mainly made of mud and wattle. This could have influenced the transmission of malaria by mosquitoes. Indeed, previous studies conducted in Uganda have associated house design with the risk of malaria. Houses made of mud and wattle, as well as those that are grass-thatched, present more opportunities, enabling an increased risk of malaria.[49] These types of house are often common in rural areas where most people do not have adequate capacities to establish modern housing. This result is important in advocating for pathways to ensure limited malaria transmission, especially in rural areas.

Livelihood sources determine the nature of housing, as well as health-seeking behaviours, among household members. For instance, households that have formal employment could have more opportunities to access information regarding the prevention and treatment of malaria. Meanwhile, households that rely mainly on informal labour for their livelihood are less likely to access malaria-related information.[51] This can therefore undermine response strategies to limit the impacts of malaria. This has been demonstrated in studies within Uganda that indicate limited livelihood sources to undermine efforts to access quality housing, providing opportunities for malaria transmission.[52]

Regarding sources of livelihoods, some activities pursued by household members can prompt them to stay outdoors long enough for bites to occur. This has been demonstrated in studies undertaken in Papua New Guinea.[53] In the current study area, where more than three-quarters of the respondents are dependent on subsistence farming for their livelihoods, the time spent outdoors could be longer, providing more opportunities for mosquito bites and malaria transmission. This finding is crucial when designing health promotion programmes. Notably, messages regarding exposure to mosquito bites and time spent outdoors could be integrated into health-messaging programmes.

Previous experience with malaria stimulates household interventions to prevent future occurrences. This can enhance strategies for prevention, as well as treatment of cases. This can imply stocking antimalarial medicines for use during occurrence of disease. This has been documented in western Kenya, where households were instructed to stock medicines, consequently lowering their chances of experiencing severe cases of malaria.[54] Having antimalarial medicines at home implies that the household has experienced malaria in the past.[54] This result is key, while advocating for prevention of malaria at community level through community healthcare workers and lower-level health facilities that may have the capacity to administer drugs. This would provide opportunities for the increased use of modern medicines to treat and control malaria. This is important in areas like Kween and the entire Elgon region, as results in this study have indicated the use of informal interventions to address malaria. This could have been because it is a rural area and hard to reach with low health coverage. This could have motivated people to explore interventions for the treatment of malaria.

Health service delivery influences the choice of response strategies for malaria at the household level. This is because it enhances the flow of public health messages regarding malaria. Over time, this influences the choices of interventions for addressing malaria at the household level. A study in India that analysed the effectiveness of integrated approaches (including community engagement) on reducing malaria burden indicated an increased uptake of mosquito nets by communities.[55] This result is similar to that in the current study, as health service delivery (including improved information flow) influences the choices of interventions for addressing malaria at the household level. Additionally, a synthesis of literature by Kizito and colleagues revealed that improving health services influenced community decisions of interventions to address the occurrence of malaria.[56] Similarly, in their synthesis, Peter and colleagues indicated that limited health service delivery influenced the use of traditional approaches to address occurrences of disease .[57] This result corresponds with that of the current study and highlights the importance of health service delivery when addressing malaria.

Conclusions

This is the first study in this hard-to-reach area of Mount Elgon to analysis health systems and malaria in the changing climate. We show that, whereas community members in the Kween area of Mount Elgon are generally satisfied with the current state of health services, they are dissatisfied with some of their components. Health systems thus ought to be enhanced by addressing the quality of the different components of information, drugs/medicines, governance and human resources, among others. This will enhance community resilience to climate change and related hazards in such areas. This is critical in the changing climate, which has been documented to have important implications for human health and overall health systems. Because this study was cross-sectional, data could have been limited to explicitly understand responses to malaria in the changing climate. Future studies thus ought to utilise cohort study designs, and for a longer period of time. This will generate large and more reliable datasets, enabling comparisons across different areas, thus supporting the design of strategic interventions.

Supplementary material

Supplementary material is available at *Transactions* online.

Authors' contributions: SA mobilised funds for the study, designed the study, supervised the data collection, analysis and interpretation. SA wrote the first draft of the manuscript. AE, BJK and JKBM reviewed the drafts and supported the writing process. SH and ATL participated in the data analysis and interpretation of results and assisted in the manuscript write-up. All the authors read and approved the final draft of the manuscript.

Acknowledgements: We thank Kween district local government, particularly the District Health Office, for supporting the data collection process. We also thank the respondents for participating in the study.

Funding: This study did not receive external funding. The corresponding author utilised his private resources to execute the fieldwork activities.

Competing interests: We declare that we have no competing interests.

Ethical approval: The study was approved by the Research Ethics Committee of Makerere University College of Veterinary Medicine, Animal Resources and Biosecurity (Reference number SBLS.SA.2018). The study followed guidelines and regulations stated in the approval document. Written and informed consent was also obtained from participants to participate in this study. Written and informed consent was sought from the participants to publish and disseminate the research findings. Informed consent was obtained from participants after information about the study was made available to them.

Data availability: The dataset and code underlying this study are available in the Zenodo repository at https://doi.org/10.5281/zenodo.10003015.

References

1 World Health Organization. World malaria report. WHO. Published online 2021.

2 Ryan SJ, Lippi CA, Zermoglio F. Shifting transmission risk for malaria in Africa with climate change: a framework for planning and intervention. Malar J. 2020;19:170.

3 Paaijmans KP, Blanford S, Bell AS, et al. Influence of climate on malaria transmission depends on daily temperature variation. Proc Natl Acad Sci. 2010;107:15135–9.

4 Oduma CO, Ombok M, Zhao X, et al. Altitude, not potential larval habitat availability, explains pronounced variation in Plasmodium falciparum infection prevalence in the western Kenya highlands. PLOS Glob Public Heal. 2023;3.

5 Wu X, Lu Y, Zhou S, et al. Impact of climate change on human infectious diseases: empirical evidence and human adaptation. Environ Int. 2016;86:14–23.

6 Siya A, Kalule BJ, Ssentongo B, et al. Malaria patterns across altitudinal zones of Mount Elgon following intensified control and prevention programs in Uganda. BMC Infect Dis. 2020;20.

7 Kamya MR, Arinaitwe E, Wanzira H, et al. Malaria transmission, infection, and disease at three sites with varied transmission intensity in Uganda: implications for malaria control. Am J Trop Med Hyg. 2015;92:903–12.

8 Kigozi SP, Kigozi RN, Sebuguzi CM, et al. Spatial-temporal patterns of malaria incidence in Uganda using HMIS data from 2015 to 2019. BMC Public Health. 2020;20.

9 Simple O, Mindra A, Obai G, et al. Influence of climatic factors on malaria epidemic in Gulu District, Northern Uganda: a 10-year retrospective study. Malar Res Treat. 2018;2018.

10 Wanzira H, Katamba H, Okullo AE, et al. Factors associated with malaria parasitaemia among children under 5 years in Uganda: a secondary data analysis of the 2014 Malaria Indicator Survey dataset. Malar J. 2017;16.

11 Lynch CA, Bruce J, Bhasin A, et al. Association between recent internal travel and malaria in Ugandan highland and highland fringe areas. Trop Med Int Heal. 2015;20:773–80 .

12 Chin NP, Dye TD. The health and wealth of mountain communities. Matern Child Health J. 2016;20:2413–4.

13 Siya A, Mafigiri R, Migisha R, et al. Uganda Mountain Community Health System—Perspectives and capacities towards emerging infectious disease surveillance. Int J Environ Res Public Health. 2021;18(16):8562.

14 Willcox ML, Bodeker G. Traditional herbal medicines for malaria. Br Med J. 2004;7475;329:1156–9.

15 Tabuti JRS. Herbal medicines used in the treatment of malaria in Budiope county, Uganda. J Ethnopharmacol. 2008;28:33–42.

16 Okello D, Kang Y. Exploring antimalarial herbal plants across communities in Uganda based on electronic data. Evidence-based Complement Altern Med. 2019;2019.

17 Wangdi K, Pasaribu AP, Clements ACA. Addressing hard-to-reach populations for achieving malaria elimination in the Asia Pacific Malaria Elimination Network countries. Asia and the Pacific Policy Studies. 2021;2:176–88.

18 WHO. Scaling up home-based management of malaria: from research to implementation. WHO. Published online 2004.

19 Salas RN, Jha AK. Climate change threatens the achievement of effective universal healthcare. BMJ. 2019;366.

20 Rocque RJ, Beaudoin C, Ndjaboue R, et al. Health effects of climate change: an overview of systematic reviews. BMJ Open. 2021;11:.

21 Opoku SK, Filho WL, Hubert F, et al. Climate change and health preparedness in Africa: analysing trends in six African countries. Int J Environ Res Public Health. 2021;9.

22 Lewis FI, Ward MP. Improving epidemiologic data analyses through multivariate regression modelling. Emerg Themes Epidemiol. 2013;1.

23 Lewis FI, McCormick BJJ. Revealing the complexity of health determinants in resource-poor settings. Am J Epidemiol. 2012;11:1051–9.

24 Hartnack S, Odoch T, Kratzer G, et al. Additive Bayesian networks for antimicrobial resistance and potential risk factors in non-typhoidal Salmonella isolates from layer hens in Uganda. BMC Vet Res. 2019;1.

25 Kratzer G, Lewis FI, Willi B, et al. Bayesian network modeling applied to feline calicivirus infection among cats in Switzerland. Front Vet Sci. 2020;7.

26 Nkurunziza H, Gebhardt A, Pilz J. Bayesian modelling of the effect of climate on malaria in Burundi. Malar J. 2010;9.

27 Chirombo J, Lowe R, Kazembe L. Using structured additive regression models to estimate risk factors of malaria: analysis of 2010 Malawi malaria indicator survey data. PLoS One. 2014;9.

28 Semakula HM, Song G, Achuu SP, et al. A Bayesian belief network modelling of household factors influencing the risk of malaria: a study of parasitaemia in children under five years of age in sub-Saharan Africa. Environ Model Softw. 2016;75:59–67.

29 Sharma A, Minh Duc NT, Luu Lam Thang T, et al. A consensus-based checklist for reporting of survey studies (CROSS). J Gen Intern Med. 2021;36:3179–87.

30 Cochran WG. Sampling Techniques. 2nd edn. Chicago, United States of America: John Wiley & Sons;1963.

31 R Core Team. R core team. 2022. R A Lang Environ Stat Comput R Found Stat Comput Vienna, Austria URL http//www R-project org. Published online 2021.

32 Andri S, Aho K, Alfons A, al et. "DescTools": tools for descriptive statistics. CRAN. 2022.

33 Linzer DA, Lewis JB. poLCA: an R package for polytomous variable latent class analysis. J Stat Softw. 2011;42:1–29.

34 Kratzer G, Pittavino M, Lewis FI, et al. abn: an R package for modelling multivariate data using additive Bayesian networks. R package version 2.4. https://cran.r-project.org/web/packages/abn/abn.pdf [accessed 15 December 2024]. Published online 2020.

35 Kratzer G, Furrer R. Flexible implementation of a structural MCMC sampler for DAGs. R package version 0.5. https://CRAN.R-project.org/package=mcmcabn. Published online 2022.

36 Abdi H, Williams LJ. Principal component analysis. Wiley Interdiscip Rev Comput Stat. 2010;4:433–59.

37 UBOS. National Population and housing Census. Uganda Bur Stat. Published online 2014.

38 Obare F, Okwero P, Villegas L, et al. Increased Coverage of Maternal Health Services among the Poor in Western Uganda in an Output-Based Aid Voucher Scheme; 2016.

39 Whitworth J, Pickering H, Mulwanyi F, et al. Determinants of attendance and patient satisfaction at eye clinics in south-western Uganda. Health Policy Plan. 1999;14:17'81.

40 Shumba CS, Kabali K, Miyonga J, et al. Client satisfaction in a faith-based health network: findings from a survey in Uganda. Afr Health Sci. 2017;3:942–53.

41 Tetui M, Ekirapa EK, Bua J, et al. Quality of antenatal care services in eastern Uganda: implications for interventions. Pan Afr Med J. 2012;13.

42 Kwesiga D, Kiwanuka S, Kiwanuka N, et al. The clients' voice: satisfaction with HIV/AIDS care in a public and private health facility in Kabale District, Uganda. J AIDS Clin Res. 2013;7.

43 Iliyasu Z, Abubakar IS, Abubakar S, et al. Patients' satisfaction with services obtained from Aminu Kano teaching hospital, Kano, northern Nigeria. Niger J Clin Pract. 2010;13:371–8.

44 Tong MX, Hansen A, Hanson-Easey S, et al. Perceptions of malaria control and prevention in an era of climate change: a cross-sectional survey among CDC staff in China. Malar J. 2017;16:177–81.

45 Konradsen F, Amerasinghe P, Van Der Hoek W, et al. Strong association between house characteristics and malaria vectors in Sri Lanka. Am J Trop Med Hyg. 2003;2.

46 Wanzirah H, Tusting LS, Arinaitwe E, et al. Mind the gap: house structure and the risk of malaria in Uganda. PLoS One. 2015;10.

47 Musiime AK, Krezanoski PJ, Smith DL, et al. House design and risk of malaria, acute respiratory infection and gastrointestinal illness in Uganda: a cohort study. PLOS Glob Public Heal. 2022;2.

48 Adiamah JH, Koram KA, Thomson MC, et al. Entomological risk factors for severe malaria in a peri-urban area of The Gambia. Ann Trop Med Parasitol. 1993;5:491–500.

49 Snyman K, Mwangwa F, Bigira V, et al. Poor housing construction associated with increased malaria incidence in a cohort of young Ugandan children. Am J Trop Med Hyg. 2015;6:1207–13.

50 Lindsay SW, Davies M, Alabaster G, et al. Recommendations for building out mosquito-transmitted diseases in sub-Saharan Africa: the DELIVER mnemonic: DELIVER. Philos Trans R Soc B Biol Sci. 2021;376.

51 Mayala BK, Fahey CA, Wei D, et al. Knowledge, perception and practices about malaria, climate change, livelihoods and food security among rural communities of central Tanzania. Infect Dis Poverty. 2015;376.

52 Tusting LS, Rek J, Arinaitwe E, et al. Why is malaria associated with poverty? Findings from a cohort study in rural Uganda. Infect Dis Poverty. 2016:78.

53 Rodríguez-Rodríguez D, Katusele M, Auwun A, et al. Human behavior, livelihood, and malaria transmission in two sites of Papua New Guinea. J Infect Dis. 2021;Supplement_2:S171–86.

54 Brooker S, Clarke S, Njagi JK, et al. Spatial clustering of malaria and associated risk factors during an epidemic in a highland area of western Kenya. Trop Med Int Heal. 2004;9:757–66.

55 Das A, Friedman J, Kandpal E, et al. Strengthening malaria service delivery through supportive supervision and community mobilization in an endemic Indian setting: an evaluation of nested delivery models. Malar J. 2015;482.

56 Kizito J, Kayendeke M, Nabirye C, et al. Improving access to health care for malaria in Africa: a review of literature on what attracts patients. Malar J. 2012;55.

57 James PB, Wardle J, Steel A, et al. Traditional, complementary and alternative medicine use in Sub-Saharan Africa: a systematic review. BMJ Glob Heal. 2018;3.