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Orginal Research Article

Anthropogenic Factors Influencing Malaria Transmission in Ngoma District

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ABSTRACT

Malaria continues to remain a major health problem in Ngoma district and Rwanda at large despite various measures that have been geared towards treatment and control of the disease. The present study aimed to examine anthropogenic factors influencing malaria transmission in Ngoma district. A cross-sectional survey employing questionnaires, observation, and interviews was used to collect primary data, while secondary data on the seasonality of malaria transmission were gathered from published and unpublished hospital reports and a nearby weather station. The target population included 946 community health workers, 16,521 individuals who suffered from malaria in the selected sectors, and 1 hospital person in charge of malaria. The sample size of 127 respondents was selected using the Alain Bouchard formula, and multistage, cluster, and simple random sampling techniques were deployed. The results indicated that hospital admission rates for malaria in adults were highest in 2014 at 51.0% and highest in children in 2014 at 64.6%. Hospital admission rates in adults were lowest in 2016 at 18.5% and lowest in children in 2017 at 13.2%. A positive relationship between malaria admission rates and rainfall and temperature (p = 0.001) was observed. The most common night-time outdoor activities were evening parties (Chi-squared value 184.068, p = 0.000), rated at 3.57. The primary reason for not owning LLINs was their unavailability, noted by 26.0% (p = 0.000). Irrigation for rice cultivation and slow-flowing fresh water from the extensive anastomosis of tributaries of River Kagera were identified as the most dominant malaria transmission factors (66.1%, p = 0.000). Malaria transmission was significantly associated with non-window screening (92.9%, p = 0.000). General sanitation was effective in reducing malaria transmission (55.9%). Livestock keeping had a significant impact on the increase in malaria transmission (38.6%) (Chi-square: 81.506, Std. Dev = 0.489, and p = 0.000) due to the rising mosquito density. This study validates anthropogenic factors, notably rice farming, poor housing, inappropriate bed net use, night parties, irrigation agriculture, and improper waste management, as the main factors causing malaria in Ngoma district in Rwanda.

Keywords: *anthropogenic factors, Malaria transmission and Ngoma district*

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1.Introduction

Although malaria is entirely transmitted by anophelines, only certain species are important vectors of the disease (Sinka, 2013). Several factors determine both the importance of each species as a vector of malaria (or other diseases) and the options for control (Oakley *et al.,* 2011). A good understanding of the biology and ecology of the principal vectors is essential to the development of an integrated vector control approach (Sinka *et al.*, 2012). These factors include time of biting (evening, dawn, night), flight range of the vector (usually 3 kilometers [km]), feeding preferences of adult female mosquitoes (humans or animals, Ndenga *et al.,* 2016), adult behavior particularly, preference for biting and resting indoors (endophagic, endophilic) or outdoors (exophagic, exophilic), and resistance to insecticides (Walker and Ph, 2002).

Different mosquito types exhibit varying interaction behaviors based on their feeding preferences; some mosquitoes that feed on animals other than humans may have limited interaction with humans (Protopopoff *et al.,* 2009). Human-vector interaction and mosquito density are crucial factors for malaria transmission in the African region, especially in Rwanda(Protopopoff *et al.,* 2009). Despite various efforts focused on the treatment and control of the disease, malaria remains a significant health concern in Ngoma district and Rwanda as a whole. Malaria prevalence has been reduced in a couple of years in African highlands (Afrane *et al.,* 2011). In africa and the Americas, malaria prevalence is associated with increasing deforestation, whereas in southeast Asia, deforestation reduces malaria prevalence (Guerra *et al.,* 2006).

According to retrospective studies conducted in Tubu village of Botswana in 2016, it was found that malaria prevalence was high in individuals over 5 years of age for five consecutive years, which aligns with the results observed in Ngami land district, Botswana, where malaria was more prevalent in older age groups (>5 years) (Chirebvu *et al.,* 2016). This provides significant evidence that malaria prevalence is higher in young children (<5 years) than in adults (Ndenga *et al.,* 2016).

In East African countries, mostly in Kenya, malaria prevalence was high where there was a high distribution and use of long-lasting insecticidal treated nets (LLIN). However, it was observed that malaria has reduced due to alternative blood meals (Ndenga *et al.,* 2016).

Several studies have shown that the hours residents spend indoors and outdoors at night without protection measures have been linked to residual malaria transmission in the community (Killeen *et al.,* 2006). Poorly constructed houses, such as those with open eaves and limited space, can become barriers to appropriate net use (Tusting *et al.*, 2015). Poorly maintained water supply, sanitation, and drainage systems, as well as irrigated farming, contribute to the transmission of malaria by providing potential breeding sites for mosquitoes (DFID, 2010) and (Boelee, 2003) within areas close to human dwellings (Wielgosz *et al.,* 2012b).

In Tanzania, it was found that mosquito nets were more likely to be used by women with a source of income. Their usage depended on individual characteristics, house type, and the quality of the nets themselves(Worrall *et al.*, 2002). Additionally, Reddy *et al.*, (2011) reported that even in areas where free mosquito nets were distributed, many households did not utilize them. About 30 percent of the nets remained unused in Kenya and similarly in southern Tanzania. A year after the distribution of free nets, it was observed that the nets were stored in bags (in the Kagera region) and had not been utilized by several households.

Similarly, Mboera *et al.,* (2011) reported that community members in Northern Tanzania resisted having their houses sprayed with IRS. The main reasons for rejecting IRS were the unpleasant smell of the insecticides and the fear that they might harm their domestic animals (Greenwood and Targett, 2009). It has also been noted by Kisinza *et al.,* (2008) and Kovats *et al.*, (2016) that, although LLINs have significantly reduced malaria in Sub-Saharan Africa, there have been some unforeseen consequences of net distribution. LLINs have been repurposed for building chicken pens, fencing around vegetable gardens, used as wedding veils, drying fish, and even for fishing rather than for malaria prevention.

Human behavior**,** often influenc**e**d by social and economic facto**rs,** can **i**mpactmalaria prevalence for individuals and communities. For instance, impoverishedrural populations in malaria-endemic regions may struggle toafford properhousing and mosquitonets for protection againstmosquitoes. These individua**ls** often lack the awarenessto identifymalaria symptomsand seek time**ly** and appropriate treatment. Cultural beliefs sometimes lead to theuse of ineffective traditional remedies like *umubirizi, umuravumba,* ibumba,andrakatsi in Rwanda. Travelers from non-endemic areas may opt out of using insect repellents or preventive medications for malaria due to reasons such as cost, inconvenience, or lack of knowledge. Human actions can inadvertently create breeding grounds for mosquito larvae, such as standing water in irrigation ditches or burrow pits **(**Endo and Eltahir, 2016). This study seeks to investigateanthropogenic factors that influence malaria transmission in Ngoma district.

2. Materials and Methods

2.1 Description of study area

Ngoma district is one of the seven districts in the Eastern Province. It is comprised of 14 administrative sectors: Gashanda, Jarama, Karembo, Kazo, Kibungo, Mugesera, Murama, Mutenderi, Remera, Rukira, Rukumberi, Rerenge, Sake, and Zaza. The district is further divided into 64 cells and 473 villages, known as “imidugudu,” spanning an area of 867.74 km2. As of the 2012 census, it has a population of 338,562 inhabitants, resulting in a population density of 393/km2. Ngoma district shares borders with Rwamagana to the North-West, Kayonza to the North-East, Bugesera to the West, Kirehe to the East, andMuyinga (Burundi) to the south. The district is equipped with one referral hospital, the Kibungo Hospital, along with 12 health centers and 9 health posts.

The study was cross-sectional and employed a prospective longitudinal design, incorporating both quantitative and qualitative methods.

2.2 Target population, Sample size and Sampling techniques

2.2.1 Target Population

The district has a total population of 338,562 inhabitants with an annual average of 16,521 (4.9%) malaria cases (Rwanda Biomedical Centre, 2016). The target population consisted of individuals who had experienced malaria in the previous year of the study, totaling 16,521 cases. Additionally, there were 946 community Health workers (CHWs) and 1 Malaria officer at the district hospital.

2.2.2. Sample size

Using theAlain Bouchard formula (1989, p. 30).

$$n.c = \frac{N}{1+\frac{N}{n}} \Rightarrow \frac{N}{\frac{N+n}{n}} \Rightarrow \frac{N \times n}{N+n} \ldots\ldots(1)$$

With:

n.c = The size of the sample corrected (for the final statistical universe)

N = The size of our statistical universe

n = The size of the sample for the finished Source: district report, 2023

statistical universe

By replacing N and n with their respective values, we can determine the exact value of n.c (the size of the sample).

$$\Rightarrow \frac{946x63}{946+66} = 59 \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$\Rightarrow \frac{16521x67}{16521+67} = 67 \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The sample size of the survey was 127 individuals (59 individuals for CHWs, 67 individuals for persons who suffered from malaria as the targeted group, and 1 person in charge of malaria at the district level).

Table1.Distribution of respondents by category

Category	Number of people who can be interviewed	Sample Size
CHWS	946	59
Persons Suffered by malaria	16521	67
Hospital person in Charge of malaria	1	1
Total	17468	127

2.2.3 Sampling Techniques

This study used a multistage sampling method to obtain a sample of 127 respondents (households and community health workers). The first stage used was simple random selection of three sectors out of the 14 sectors in Ngoma district from three clusters of sectors with similar characteristics.

Thesecond stage involved the simple random selection of one village in each of the three selected sectors (totaling three villages). The third stage was conducted at the household level to choose interviewees from each village. Twenty-three households (one from each family) were selected randomly, with a proportion of 1 household to 10 households at 10%.Community health workers were purposivelyselected using simple random sampling, and the malaria officer in charge was also purposivelyselected due to their expertise in malaria management.

3. Results and Discussion

3.1 Socio-demographic Characteristics of the Respondents

Table 2 highlighted personal traits such as age, gender, education, occupation, marital status, and *ubudehe* and family size.(*Ubudehe* refers to the long-standing Rwandan practice and culture of collective action and mutual support to solve problems within a community) (MINALOC, 2000).

The study identified the gender of individuals involved, revealing that 41.7% were males and 58.3% were females. This analysis indicated a dominance of females at a rate of 58.3%, with a mean of 1.58 and a standard deviation of 0.495.

Age of the respondents was a crucial aspect investigated in this study. Identifying the age group of respondents is important to ensure that they are mature enough to understand the study topic and respond accordingly.

The results from table2 indicate that the dominant age group was between 31 to 40 years old at 41.7%, followed by the range of 41-50 years at 18.9%, 51-60 years at 12.6%, and less than 20 years at 4.7%. The findings revealed that the majority of respondents interviewed in Ngoma District fell within the 31 to 40 age range (41.7%), with a mean of 3.22and a standard deviation of 1.147.

Education levels of the respondents were examined in this study. The results revealed that 6.3% had completed primary education, 73.2% had attained secondary education, 17.3% had pursued university education, and 3.1% had attended other technical schools. As shown in Table 2, the majority of participants had a background in secondary education, accounting for 73.2%, with a mean of 3.17 and a standard deviation of 0.579.

Regarding the occupation of respondents, the findings indicated that 31.5% were farmers, 9.4% were teachers, 9.4% were businessmen, 28.3% were unemployed, and 21.3% of respondents were engaged in other occupations not specified during the study. The dominant occupation among the interviewed individuals was farming (31.5%) with a mean of 2.98 and a standard deviation of 1.584

Ubudehe is the socio-economic categorization of citizens in Rwanda based on their income, where category I represents the poorer population, category II includes those who can afford at least one meal per day, category III consists of moderate income earners regardless of salary, and category IV encompasses the wealthy, including government officials. The results revealed that 0.8% of respondents fell into category I, 20.5% in category II, 74% in category III, and 4.7% in category IV. This suggests that the majority of respondents were moderate income earners, accounting for 74% of the sample.

The family size of the respondents was investigated as a crucial factor in assessing the local epidemiological factors affecting malaria transmission in Ngoma district, Rwanda. The findings revealed that 27.6% of the respondents had fewer than four family members, 51.2% had 5-9 family members, and 21.3% had 10-15 family members. It was observed that the majority of those interviewed had family sizes ranging from 5 to 9 members (51.2%)

Table 2. Presentation of socio-demographic characteristics of Ngoma District (N=127)

Gender	N	Percent	Mean	SEM	Std
Male	53	41.7			
Female	74	58.3	1.58	0.044	0.495
Age					
<=20	6	4.7			
21-30	27	21.3			
31-40	53	41.7	3.22	0.102	1.147
41-50	16	12.6			
51-60	24	18.9			
>=61	1	0.8			
Education					
Primary	8	6.3			
Secondary	93	73.2	3.17	0.051	0.579
University	22	17.3			
Others (specify)	4	3.1			
Occupation s					
Farmers	40	31.5	2.98	0.141	1.584
Teacher	12	9.4			
Businessman	12	9.4			
Unemployed	36	28.3			
Others (specify)	27	21.3			
Ubudehe categories					
Category I	1	0.8			
Category II	26	20.5			
Category III	94	74.0	2.83	0.045	0.505
Category IV	6	4.7			
Family size					
<=4	35	27.6			
5-9	65	51.2	1.94	0.062	0.699
10-15	27	21.3			

Research data 2023

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3.2 Presentation of findings

3.2.1 Malaria information at house hold level

Table 3 revealed that malaria hospital admission rates were observed at household level with a mean of 1.30 and standard deviation of 0.460 and malaria was dominant in women with a mean of 1.39 and standard deviation of 0.491 and rainy season was major dominant season for the outbreak of malaria with a mean of 1.36 and standard deviation of 0.483. With January –April as the appreciated months of high malaria with a mean of 1.79 and standard deviation of 0.793

Table 3: Malaria information at household level

Variables	N (%)	MEAN	Std Dev.
Malaria detection			
YES	89(70)	1.30	0.460
NO	38(29)		
Gender with Malaria			
FEMALE	77(60.6)	1.39	0.491
MALE	50(39.4)		
Season of malaria			
Rainy season (September to May)	81(63.8)	1.36	0.483
Dry season (June to August)	46(36.2)		
Months with malaria			
January-April	56(44.1)	1.79	0.793
May-August	42(33.1)		
September-December	29(22.8)		

Primary data, 2023

3.2.2 Malaria positivity rate by seasons in Ngoma district

The results revealed that malaria hospital admission rates in adults in Ngoma district are seasonal, with the highest peaks occurring in October through December and April to June every year, as shown in Figure 1. Additionally, Figure 2 displays themonthly malaria hospital admission rates in children under five years of age in Ngoma district from 2012 to 2017. It was observed that the highest peaks for this age group were in the months of May to June, except for the year 2014 when the peak was in October through December. Therefore, 2014 was a year of significant malaria incidence in Ngoma district.

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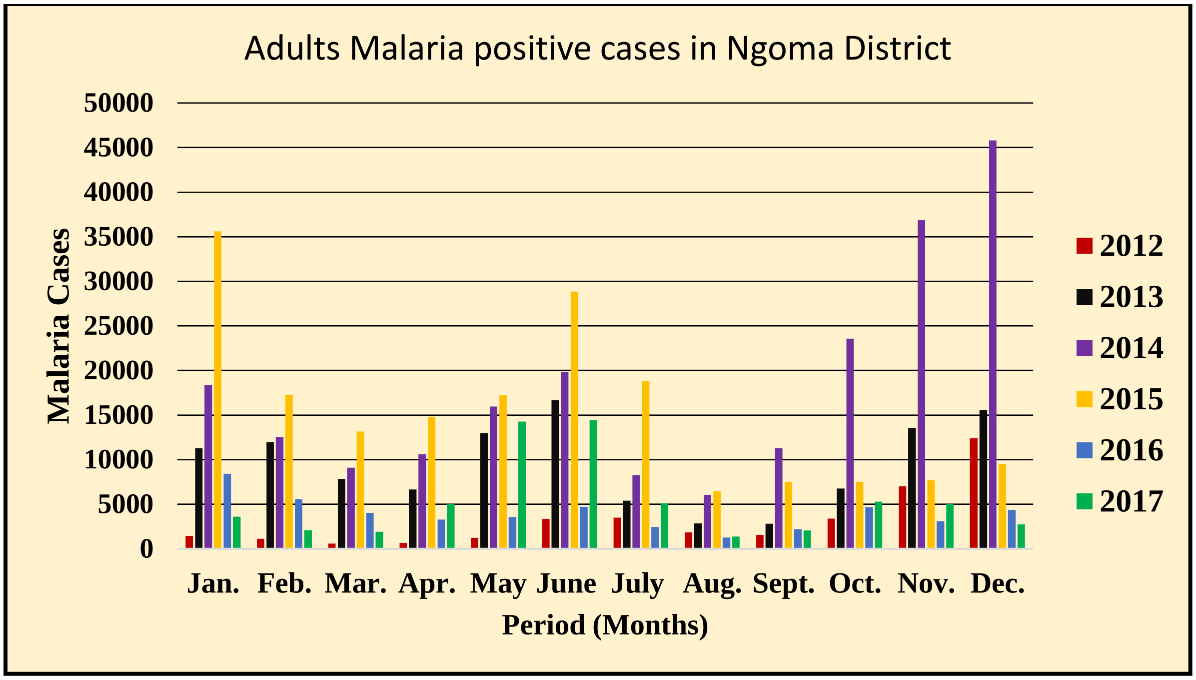

Figure 1: Monthly Malaria positive case in adults in Ngoma district from 2012 to 2017

Field data 2023

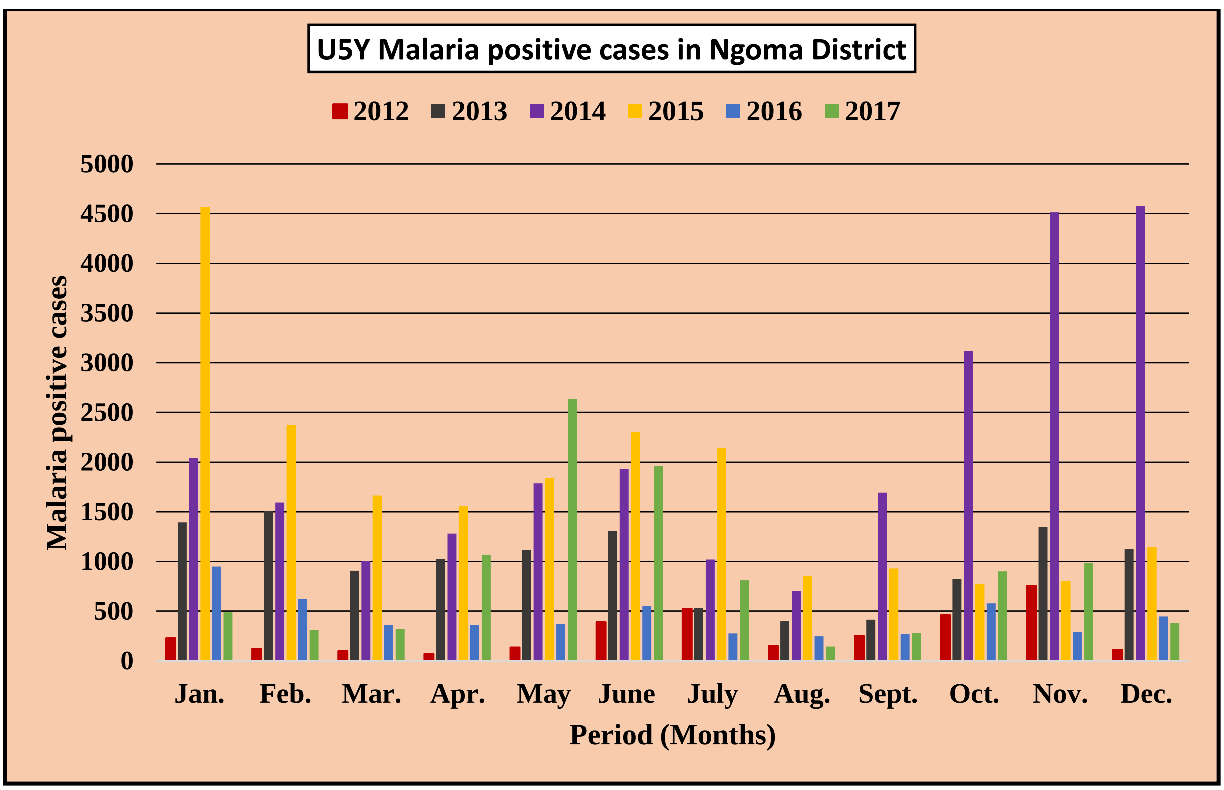

Figure 2: Monthly positive malaria cases among children under five years of age in Ngoma district from 2012 to 2017

Primary data 2023

3.2.3 Awareness of night-time outdoor activities that contribute to the risk of malaria infection

Table 4 highlights the night-time outdoor activities that contribute to the risk of malaria infection.

This analysis employed the Friedman Test and was conducted using a 10-point likertscale ranging from 1 (very important) to 10 (least important). According to this scale, the lower the mean score, the higher the importance attached by respondents to a specific night-time outdoor activity.

A non-parametric test (Friedman's Test) was utilized to rank the various night-time outdoor activities involving respondents in terms of the most common activities contributing to the risk of malaria infection. The most significant night-time outdoor activity was evening parties (Chi-squared value 184.068, p=0.000), with a ranking of 3.57.

Table 4: Human Night-time outdoor activities leading to the risk of malaria infection

Variables	Mean Rank	Std	Chi(X^2)	Df	P	(N=127)
Evening parties and out sleeping,	3.57	0.492	184.068	9	0.000	
Wedding	5.85	0.350				
Ceremony after harvesting season	5.78	0.366				
Sports watching	5.66	0.387				
Hunting,	5.46	0.416				
Guarding property	5.26	0.440				
Funerals	6.41	0.175				
Small business	6.01	0.314				
Cooking outside at night hours	4.99	0.466				
Others (Fishing)	6.01	0.314				

Friedman test

Source: Research data (2023)

3.2.4 Mosquito avoidance behaviour

3.2.4.1 The use of malaria vectors preventive measures and ownership of bed net in Ngoma District

Table 5 presents the use of preventive measures to reduce transmission of malaria in Ngoma District. This analysis was done using Friedman Test through the use of a different points Liker scale ranging from 1 very important through least important and according to this scale the lower the mean the higher the importance attached by respondents to the use of available preventive measures that affect malaria transmission. A non-parametric test (Friedman's Test) was used to rank the different parameters regarding the use of available preventive measures that affect malaria transmission. Table 3.8 shows that the most common available preventive measure was IRS (In door residue spraying) (Chi-squared value132.704, p=0.000) where it is ranked by 1.70±0.373

Table 5: Malaria vectors preventive measures

Variables	Mean Rank	Std.Dev	Chi(X2)	Df	P (N=127)
Bed net use	2.54	0.466			
Treated net use	1.76	0.449			
IRS	1.70	0.373	132.704	2	0.000

Friedman Test

Source: Research data (2023)

The following Figure 3 highlighted the frequencies of respondents reporting the use of bed nets. The results showed that 81% of respondents in Ngoma District used bed nets, while 19% did not. This contrasts with direct observations, where 72% of visited households had bed nets, albeit in varying conditions (some torn, others in good shape), and only 28% had no bed nets in any condition. Among the 72% with bed nets, some were repurposed for chicken coops and others for gardening.

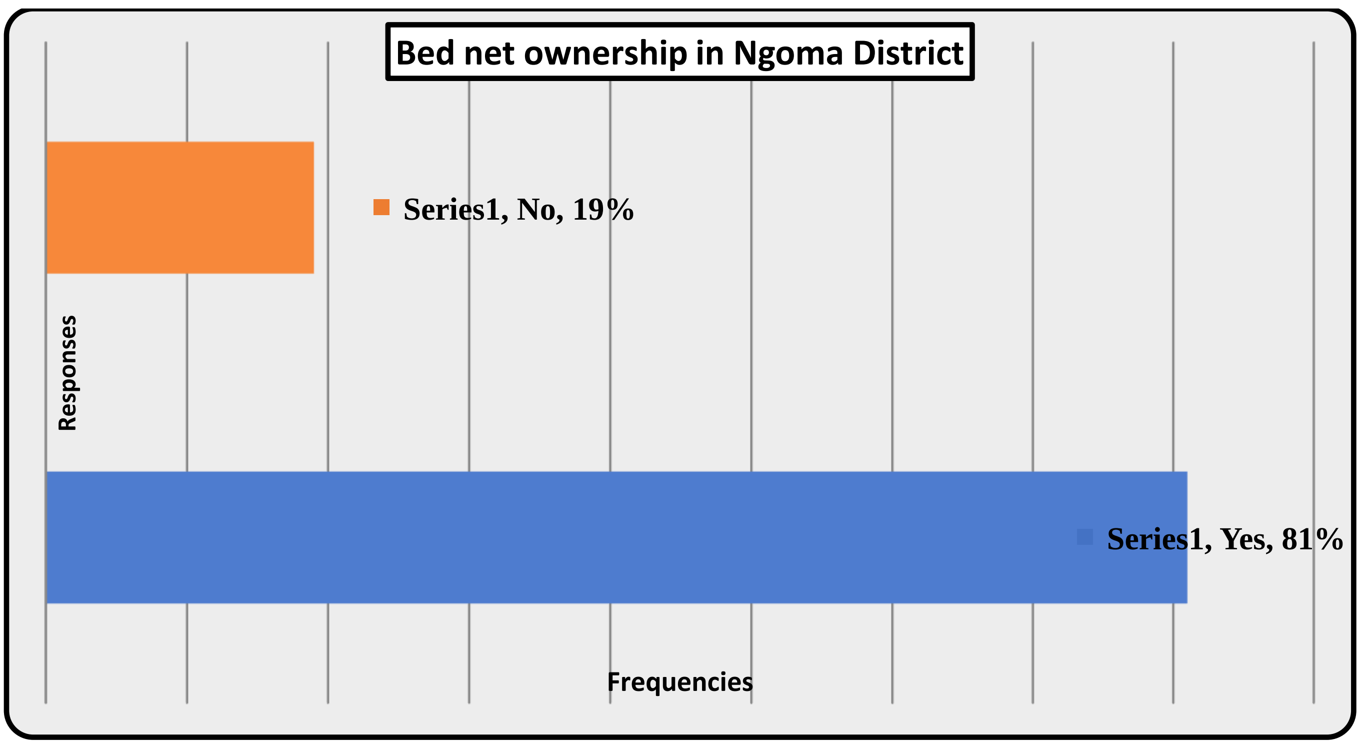

Figure 3: Bed net use in Ngoma District

According to table 6, it is evident that there is a shortage of bed nets in the study area, with only 25% of households having at least one bed net for every two individuals. Additionally, the data shows that 36% of families with more than four members have all individuals sleeping under a single mosquito net, thereby heightening the susceptibility to mosquito bites and ultimately raising the malaria risk in the region.

Table 6: Observation of Distributed bed net use in Ngoma District

Bed net	1 person (%)	2 persons (%)	3 persons (%)	4 and above persons (%)
1 Bed net	7 (6)	23 (19)	47 (39)	43 (36)
Family size	0 (0)	13 (11)	31(26)	76 (63)

Source: Observation Field data 2023

3.2.4.2. Reasons for not owning the Bed nets and LLINs

The findings from Table 7 indicated reasons for not having LLINs. Among the respondents, 26% mentioned unavailability, 14.2% cited affordability issues, 7.9% pointed to a lack of mosquitoes, and 19% mentioned alternative uses like fishing (6.3%) and unspecified reasons (16.5%). The primary reason for not owning LLINs, as highlighted in the findings, was their unavailability, noted by 26.0% of respondents in Ngoma District.

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Table 7: Reason for not owning LLIN in Ngoma district

Variables	N	%	Mean	Ch-X^2	SEM	Std	Df	P
Not available	33 (127)	26.0	3.15	22.965[a]	0.039	0.440	5	0.000
Unaffordable to buy	18(127)	14.2	3.50		0.031	0.350		
Old; then thrown away	10(127)	7.9	3.69		0.024	0.270		
Unavailability of mosquitoes	19(127)	15.0	3.48		0.32	0.358		
Used for fishing	8(127)	6.3	3.74		0.022	0.244		
Making chicken house or green garden	21(127)	16.5	3.43		0.033	0.373		

Friedman Test

Source: Primary data (2023)

3.2.4.3 Perception (attitude) of respondents about bed net use in Ngoma District

The findings presented in Table 8 indicated the reasons for not using bed nets in Ngoma District. The results regarding the reasons for not using LLINs, as shown in Table 3.6, indicate that 22% of the respondents agreed that housing types and structures affect bed net use, while 7% mentioned the absence of LLINs. Furthermore, 40.2% of respondents expressed fear of toxicity as a deterrent. Additionally, 3.1% cited unfavorable weather conditions, and 0.8% believed that bed nets do not prevent malaria. Only 1.6% of respondents provided other reasons. The primary reason for not using available LLINs, as indicated in the findings, was the fear of toxicity (40.2%), with a Chi-square value of 140.626 and p<0.001.

Table 8: Reasons for not using the available LLINs

Variables	N	%	ChX^2	Std	Df	P
Housing type and structure affects the net use	28 (127)	22		0.416		
Absence of beds	9(127)	7.1		0.258		
Afraid of its toxicity	51(127)	40.2	140.626	0.492	5	0.000
Weather not conducive	4(127)	3.1		0.175		
Nets do not prevent malaria	1(127)	0.8		0.089		
Mosquito nets are hot	2(127)	1.6		0.125		

Source: Research data (2023)

3.2.5 Livestock keeping practices influencing malaria transmission in Ngoma District

In this section the results included the types of animals kept, the number of animals kept per house, where those animals are kept (kept indoors or outdoors) and the distance of outdoors animals sheds.

The Table 9 provides an overview of livestock practices influencing malaria transmission in Ngoma District. Cows are the most commonly kept animals, representing 38.6% of the total, followed by goats at 13.4%, sheep at 4.7%, and poultry at 12.6%. These findings highlight that cows are the predominant livestock in the district, accounting for 38.6% (Chi-square: 81.506, Std.Dev.=0.489, p:0.000).Regarding the number of animals kept per household in Ngoma District, 42.5% of respondents reported having less than 2 animals, while 37.8% had between three to five animals, and 19.7% had over six animals. In terms of how animals are kept, 23.6% of respondents keep their animals outdoors, 45.7% keep them indoors, and 30.7% keep them both indoors and outdoors. The study also examined the distance of animal sheds in Ngoma District, with 48.8% of respondents indicating a distance of less than 50 meters, 35.4% reporting a distance between 50 to 100 meters, and 15.7% stating a distance of over 100 meters.

Table 9: Livestock and malaria transmission in Ngoma District

Variable	% (N)	Chi-X^2	Std Dev.	Df	P
		Type of animal kept			
Cows	38.6 (127)	81.506	0.489	3	0.000
Goats	13.4(127)		0.342		
Sheep	4.7(127)		0.213		
Chicken/Poultry	12.6(127)		0.333		
		Animal kept per house			
< 2 animals	42.5	NA	0.758	NA	NA
3-5 animals	37.8				
Over 5 animals	19.7				
		Kept indoors or outdoors			
Kept outdoor	23.6	NA	0.737	NA	NA
Kept indoor	45.7				
Both	30.7				
		Distance of outdoors animal sheds			
< 50 M	48.8	NA	0.737	NA	NA
50-100 M	35.4				
> 100 M	15.7				

NA: Not Applicable
Source: Research data (2023)

3.2.6 Demographic characteristics and malaria prevalence

3.2.6.1 Age and bed net use

The table 10 shows the relationship between the age and bed net use in Ngoma district regarding to the malaria transmission. It is noteworthy that individuals between the ages of 31 to 50 years old are more likely to use bed nets while sleeping. The research findings indicate that children are particularly vulnerable to malaria infection.

Table 10: Cross tabulation of Age and bed net use in Ngoma District

	Years of households	Bed net use		Total
		YES	NO	
Age	<=20	0	6	6
	21-30	1	26	27
	31-40	9	44	53
	41-50	9	7	16
	51-60	1	23	24
	>=61	1	0	1
Total		21	106	127

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	30.411[a]	5	0.000
Likelihood Ratio	26.814	5	0.000
Linear-by-Linear Association	3.037	1	0.081
N of Valid Cases	127		

a. 6 cells (50.0%) have expected count less than 5. The minimum expected count is .17.

3.2.6.2 Education and bed net use

The table 11 shows the relationship between the education and bed net use in Ngoma district regarding to the malaria transmission. It is noteworthy that the majority of individuals who attended secondary school did not use bed nets during nighttime. Therefore, education does not seem to have an influence on bed net usage in Ngoma district.

Table 11: Education and bed net use Cross tabulation

		bed net use		Total
		YES	NO	
Education	Primary	1	7	8
	Secondary	12	81	93
	University	7	15	22
	Others (specify)	1	3	4
Total		21	106	127

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.914[a]	3	0.178
Likelihood Ratio	4.331	3	0.228
Linear-by-Linear Association	3.242	1	0.072
N of Valid Cases	127		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .66.

3.2.6.3. Sex and bed net use

The table 12 shows the relationship between the gender and bed net use in Ngoma district regarding to the malaria transmission. It is worth noting that the majority of individuals interviewed were females who did not use bed nets during nighttime. The number of individuals using bed nets was still low, which could lead to an increase in malaria prevalence. Therefore, gender does not seem to have an influence on the use of bed nets in Ngoma district.

Table 12: Gender and bed net use Cross tabulation

Gender	Bed net use		
	Yes	No	Total
Male	10	43	53
Female	11	63	74
Total	21	106	127

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	0.359[a]	1	0.549
Likelihood Ratio	0.355	1	0.551
Linear-by-Linear Association	0.356	1	0.551
N of Valid Cases[b]	127		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.76.

3.2.6.4. Socio-economic status and bed net use

The table 13 indicated the relationship between the ubudehe category and bed net use in Ngoma district. The ubudehe category is income-based, with the first two categories showing low bed net usage.

Table 13: Cross tabulation of ubudehe Category and bed net use in Ngoma district

	Bed net use		
Ubudehe category	Yes	No	Total
Category I	1	0	1
Category II	1	25	26
Category III	19	75	94
Category IV	0	6	6
Total	21	106	127

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.191[a]	3	.017
Likelihood Ratio	10.800	3	.013
Linear-by-Linear Association	.091	1	.763
N of Valid Cases	127		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .17.

Despite the significant population in the third category in Ngoma district, the majority did not use bed nets properly at night, potentially contributing to the increased malaria prevalence. This was supported by the chi-square test, which showed statistical significance (P<0.05 at a 5% level of significance).

3.2.7 Waste disposal Management and malaria transmission

The table 14 presents the findings relating to the management of the waste disposal in Ngoma District and malaria transmission.

The findings reveal that waste is often disposed of near the living houses at a rate of 52.6%. Additionally, the waste is typically collected in sacs (63.8%), with unused basins being the most common type of waste found in Ngoma District (28.3%). Furthermore, the frequency of waste collection is reported as daily, accounting for 44.1%.

Table 14: Description of waste and malaria transmission in Ngoma District

Variables	N (%)	Ch-X2	Std Dev.	Df	P
Where the waste is deposited					
Near the living house	67 (52.6)	0.386	0.501	1	0.535
Far the living house	60 (47.2)				
Waste is collected in					
Polythene bags	23 (18.1)				
Cut jerry cans	18 (14.2)				
Sacs	81 (63.8)	107.299	0.834	3	0.000
Others	5 (3.9)				
Type of waste commonly available					
Broken glasses	32 (25.2)				
Broken pots	22 (17.3)				
Unused basins	36 (28.3)	19.024	1.253	4	0.001
Cut jerry cans	29 (22.8)				
Others (specify)	8 (6.3)				
Frequency of waste collection					
Daily	56 (44.1)	35.677	1.098	3	0.000
Weekly	38 (29.9)				
Monthly	12 (9.4)				
Never	21 (16.5)				

a. Consideration of Waste disposal as breeding site of mosquitoes

The respondents considered this as follows: strongly disagree (3.1%), disagree (11.8%), agree (14.2%), and strongly agree (70.9%)

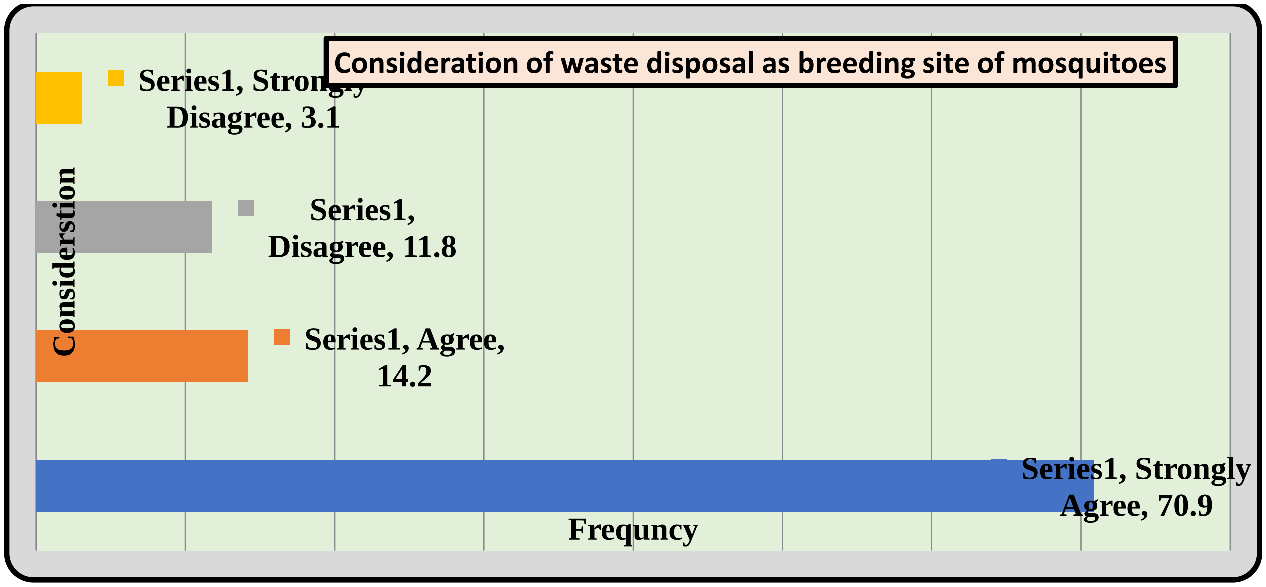

Figure 4: Consideration of waste disposal as breeding site of the mosquitoes

3.3. Discussion

Human night-time outdoor activities such as evening parties, funerals, and sports watching were identified as significant contributors to malaria transmission by the respondents. Despite the widespread use of LLINs, concerns remain about the high incidence of malaria infections, with individuals being more susceptible to mosquito bites outdoors than indoors, indicating continued outdoor transmission of malaria in the area under study. These findings align with previous research showing limited protection against malaria even with extensive LLIN and IRS coverage (Matowo *et al.*, 2013).Engaging in night-time outdoor activities in an environment where malaria vectors exhibit exophagic and exophilic behavior heightens the risk of outdoor mosquito bites and subsequent malaria transmission (Gryseels, *et al.*, 2015).

These activities are habitual, indicating a long-standing risk of exposure to outdoor mosquito bites and malaria transmission in the area, particularly because nearly 99% of the local vector population comprises*Anopheles* arabiensis, which exhibits strongexophagic and exophilic behavior. Molecular identification of *An. gambiae* s.l. in Rwanda has revealed*An. arabiensis*as the dominant species (Hakizimana, 2018). *An. arabiensis* are known to be opportunistic indoor or outdoor feeders, making them more resilient to indoor-based interventions compared to*An. gambiae s.s.* Similar nighttime activities to those observed in this study have been documented elsewhere (Harvey *et al.*, 2014; Gryseels, *et al.*, 2015).

Outdoor control interventions need to be prioritized due to the increased outdoor biting and the close proximity of households to breeding areas. Furthermore, people in the study areas rely primarily on the use of bed nets indoors to prevent malaria, leaving them unprotected before going to bed and/or when outdoors.

The results on bed net use indicated that bed nets are not widely used by people in the study area as a means of protection against malaria transmission despite the wide distribution through malaria control programs.Similar studies conducted in Equatorial guinea byReddy *et al*., (2011) reported that, even where the distribution of free mosquito net programs is expanded,many households do not use them. In Kenya, approximately 30 percent of the nets were unused. Mboera *et al*. (2011) reported that community members in Northern Tanzania resisted having their houses sprayed with IRS. The reasons for rejecting IRS were mainly the bad smell of the insecticides and the fear that the insecticides might harm their domestic animals (Greenwood & Targett, 2009).

It has also been reported byKisinza *et al.*, (2008) and Kovats *et al*., (2016) that, despite the significant decrease in malaria cases in Sub-Saharan Africa due to LLINs, some unintended consequences of net distribution have emerged. LLINs have been repurposed for building chicken pens and fences around vegetable gardens, used as wedding veils, for drying fish, and even for fishing, rather than for malaria prevention.

According to Breman (2009), important components for reducing new cases of malaria and death include more sensitive diagnostic tools, effective use of antimalarial drugs, and improved personal protection by LLINs. Consequently, Yadav *et* al.(2007) revealed that cultural and socioeconomic factors have a positive and significant effect on the risk of malaria morbidity and mortality,and that poverty rates are directly associated with socioeconomic status and people's beliefs about the causes of malaria transmission.

Rwanda achieved universal coverage of insecticide-treated mosquito nets (ITNs) in 2011 for all age groups. Since then, PMI has collaborated with the MOPDD and the Global Fund (GF) to continue the procurement and distribution of ITNs. PMI procures ITNs for routine distribution. These ITNs are distributed through antenatal clinics (ANCs), expanded program for immunization clinics (EPI), and boarding schools. In 2015, PMI procured 1,000,000 ITNs to support a rolling mass distribution campaign planned for 2016. It was expected that in 2016 over six million ITNs would be distributed as part of a planned mass campaign with Global Fund and PMI support (President's Malaria Initiative-RWANDA, 2017). However, the present study revealed that about 27% of household members never slept under an insecticide-treated mosquito net. On the other hand, almost half of the respondents (46%) never checked for holes or repaired mosquito nets, even though they slept under mosquito nets.

There are concerns that many people are still contracting malaria despite the widespread use of LLINs, and the fact that individuals are more frequently bitten outdoors than indoors suggests ongoing outdoor malaria transmissions in the study area. This aligns with previous studies where limited protection against malaria was observed even with full LLIN and IRS coverage (Matowo *et al*., 2013). The distribution of insecticide-treated bed nets has emerged as a critical malaria control strategy in endemic regions.

However, a gap exists between the availability and actual utilization of these nets. This study revealed that the majority of respondents had access to bed nets (81%), yet approximately 27% did not use them for malaria prevention. Previous research has shown that the effectiveness of bed nets may vary according to the seasons and the acceptability of nets in terms of size, color, and shape. Demographic factors such as age, education, household size, and ethnicity have been identified as influencing the utilization of bed nets (Binka *et al*., 1998). Therefore, the same considerations, including the selection of individuals within households to use bed nets, need to be taken into account, especially since the data in table 3.10 indicates that bed nets may not always be readily available.

According to the study conducted in Mali revealed that the most common reasons for not using bed nets were cost, availability, and lack of knowledge regarding the effectiveness of bed net in preventing malaria (Rhee *et al*., 2005). Contrary, a similarly study conducted in Nigeria on Insecticide-treated bed net ownership and utilization in Rivers State, showed that although 552 (68.1%) of the households owned bed nets, only 245 (30.2%, 95% CI=27.1–33.5) of them owned long-lasting insecticide nets (LLINs) and only 37.2% of those who owned ITNs slept under them at night (Tobin *et al.*, 2011).

In the case of Ngoma district, housing also influences the utilization of mosquito nets. For instance, a family with 12 members residing in a three-room house would result in four members sharing one bed net, leading to increased exposure to mosquitoes outside the bed net. This observation was made firsthand.

The results indicated that over 53.5% of the living areas were located more than three kilometers away from mosquito breeding sites. The maximum flight distance of *An. gambiae* is estimated to be between 9-12 km (Kaufmann and Briegel, 2004), placing the observed distance from breeding habitats in Ngoma district within the flight range of malaria vectors. Previous studies (*Lindsay et al., 2000;* Staedke *et al.*, 2003*)* have demonstrated a strong correlation between the risk of malaria infection and the proximity of anopheles breeding sites to human dwellings. They have also noted that the risk of malaria infection increases as residents live closer to anopheles breeding sites, attributable to the higher density of anophelesin these areas. Anopheles mosquitoes breed in diverse habitats, including manmade or natural, sunny or shaded, permanent or temporary ones Machault *et al.*, 2009 as cited by Nyirakamana *et al.*,2017). The current study revealed varying distances from breeding sites to homesteads, with some households located near breeding sites and others situated farther away. The impact of rice farming on mosquito density and human-vector interactions, thereby influencing malaria outbreaks, is influenced by the proximity to breeding sites. Previous research has shown a positive relationshipbetween malaria transmission and rice farming (Chang, 2007).

4.Conclusion

According to the current study, the distance from breeding sites to homesteads varies, intensifying mosquito populations and increasing human-vector interactions, leading to malaria outbreaks. It has been observed that anthropogenic factors such as poor housing conditions, improper waste management, outdoor activities, and clothing habits influence malaria transmission in Ngoma district. Therefore, this study confirms anthropogenic factors, notably rice farming, poor housing, inappropriate bed net use, evening parties, irrigation agriculture, and improper waste management, as the main contributors to malaria transmission in Ngoma district, Rwanda.It is important to consider extending thescope and accuracy of malaria reports beyond healthcare coverage limitations, recognizing the impact of anthropogenic factors.

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