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Socioeconomic and environmental predictors of lassa fever transmission in Lower Bambara Chiefdom, Kenema District, Eastern Sierra Leone

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Abstract

Background Lassa fever (LF), is a viral hemorrhagic illness endemic to West Africa and poses significant public health challenges. This study explores and identifies socioeconomic, and environmental markers contributing to transmission of LF in Lower Bambara Chiefdom, Kenema District, Eastern Sierra Leone.

Methods A descriptive cross-sectional quantitative survey was used, and through stratified sampling and a systematic data collection approach, we selected 26 enumeration areas (EAs) generating 2,167 households. A structured questionnaire was administered to capture respondents' demographics, community characteristics, and LF-related risk factors. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS). These included descriptive statistics to summarize the data, Chi-square tests to assess associations between categorical variables, and bivariate analyses specifically cross-tabulations and Chi-square tests to identify potential risk factors and correlations between sociodemographic/environmental variables and LF transmission.

Results Less-bushy surroundings (53.9% to 73.5%); common mixed farming practice (61.5%); standpipes water source (40.5%) and waste burning practice (77.3%) are the most dominant environmental markers. Socioeconomic markers: farming (53.9%); construction materials included mud walls (72.0%) and zinc roofing (90.0%). Logging activities (36.9%) were conducted close to residential areas, with an average distance of just 14.7 m. Demographic variables sex, age, education, occupation, and relationship to the household head were statistically significant to LF transmission ($p < 0.05$). Environmental and socioeconomic markers such as farming practices, construction materials, palm-fruit storage, slashing and burning activities were significant ($p < 0.05$) LF transmission markers.

Conclusion In conclusion, demographic factors and poor environmental and socioeconomic practices like inadequate waste disposal, close proximity to logging sites and unsafe farming practices were significantly associated with LF transmission. These findings highlight areas that community education and environmental sanitation should be prioritised by public health policymakers and community-based prevention programs.

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Keywords Lassa fever, Transmission, Socioeconomic markers, Environmental markers, Lower Bambara chiefdom

Introduction

Lassa fever (LF), a severe viral haemorrhagic infection that causes a significant public health concern, particularly in Sub-Saharan Africa. It was first discovered in the 1950 s in West Africa and identified as a virus in 1969 [1] and has been classified by the World Health Organization (WHO) as a neglected tropical infection [2]. The disease is closely linked to the Mastomys rodent, which carries and transmits the Lassa virus (LASV) [3, 4]. The virus is spread to humans through contact with their urine or faeces or contact with the bodily fluids of infected individuals [5]. LF can result in fever, bleeding, organ problems, and even death [6, 7]. LF outbreaks are frequent in West Africa and have resulted in significant illness and mortality [8, 9]. LF affects around 300,000 to 500,00 people worldwide annually, leading to illness and approximately 5,000 mortalities (Case fatality rate (CFR) = 15%–25%) [10, 11]. The disease burden has devastating effects in Nigeria, Liberia, Guinea, and Sierra Leone [8, 12] and poses a considerable risk to every population. For instance, in Sierra Leone, particularly in the Tongo Field and Panguma areas of Kenema District, LF has caused numerous deaths and cases [13, 14]. Most LF cases are concentrated in the eastern and southern parts of the country, with fewer cases in the north. According to Kassim Kamara et al., 2023 from 2012 to 2018 review identified LF cases in four districts: Kambia, Kono, Kenema, and Panguma [15]. Furthermore, a serosurveillance study showed a high prevalence of LF in Kenema (20.1%) compared to Port Loko (14.1%) and Tonkolili (10.6%) [16]. Notably, Lower Bambara Chiefdom in Kenema District has the highest rate of LF in the country [17]. Despite the concentration of LF in specific regions, outbreaks continue to emerge in both endemic and non-endemic zones, suggesting ongoing transmission risks [17, 18], and this persistence indicates gaps in understanding localized transmission dynamics, presenting ongoing challenges for disease control [19, 20].

Moreover, LF remains prevalent due to environmental and social factors that facilitate its spread, leading to severe impact in the region [20, 21]. The disease's spread in endemic areas is influenced by various factors such as society, economy, culture, and the environment, extending beyond the typical interaction between the vector (rat) and the host (human) [20, 22]. A Sierra Leone study showed that environmental markers such as poor housing infrastructure, proximity to bushlands, forest areas and refuse contribute to high LF incidence [16]. Additionally, improper waste disposal can increase the rodent population, and dense vegetation around homes provides hiding places for rodents [20]. Housing construction and materials used can impact the likelihood of rodent infestations [23] and access to safe water sources is crucial, as consumption of contaminated water directly contributes to the virus's spread [20, 24]. These persistent outbreaks suggest the need for a deeper understanding of the community factors influencing the spread and impact of LF. More so, incorrect actions like improper waste disposal and inadequate environmental cleanliness, as well as the consumption of diseased rats, are other contributing causes [25, 26]. Due to the prevalence of risk factors in rural areas, such as poverty and cultural practices like hunting, processing, and consuming rodents as a source of protein and drying food by the side of the road, it has been reported that the burden of LF is more prevalent in these areas [27, 28] depicting Lower Bambara chiefdom in Kenema district, Eastern Sierra Leone.

Regardless the enormous studies done on LASV spread and transmission [27, 28], its prevention efforts have been partly challenged by limited community awareness and effective control methods as socioeconomic and environmental predictors continue to sustain the disease endemicity and transmission. While prior studies have broadly identified socioeconomic and environmental determinants of LF, our study provides a context-specific, community-level analysis using stratified EA-based sampling within the most endemic chiefdom in Sierra Leone. Furthermore, unlike past studies that relied on hospital data or secondary reports [29, 30], our work directly assesses proximity-based environmental risks, their specific interaction and intensity, localized waste and water practices, and granular farming activities elements within Lower Bambara remain underexplored in LF literature. The findings of this study will be beneficial for legislators, public health professionals, and community stakeholders when designing prevention initiatives. Additionally, the study highlights the need for stronger health promotion and community engagement to encourage behavioral changes that can mitigate the spread of the LASV. An evidence-based approach will enhance public health planning and preparedness in Sierra Leone and other endemic regions.

This study explores and identifies the socioeconomic and environmental factors that contribute to the spread of LF in the Lower Bambara Chiefdom which is crucial to understanding the risk factors for developing targeted interventions for high-risk groups. Although the study does not involve direct interventions, its findings provide a granular, localized data specific to Lower Bambara offering a unique lens into the interplay between socioeconomics, land use which is an environmental factor,

and risk of exposure to LF vectors which is not well documented in Sierra Leone's endemic hotspots.

Methods

Study setting

The study was conducted in Lower Bambara chiefdom of Kenema district in the eastern part of Sierra Leone. The study targeted communities in all six administrative sections known as the Lassa Belt [31]. Tongo and Panguma are the major towns both of which hosted the majority of the chiefdom population of 76,281 according to Statistics Sierra Leone census report 2021 [32]. These towns constitute the most Lassa-prone communities with the majority of all reported Lassa morbidity and mortality in Sierra Leone since it was discovered in the country in 1957 [33]. The chiefdom is inhabited by diverse ethnic groups and religious beliefs with the Mende ethnic group and Muslims predominating the area respectively. Mining and farming are two of the most important economic activities providing livelihoods for locals in the study area. The relief of the study area is mountainous and moderately vegetative. The chiefdom houses a LF referral hospital and multiple community health centers which helps to provide health delivery for the residents [31].

Study design

This study employed a descriptive cross-sectional quantitative design to explore and identify the relationship between socioeconomic and environmental factors and the transmission of LF in Lower Bambara Chiefdom. Given the persistent LF burden in this region and the need to understand community-level drivers of transmission, this design was appropriate for capturing a snapshot of population characteristics, behaviors, and environmental exposures at a specific point in time. It allowed for the identification of statistically significant associations between known risk factors such as housing conditions, waste disposal methods, and livelihood practices and LF transmission. While the design does not establish causality, it provides a foundational basis for future longitudinal or intervention-based research aimed at informing targeted LF prevention and control strategies in endemic areas like Lower Bambara [34–36].

Study subjects, sample size calculation and technique

The study included respondents aged 18 years and older encompassing adult males and females who hold significant roles within their households, either as heads or as members with substantial knowledge of the household in the Lower Bambara Chiefdom. The study did not directly assess whether the surveyed households had confirmed LF cases within the past five years. However, households were sampled within high-incidence administrative sections of the chiefdom based on historical surveillance data and proximity to known LF hotspots, such as Panguma and Tongo Field.

Also, respondents were selected based on their residence in the household for at least one year and their involvement in key household decisions or knowledge of living conditions. This approach was crucial for gathering in-depth insights into the living conditions and preferences that prevail within these households [31].

To calculate the minimum sample size, the study incorporated all 112 EAs - defined as a geographically demarcated unit containing 80–100 households, as per Statistics Sierra Leone standards [37] as the initial pool for selection and was used to guide the sampling strategy and ensure that the selected EAs adequately represented the demographic and socioeconomic diversity of Lower Bambara Chiefdom [38]. The 112 EAs were established as the maximum sample size. The Relief Sample Size Calculator determined the minimum required sample size. This tool uses standard statistical formulas to calculate the sample size based on the desired confidence level, population size, and precision [39]. For this study, a confidence level of 95% (Z=1.96) and a precision level of 5% (d = 0.05) were applied to the finite population of 112 EAs in Lower Bambara Chiefdom.

$$n = \frac{Z^2 \cdot p \cdot (1-p)}{d^2}$$

Where:

n: Required sample size

Z: Z-score corresponding to the confidence level (e.g., 1.96 for 95% confidence)

p: Estimated prevalence or proportion of the outcome of interest.

d: Desired precision or margin of error

A conservative prevalence estimated of p = 0.5 was used to maximize variability and ensure statistical precision in the absence of prior prevalence data for LF in the study area. Given a maximum of 112 EAs, the sample size was adjusted using the finite population correction formula, resulting in a minimum required sample size of 26 EAs. The sampling approach was designed to ensure proportional representation and statistical precision across the study area. A stratified and systematic sampling approach was used to select the 26 EAs. EAs were stratified based on geographic location, and systematic sampling was applied to select every nth EA within each stratum. The number of EAs chosen from each stratum was proportional to the entire number of EAs in that stratum, guaranteeing that larger strata had better representation in the final sample.

Number of EA by Stratum

Stratum A: 20 EAs

Stratum B: 18 EAs
Stratum C: 22 EAs
Stratum D: 16 EAs
Stratum E: 18 EAs
Stratum F: 18 EAs

To select an EA within each stratum, systematic sampling was used to choose 26 EAs. This process involved randomly listing the EAs and selecting every nth EA, based on a calculated interval. For instance, if within a stratum with 20 EAs, 5 needed to be chosen, the sampling interval would be 4 (20/5). Combining stratification and systematic selection of EAs helped minimise bias and maintain population diversity.

Calculation:

$$\text{Stratum A} : (20/112) \times 26 \approx 5 \text{ EAs}$$

$$\text{Stratum B} : (18/112) \times 26 \approx 4 \text{ EAs}$$

$$\text{Stratum C} : (22/112) \times 26 \approx 5 \text{ EAs}$$

$$\text{Stratum D} : (16/112) \times 26 \approx 4 \text{ EAs}$$

$$\text{Stratum E} : (18/112) \times 26 \approx 4 \text{ EAs}$$

$$\text{Stratum F} : (18/112) \times 26 \approx 4 \text{ EAs}$$

After selecting the EAs, we obtained boundary maps from the Statistics Sierra Leone office in Freetown to guide the data collection process. This ensured that all perspectives within the chosen EAs were represented, providing a detailed understanding of the community's household dynamics. In total, the survey gathered 2,167 responses.

Data collection and processing

The data collection tool used was a structured questionnaire that included community characteristics related to LF viral infection at sectional levels within the sampled EAs. The questionnaire was developed based on a review of relevant literature and discussions among a team of four public health professionals who also served as co-authors [40–44]. The questionnaire was designed as an xls file and deployed on the Ona server. The forms were then accessed on Android phones to administer the survey. The questionnaire comprises respondents' sociodemographics (which includes individual-level traits and household details such as the number of individuals per household and room), and environmental and socioeconomic markers. The demographics included: age, sex, marital status, occupation, and relationship to the head of the family.

Environmental markers included: the presence of grass, bushy areas, farming practices, source of drinking water, waste disposal, and materials used in household construction. Farming activities included mixed farming (both crops and livestock), shifting cultivation, and slashing-and-burning as common practices.

Socioeconomic markers included: palm-wine consumption, logging activity, and reasons for logging, logging proximity to dwelling, livelihood activities, etc. Logging activities and livelihood activities, including firewood collection, charcoal production, and timber processing, were also assessed, as these practices influence rodent migration and habitat disruption near homes [45]. The questionnaire consisted of 31 questions and took approximately 25–30 minutes to complete per respondent.

A researcher-developed structured observation checklist was used to record environmental factors, such as grass height and density, proximity to logging sites, and waste disposal practices. This helped ensure consistency across observations. For instance; observations of grass height, ground coverage and density were standardized using predefined benchmarks to minimize subjectivity. Bush presence was recorded via manual and direct observation using pre-set criteria: grass >1m, >75% ground cover, and proximity <5m to dwellings. Enumerators received training to ensure consistent interpretation and application of these criteria during data collection. Well-maintained grass around homes was categorized as 'non-bushy,' while moderately maintained grass was classified as 'less bushy.' Logging proximity to homes was recorded to assess its potential impact on rodent habitats [46]. Also, street vendors selling fruits and vegetables, market stall operators offering clothing and household items, and individuals going door-to-door selling snacks or handmade crafts were regarded as petty traders. Multiple responses were used for questions related to construction materials, waste disposal methods, and water sources.

The validity of the data collection tool was assessed through a pretest conducted in the Kowama community of Bo City, 45 miles away from Kenema district but shares similar characteristics with the study area. Feedback gathered from this pretest was instrumental in refining the tool to ensure its reliability, consistency, and clarity. The pretest was conducted for one week by 16 enumerators who underwent a week of in-class training. During this training, they learned how to accurately translate the questions and interpret the EA maps required for data collection. The enumerators were organized into four teams, each comprising four individuals. Enumerators verbally administered the structured questionnaire, a pre-arranged android-based questionnaire using Ona collect, an improved version of the software to household heads or representatives who met the inclusion criteria

capturing participant responses in a time-efficient manner Throughout the pretesting phase, the enumerators provided daily feedback, which researchers reviewed to further enhance the tool's clarity and validity. Actual data collection commenced one month after all necessary corrections and adjustments were implemented. The data collection process took place over two weeks, from February 1st to February 14th, 2023. It involved enumerating all structures or houses and households within the demarcated EA. Each enumerator collected approximately 20–25 responses per day, guided by EA mapping and local guides. To achieve a 100% response rate, we enhanced strong collaboration with local chiefs and then use of trained local enumerators fluent in Mende and Krio. In the context of this study, a household was defined as a group of individuals who habitually share meals and resources, typically cooking from the same pot. This approach distinguishes between multiple households that may reside within a single dwelling.

Data analysis

The data were double-entered into SPSS version 26.0 for cleaning, verification, and analysis. Discrepancies were reconciled using original data sources. Descriptive statistics such as counts, proportions, and percentages were presented as tables and charts to summarize key demographic, environmental, and socioeconomic characteristics of the respondents.

To examine associations between dependent and independent variables, bivariate analyses such as cross-tabulation and chi-squire tests were conducted. The dependent variable, LF transmission, was operationalized based on key environmental and socioeconomic markers within the six administrative sections of the study area. Environmental factors included vegetation, waste disposal and management and water sources, while socioeconomic factors encompassed construction materials type, occupations, livelihood practices, logging proximity and consumption habits like palm wine intake. Independent variables included demographics (e.g., age, gender, education level, occupation), environmental and socioeconomic markers.

The Chi-square test was used for categorical data to determine statistically significant associations between LF transmission or spread and potential predictors. This test was appropriate for identifying relationships between categorical variables, such as the presence of bushy surroundings and LF risk, or waste disposal practices and rodent infestation risks.

The level of statistical significance was set at $p < 0.05$ for all tests, ensuring robust inferential insights [47].

Ethical approval

Ethical clearance and approval for this study were obtained from the Njala University Institutional Review Board (NU-IRB) (*See attached ethical approval letter*), which is the official ethics committee of the Njala University, Sierra Leone. The study was conducted in full compliance with the ethical principles outlined in the Declaration of Helsinki for research involving human participants.

Before data collection, the purpose and procedures of the study were explained in the local languages (Mende and Krio) to all selected respondents. Written informed consent was obtained from all participants who were literate, while for participants who could not read or write, the consent form was read aloud to them in their preferred language. Thumbprints were then taken in the presence of an impartial witness, and the witness provided a signature confirming that informed consent had been freely given. Where applicable, legal guardians or appropriate household representatives provided consent on behalf of participants who were not capable of providing informed consent themselves.

All participants were assured that their participation was voluntary and that they could withdraw at any time without penalty. Confidentiality and anonymity were maintained by using unique participant codes instead of names or any other personal identifiers in the dataset and analysis.

Results

There were 2,167 households and 1,200 houses, translating to a 100% response rate. This exceptionally high participation reflects the strong community engagement and the effectiveness of the data collection strategy, ensuring that the findings are highly representative of the target population in Lower Bambara Chiefdom.

Sociodemographic characteristics of study respondents

Table 1 presents the sociodemographic distribution of the study group. Among the 2,167 respondents, 54.6% (1,184/2,167) were male. Age was categorized into equal intervals for analysis as follows: 18–25 years, 26–33 years, 34–41 years, 42–49 years, and over 49 years. The mean age was 39.8 years, with a standard deviation (SD) of 10.0 years, at a 95% confidence level. The highest proportion of respondents fell within the age range of 34–41 years (27.0%, 588/2,167), followed by those aged 42–49 years (22.0%, 476/2,167), and those aged 26–33 years (21.6%, 468/2,167). Notably, 61.7% (1336/2,167) of respondents had never attended school. Additionally, 12.0% (277/2,167) had completed primary education, 11.0% (254/2,167) had completed junior secondary, and 9.0% (215/2,167) had completed senior secondary education. A significant number of respondents were farmers

Table 1 Sociodemographic characteristics of study participants

Variable	Category	Frequency (n)	Percentage (%)	Chi. Square test
Sex	Female	983	45.40	0.0001*
	Male	1184	54.60	
Age	18–25	202	9.30	0.006*
	26–33	468	21.60	
	34–41	588	27.10	
	42–49	476	22.00	
	>49	433	20.00	
Educational Level	Never Attended School	1336	61.70	0.0001*
	Illiterate	55	2.50	
	Primary	277	12.80	
	Junior Secondary	254	11.70	
	Senior Secondary	215	9.90	
	Tertiary	24	1.10	
	Non-Formal	6	0.30	
Occupational Status	Civil servant	6	0.30	0.0001*
	Farmer	1406	64.90	
	Health worker	8	0.40	
	Miner	133	6.10	
	Okada rider	31	1.60	
	Trader	406	18.20	
	Teacher	59	2.70	
	Timber Logger	5	0.20	
	Student	89	4.10	
	Others	30	1.40	
Marital Status	Cohabiting	49	2.30	0.08
	Divorced	10	0,50	
	Married (Monogamous)	1428	65.90	
	Married (Polygamous)	383	17.70	
	Separated	32	1.59	
	Single/never married	131	6.00	
	Widow/Widower	134	6.20%	
Relationship to Head of Household	Head	1428	65.90	0.0001*
	Parent	107	4.90	
	Sibling	33	1.50	
	Son/daughter	73	3.40	
	Spouse	507	23.40	
	Uncle/Aunt	4	0.20	
	Other	15	0.70	

N = 2167; * = significant association

(64.9%, 1406/2,167)). The majority of respondents were married, with both monogamous and polygamous unions combined accounting for 83.6% (1811/2,167) of the group. Furthermore, many of the respondents served as heads of their households (65.9%, 1428/2,167)). Chi-square tests revealed that sex, age, occupation, education, and household relationship were significantly associated with LF spread at $p < 0.05$, while marital status showed no significant association [31].

Household composition

Table 2 presents household composition calculated in means. The mean number of household members for all age categories per household in the Lower Bambara Chiefdom was 5.7 (SD = ±2.8). The minimum and maximum number of household members were 11 and 18 respectively. Across sections, Fallay had the mean of household members between 6 and 7 per household while Bonya, Korjei Ngeiya and Gboro recorded means household members of less than 6 per household.

Average size of household members per room

As per households' members per room across sections calculated in means, Sei section had the highest density of persons per room at 2.6 while Korjei Ngeiya had the lowest at 2.2. The minimum number of persons per room reported for all sections was 1.00. Bonya and Gboro Sections had 12.00, the maximum number of persons recorded per room. Fallay and Korjei Ngieya had the smallest maximum mean of 6.00 while Nyawa recorded a maximum mean of 10. The mean number of persons per room for the chiefdom was 2.3 (SD = 1.1) (*See* Table 3). These findings suggests that household overcrowding, particularly in sections like Sei attributed to extended household structures and limited housing availability and may contribute to increased vulnerability to LF transmission, given the close contact among household members and the higher person-to-room ratio.

Environmental variables influencing LF infection and mortality risk factors

Presence of bush around the house

Figure 1 illustrates the presence of a bush around the house across the studied localities. The chart indicates that less-bushy surroundings were the most common around houses across sections, accounting for 53.9% (647/1,200) to 73.5% (882/1,200). Additionally, 4.40% (53/1,200) to 30.20% (362/1,200) were bushy across sections whilst 15.40% (184/1,200) to 37.10% (445/1,200) were non-bushy surroundings across the sections. Regarding sectional distribution, the Fallay section (37.10%, 75/201) has the highest proportion of non-bushy surroundings whilst Gboro has the lowest (15.4%, 7/169). Conversely, Gboro has the largest bushy surroundings (30.2%, 51/169), while Korjei Ngieya has the lowest (4.4%, 6/145). These findings suggest that the presence of bushy surroundings near residential areas may contribute to increased exposure to rodent vectors, thereby elevating the risk of LF transmission. Bushy surroundings in Gboro may reflect terrain difficulties or low community participation in environmental upkeep increasing the risk of LF vector. Conversely, sections with more non-bushy surroundings, such as Fallay, may have comparatively reduced risk.

Table 2 Household composition across sections

Age category	Sections	N	Mean (SD)	Std. Error	95% C I for mean	
					LB	U B
Adult Male 18 and above	Bonya	912	1.46 (0.911)	0.030	1.40	1.52
	Fallay	89	1.94 (1.112)	0.118	1.71	2.18
	Gboro	162	1.56 (0.878)	0.069	1.42	1.69
	Korjei Ngieya	136	1.42 (0.775)	0.066	1.29	1.55
	Nyawa	793	1.62 (1.028)	0.036	1.55	1.69
	Sei	75	1.71 (1.206)	0.139	1.43	1.98
Adult Female 18 and + above	Bonya	912	1.64 (0.968)	0.032	1.58	1.70
	Fallay	89	1.87 (0.991)	0.105	1.66	2.07
	Gboro	162	1.70 (0.926)	0.073	1.55	1.84
	Korjei Ngieya	136	1.59 (0.821)	0.070	1.45	1.73
	Nyawa	793	1.66 (1.142)	0.041	1.58	1.74
	Sei	75	1.68 (0.947)	0.109	1.46	1.90
Boy Children 3 to17	Bonya	912	1.13 (1.101)	0.036	1.06	1.20
	Fallay	89	1.42 (1.064)	0.113	1.19	1.64
	Gboro	162	1.05 (1.136)	0.089	0.87	1.23
	Korjei Ngieya	136	1.13 (0.962)	0.082	0.96	1.29
	Nyawa	793	1.36 (1.255)	0.045	1.28	1.45
	Sei	75	1.32 (1.275)	0.147	1.03	1.61
Girl Children 3 to 17	Bonya	912	0.90 (1.061)	0.035	0.83	0.96
	Fallay	89	1.06 (1.048)	0.111	0.84	1.28
	Gboro	162	0.80 (1.068)	0.084	0.64	0.97
	Korjei Ngieya	136	0.90 (0.965)	0.083	0.74	1.07
	Nyawa	793	1.10 (1.173)	0.042	1.02	1.19
	Sei	75	1.01 (1.121)	0.129	0.76	1.27
Baby boys under 3	Bonya	912	0.17 (0.416)	0.014	0.15	0.20
	Fallay	89	0.28 (0.543)	0.058	0.17	0.40
	Gboro	162	0.21 (0.776)	0.061	0.09	0.33
	Korjei Ngieya	136	0.18 (0.407)	0.035	0.11	0.25
	Nyawa	793	0.14 (0.428)	0.015	0.11	0.17
	Sei	75	0.19 (0.392)	0.045	0.10	0.28
	Total	2167	0.17 (0.462)	0.010	0.15	0.19
Baby girls under 3	Bonya	912	0.14 (0.390)	0.013	0.12	0.17
	Fallay	89	0.17 (0.376)	0.040	0.09	0.25
	Gboro	162	0.07 (0.252)	0.020	0.03	0.11
	Korjei Ngieya	136	0.19 (0.413)	0.035	0.12	0.26
	Nyawa	793	0.14 (0.407)	0.014	0.11	0.17
	Sei	75	0.19 (0.456)	0.053	0.08	0.29

N = 2167

Table 3 Average size of household members per room

Sections	N	Mean (SD)	Std. Error	95% Confidence interval for Mean	
				Lower B	Upper B
Bonya	912	2.2359 (1.054)	0.03492	2.1674	2.3044
Fallay	89	2.2658 (0.741)	0.07854	2.1097	2.4219
Gboro	162	2.3473 (1.341)	0.10537	2.1392	2.5554
Korjei Ngieya	136	2.2083 (0.813)	0.06969	2.0705	2.3461
Nyawa	793	2.4248 (1.162)	0.04125	2.3438	2.5058
Sei	75	2.5719 (1.068)	0.12331	2.3262	2.8176
Total	2167	2.3245 (1.099)	0.02360	2.2782	2.3708

N = 2167; *SD* Standard Deviation

household farming practices across sections

Table 4 depicts the common farming practices of residents (farming: 78.5%, 1,702/2,167) in the study area. Mixed farming was the most commonly practiced type (61.5%, 1,047/1,702) across all sections. Sei and Nyawa sections were ahead of other sections in this type of farming, accounting for 72.6% (53/73) and 65.5% (397/606) respectively. Shifting cultivation, on the other hand, was practiced by only 25.3% (430/1,702) of those that practiced farming. These findings suggest that the predominance of mixed farming particularly in Sei and Nyawa may have public health implications, as this method often involves storing food like grains and poor waste handling

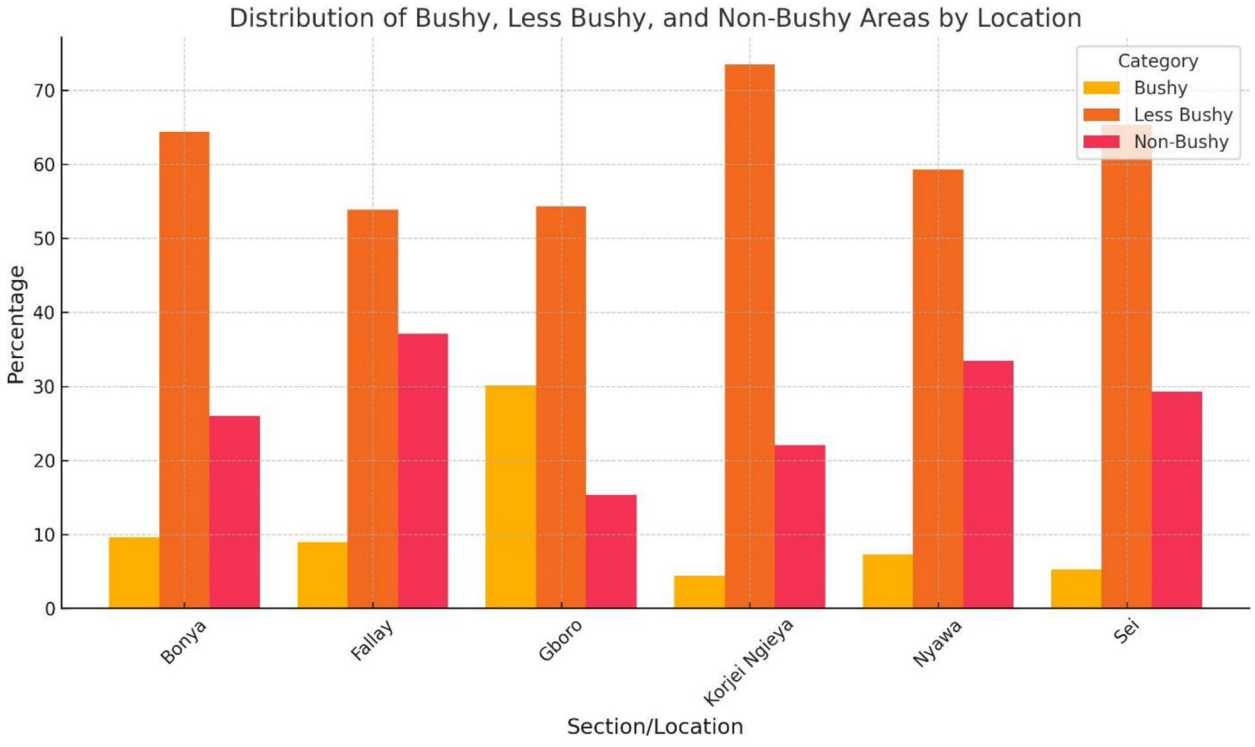


Fig. 1 Presence of grass/shrubs around the house

Table 4 Various household farming practices across sections in lower bambara chiefdom

Section	Farming practice					To-taln (%)
	Mixed farming n (%)	Mixed livestock n (%)	Other, please specify n (%)	Permanent cropping n (%)	Shifting cultivation n (%)	
Bonya	420	3	34	67	163	687
	61.1	0.4	4.9	9.8	23.7	100.0
Fallay	28	0	0	6	36	70
	40.0	0.0	0.0	8.6	51.4	100.0
Gboro	76	0	11	8	54	149
	51.0	0.0	7.4	5.4	36.2	100.0
Korjei Ngieya	73	0	3	16	25	117
	62.4	0.0	2.6	13.7	21.4	100.0
Nyawa	397	1	33	34	141	606
	65.5	0.2	5.4	5.6	23.3	100.0
Sei	53	0	0	9	11	73
	72.6	0.0	0.0	12.3	15.1	100.0
Total	1047	4	81	140	430	1702
	61.5	0.2	4.8	8.2	25.3	100.0

*$P < 0.0001$; $N = 1702/2167$; n = frequency; % = percentage

which increase human-rodent interactions. Such conditions could heighten the risk of exposure to rodent-borne diseases like LF.

Sources of household drinking water

Table 5 shows sources of drinking water across sections. Based on the survey results, it was found that 40.5% (877/2,620) of households rely on public standpipes as their primary water source. Unprotected dug wells were the second most used water source, accounting for 33.0% (715/2,620) of households. Meanwhile, 27.3% (592/2,620) of households used protected dug wells, and 9.3% (201/2,620) used surface water sources such as rivers, dams, lakes, ponds, streams, canals, or tanker trucks. The least common types of household water sources used were unprotected springs (7.5%, 162/2,620)), protected springs (1.4%, 30/2,620)), rainwater collection (1.3%, (30/2,620)), and piped household water connections

Table 5 Sources of household drinking water across sections

Water source	Bonya n (%)	Fallay n (%)	Gboro n (%)	Korjei Ngieya n (%)	Nyawa n (%)	Sei n (%)	TOTAL n (%)
Unprotected dug well	228	33	119	55	270	10	715
	25.0	37.1	73.5	40.4	34.0	13.3	33.0
Unprotected spring	73	2	24	21	29	13	162
	8.0	2.2	14.8	15.4	3.7	17.3	7.5
Surface water rivers dam lake pond stream canal tanker truck	118	0	7	25	19	32	201
	12.9	0.0	4.3	18.4	2.4	42.7	9.3
Piped household water connection	6	4	0	0	3	0	13
	0.7	4.5	0.0	0.0	0.4	0.0	0.6
Public stand pipe	448	48	22	36	306	17	877
	49.1	53.9	13.6	26.5	38.6	22.7	40.5
Protected dug well	249	12	11	12	303	5	592
	27.3	13.5	6.8	8.8	38.2	6.7	27.3
Protected spring	17	0	0	0	13	0	30
	1.9	0.0	0.0	0.0	1.6	0.0	1.3
Rain water collection	13	2	0	0	12	3	30
	1.4	2.2	0.0	0.0	1.5	4.0	1.3

(0.6%, 13/2,620). These findings carry important public health implications, as a substantial proportion of households depend on unsafe or potentially contaminated water sources. The widespread reliance on unprotected dug wells and surface water raises concerns about the transmission of waterborne diseases and environmental exposure risks, particularly in communities already vulnerable to endemic infections like LF.

Household waste disposal

Table 6 details how households managed their waste. Waste burning was the most commonly used temporary waste storage and disposal method, accounting for 65.1% (1,676/2,575) of all methods used. This was followed by open dumping (17.6%, 453/2,575) and waste burying which accounted for 15.3% (1,336/2,575). Additionally, the majority of the households (78.6%, 2,052/2,610) used hands to transport their waste and 19.3% (504/2,610) of households used hand carts.

Lastly, more than half of the respondents (50.1%, 1,205/2,389) openly dump their waste whilst a large proportion used an open storage bin (43.7%, 1,044/2,389). These findings imply a significant gap in access to formal waste management infrastructure and services, which may contribute to environmental contamination and the proliferation of rodents and other disease vectors. The dominance of open dumping and waste burning, combined with manual waste transport, suggests that households are at heightened risk of exposure to zoonotic pathogens, including those associated with LF.

Materials and toilet type used in respondents' house construction

Table 7 presents the common materials and toilet types used by localities in Lower Bambara to construct their houses. At the chiefdom level, more than 57.6% (1,454/2,525) of all houses were constructed with mud walls and was highly dominant in Korjei Ngieya (72.0%, 118/164), Sei (71.4%, 60/84) and Gboro (60.6%, 117/193). Rat holes on habitable house walls were the least observed accounting for 6.1% (154/2,525) across sections. Gboro (9.3%, 18/193) and Korjei Ngieya (9.1%, 15/164) had the highest percentage of rat holes on the walls of inhabitable houses. Across sections, over 90% (1957/2,167) of houses in all 6 sections were constructed with zinc roofs which typically refers to a roof made of corrugated iron sheets that are galvanized or coated with zinc to prevent rust and increase durability, while thatch roofs were used in only 9.1% of houses. A negligible percentage of houses (0.5%, 11/2,167) were constructed with bamboo roofs.

Based on toilet facility use, 79.4% (1,721/2,167) of the toilet facilities used by households across the sections were pit latrines, of which it was dominantly slab (29.1%, 630/1721), open pit latrines (26.3%, 570/1,721), and pit latrines with superstructure (24.0%, 521/1721). Wooden doors and windows were used in over 97% (2,107/2,167) of all households across sections.

A chi-square test was conducted to assess the relationship between the materials used in household construction and endemic to LF sections, a known risk factor for the disease. All house construction materials tested showed a significant association with LF spread, with p-values less than 0.05. However, wooden doors and windows did not show a significant correlation with LF risk,

Table 6 Household waste disposal

Waste management	Practice	Bonya n (%)	Fallay n (%)	Gboro n (%)	Korjei Ngieya n (%)	Nyawa n (%)	Sei n (%)	Total n (%)
How is waste temporarily stored	Burning	713	82	151	83	630	17	1676
		78.2	92.1	93.2	61.0	79.4	22.7	65.1
	Burying	175	20	30	23	133	14	395
		19.2	22.5	18.5	16.9	16.8	18.7	15.3
	Incineration	15	5	7	0	24	0	51
		1.6	5.6	4.3	0.0	3.0	0.0	2.0
	Open dumping	204	7	11	46	136	49	453
		22.4	7.9	6.8	33.8	17.2	65.3	17.6
How is waste transported	Hand	848	87	154	134	754	75	2052
		93.0	97.8	95.1	98.5	95.1	100.0	78.6
	hand cart	208	31	33	23	209	0	504
		22.8	34.8	20.4	16.9	26.4	0.0	19.3
	wheel barrow	10	3	0	0	6	0	19
		1.1%	3.4	0.0	0.0	0.8	0.0	0.7
	Vehicle	1	1	0	1	3	0	6
		0.1%	1.1%	0.0%	0.7%	0.4%	0.0	0.2
	Sac	19	0	1	2	7	0	29
		2.1	0.0	0.6	1.5	0.9	0.0	1.1
How is waste permanently disposed	Open storage bin	377	42	85	52	470	18	1044
		41.3	47.2	52.5	38.2	59.3	24.0	43.7
	Storage bin with lid	11	4	2	0	42	0	59
		1.2	4.5	1.2	0.0	5.3	0.0	2.5
	Open dump	600	51	91	88	332	43	1205
		65.8	57.3	56.2	64.7	41.9	57.3	50.4
	No storage	23	1	0	6	35	16	81
		2.5	1.1	0.0	4.4	4.4	21.3	3.4

as indicated by a *p*-value of 0.07. These findings have critical implications for disease prevention strategies. The widespread use of mud walls particularly in endemic sections along with the presence of rat holes, may facilitate rodent infestation and increased human-rodent contact, thereby elevating the risk of LF transmission. Additionally, the predominance of pit latrines and limited use of improved sanitation infrastructure may further contribute to environmental contamination and disease spread.

Social and economic risk factors influencing LF transmission

Palm wine consumption lifestyle

Table 8 shows the results of the consumption of palm wine. The study found that the majority of people (85.5%, 1852/2,167) in the area did not consume palm wine. However, about 14.5% (315/2167) of respondents reported consuming palm wine. The main source of palm wine for consumption was from the market (87.0%, 274/315), while an insignificant percentage (12.7%, 40/315) harvested it. These findings have important public health implications, particularly in the context of zoonotic disease transmission. The consumption of palm wine especially when sourced from markets with uncertain handling, palm wine fermentation containers, especially when left uncovered and storage conditions may pose contamination risks, including exposure to rodents or rodent excreta. Given that LF is a rodent-borne disease, the informal nature of palm wine collection, storage, and sale warrants attention as a potential risk factor in endemic regions. Additionally, tapping sites often occur in bushy or forested areas with high rodent activity

Logging practice

Figure 2 depicts the practice of logging (36.9%, 801/2,167) as an economic activity. Respondents from the Sei section had the highest percentage (29.0%, 232/801) of positive responses acknowledging active participation in logging practices. This was followed by Korjei Ngieya (25%, 200/801), Fallay (21%, 168/801) and Nyawa (20.8%, 167/801) sections respectively. In contrast, respondents from the Gboro and Bonya sections had the lowest proportion of residents who engaged in logging as a means of livelihood, with only (2.2%, 18/801) and (2.0%, 16/801) positive responses, respectively. These findings suggest that logging is a significant livelihood activity in several sections of Lower Bambara, with potential environmental

Table 7 Materials used in house construction across sections

Structure	Material	Bonya	Fallay	Gboro	Korjei Ngieya	Nyawa	Sei	Total	Chi-Square
Dominant Wall Material	Concrete	57	12	8	4	83	2	166	< 0.0001*
		5.3	12.1	4.1	2.4	9.2	2.4	6.6	
	Semi concrete	323	21	50	27	309	21	751	
		29.9	21.2	25.9	16.5	34.2	25.0	29.7	
	Mud	644	59	117	118	456	60	1454	
		59.6	59.6	60.6	72.0	50.4	71.4	57.6	
	Rat holes seen	57	7	18	15	56	1	154	
		5.3	7.1	9.3	9.1	6.2	1.2	6.1	
Dominant Roof Material	Bamboo	5	0	1	0	4	1	11	< 0.001*
		0.5	0.0	0.6	0.0	0.5	1.3	0.5	
	Thatch	103	1	33	14	41	6	198	
		11.3	1.1	20.4	10.3	5.2	8.0	9.1	
	Zinc	804	88	128	122	747	68	1957	
		88.2	98.9	79.0	89.7	94.2	90.7	90.3	
	Other	0	0	0	0	1	0	1	
		0.0	0.0	0.0	0.0	0.1	0.0	0.0	
Door Material	Steel door and glass windows	2	0	0	0	8	1	11	0.07
		0.2	0.0	0.0	0.0	1.0	1.3	0.5	
	Steel door sand wooden windows	19	3	0	1	21	1	45	
		2.1	3.4	0.0	0.7	2.6	1.3	2.1	
	Wooden doors and windows	891	85	162	135	761	73	2107	
		97.7	95.5	100.0	99.3	96.0	97.3	97.2	
	Other	0	1	0	0	3	0	4	
		0.0	1.1	0.0	0.0	0.4	0.0	0.2	
Toilet Facility	Flush	3	0	0	0	3	0	6	< 0.001*
		0.3	0.0	0.0	0.0	0.4	0.0	0.3	
	Latrine with mud walls and thatch	46	1	6	3	26	0	82	
		5.0	1.1	3.7	2.2	3.3	0.0	3.8	
	Open defecation	113	7	49	18	39	28	254	
		12.4	7.9	30.2	13.2	4.9	37.3	11.7	
	Open pit	234	19	42	65	188	22	570	
		25.7	21.3	25.9	47.8	23.7	29.3	26.3	
	Pit latrine with slab	226	43	43	21	288	9	630	
		24.8	48.3	26.5	15.4	36.3	12.0	29.1	
	Pit latrine with super structure	256	19	22	28	184	12	521	
		28.1	21.3	13.6	20.6	23.2	16.0	24.0	
	Pour flush	18	0	0	1	9	2	30	
		2.0	0.0	0.0	0.7	1.1	2.7	1.4	
	Uses Neighbour's Toilet	6	0	0	0	48	0	54	
		0.7	0.0	0.0	0.0	6.1	0.0	2.5	
	Ventilated improved pit latrine	10	0	0	0	8	2	20	
		1.1	0.0	0.0	0.0	1.0	2.7	0.9	

N = 2167; * = Significant association

and health implications. Logging often leads to deforestation and habitat disruption, which may increase human exposure to wildlife reservoirs, including rodents known to transmit LF. Moreover, individuals engaged in logging may spend extended periods in forested environments, heightening their risk of zoonotic disease exposure.

Reasons for logging

Table 9 provides information on the reasons for logging in the 6 sections of Lower Bambara Chiefdom. It was observed that the proportion of respondents engaged in timber processing was relatively low, ranging from 2% (16/801) to 32% (256/801), with the highest proportion being in the Nyawa section. Similarly, the proportion of respondents engaged in charcoal production was also low, ranging from 1% (8/801) to 22.4% (179/801),

Table 8 Palm wine consumption

Variable	Bonya n (%)	Fallay n (%)	Gboro n (%)	Korjei Ngieya n (%)	Nyawa n (%)	Sei n (%)	Total n (%)	Chi-Square
Are there people who consume palm wine								
No	803	69	145	114	657	64	1852	0.06
	88.0	77.5	89.5	83.8	82.8	85.3	85.5	
Yes	109	20	17	22	136	11	315	
	12.0	22.5	10.5	16.2	17.2	14.7	14.5	
Source of Palm Wine for Consumption								
They buy from the market	100	19	16	20	109	10	274	0.32
	91.7	95.0	94.1	90.9	80.1	90.9	87.0	
They harvest for themselves	9	1	1	2	26	1	40	
	8.3	5.0	5.9	9.1	19.1	9.1	12.7	
Others (specify	0	0	0	0	1	0	1	
	0.0	0.0	0.0	0.0	0.7	0.0	0.3	

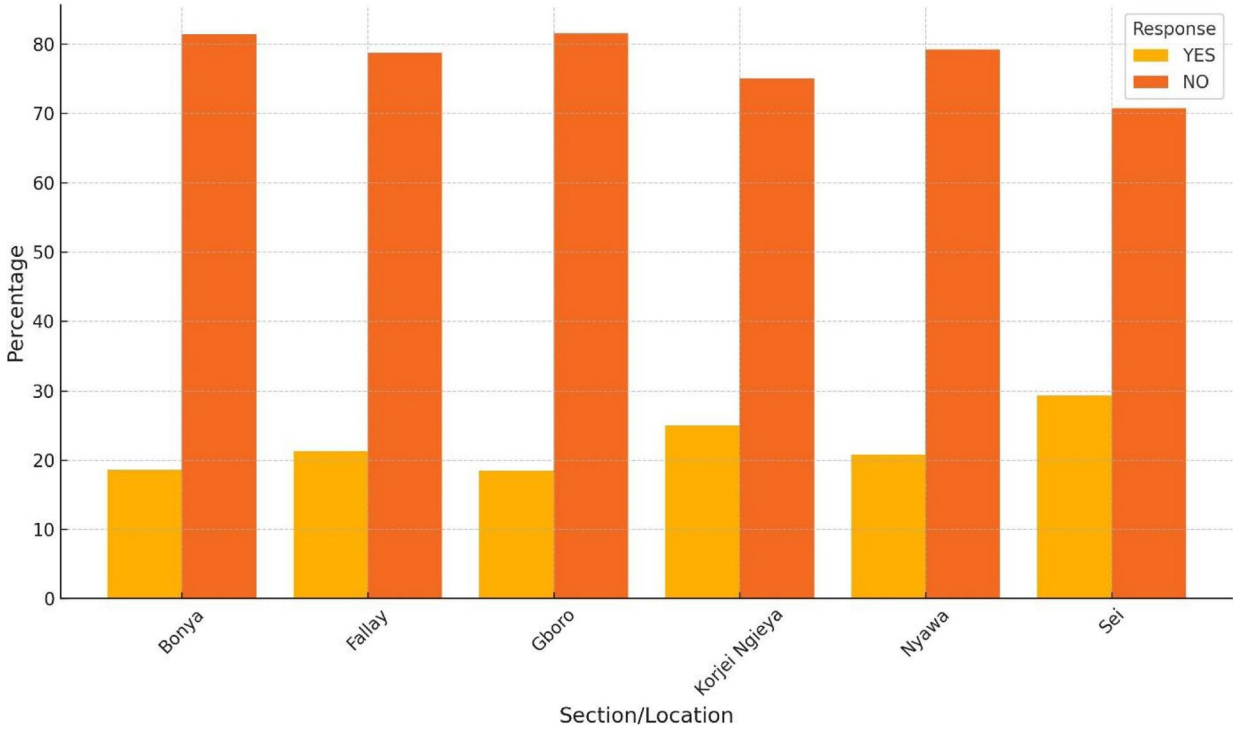


Fig. 2 Proportion of logging activities across sections in Lower Bambara Chiefdom

with the highest proportion being in the Nyawa section. In contrast, firewood collection was the most common reason for logging, with proportions ranging from 63.6% (509/801) to 84.2% (674/801), and the highest proportion being in the Fallay section. These findings have notable environmental and public health implications. The dominance of firewood collection as a logging activity reflects a heavy reliance on natural forest resources for domestic energy needs, which may contribute to deforestation and habitat disruption. Such environmental changes can alter rodent populations and increase human exposure to disease reservoirs, thereby exacerbating the risk of zoonotic infections such as LF.

Nearness of logging activities to households

Table 10, shows the distance of logging activities in the study area. It was observed that the mean logging nearness ranged from 9.95 meters in the Sei section to 18.7 meters in the Gboro section. The overall mean logging nearness for all sections combined was 14.7 meters. The SD for the logging nearness in each section ranged from 4.64 meters in Fallay section to 6.79 meters in the Bonya section, indicating some variability in the distances at

Table 9 Reasons for logging

Reasons for logging	Bonya n (%)	Fallay n (%)	Gboro n (%)	Korjei Ngieya n (%)	Nyawa n (%)	Sei n (%)	Total n (%)
Timber processing	17	2	2	2	32	7	62
	10.0	10.5	6.7	5.9	19.4	31.8	7.7
Charcoal production	17	1	1	1	37	2	59
	10.0	5.3	3.3	2.9	22.4	9.1	7.4
Farming	98	18	13	33	76	12	250
	57.6	94.7	43.3	97.1	46.1	54.5	31.2
Mining	11	5	0	2	24	0	42
	6.5	26.3	0.0	5.9	14.5	0.0	5.2
Firewood	138	16	25	28	119	14	340
	81.2	84.2	83.3	82.4	72.1	63.6	42.4
Others	16	0	4	1	25	2	48
	9.4	0.0	13.3	2.9	15.2	9.1	6.0

N = 801; *n* = frequency, % = percentage

Table 10 Nearness of logging activities to households

Logging nearness	N	Mean (SD)	Std. Error	95% Confidence for mean	
				LB	UB
Bonya	170	13.9 (6.8)	0.52075	12.8602	14.9162
Fallay	19	15.5 (4.6)	1.06614	13.2864	17.7662
Gboro	30	18.7 (4.9)	0.90230	16.8546	20.5454
Korjei Ngieya	34	13.3 (5.7)	0.97226	11.2866	15.2428
Nyawa	165	15.5 (6.4)	0.49697	14.5278	16.4904
Sei	22	10.0 (4.7)	0.99452	7.8863	12.0228
Total	440	14.7 (6.5)	0.30835	14.0440	15.2560

LB Lower boundary, *UB* Upper boundary, *SD* Standard deviation, *Std.* Standard

which logging activities are taking place in each section. However, the standard errors are relatively small (0.49697 - 1.06614), indicating that the sample means are likely to be a good estimate of the true population means. These findings carry critical environmental health implications, as the proximity of logging sites to residential areas may increase human interaction with disturbed rodent habitats, potentially elevating the risk of zoonotic transmission, including LF.

Palm fruit harvesting and storage at home

Figures 3 and 4 show respondents who were involved in harvesting palm fruit within sections and were palm fruits storage at home respectively. Across sections, more than half 54.9% (934/1,702) to 75.0% (1,277/1,702) of the respondents were involved in palm oil harvest except Sei who recorded only 40.0% (681/1,702) of palm oil harvest (Figure 3). Conversely in terms of palm oil storage in homes, about 55.0% (936/1,702) to 81.0% (1,379/1,702) across all sections do keep palm oil at home after harvest. However, only 42.0% (714/1,702) in the Fallay section were involved in palm oil home storage (Figure 4). These findings have notable implications for public health and zoonotic disease prevention. The widespread practice of harvesting and storing palm fruits at home may inadvertently create conditions that attract rodents, particularly if storage methods are not rodent-proof. In endemic areas for LF, such practices could heighten the risk of rodent-human contact and disease transmission.

3.3.6 Household that practices slashing and burning across sections in lower bambara chiefdom

Table 11 displays the practices of slashing, burning and the duration that farms are left to fallow in various parts of the study area. The table highlights that a significant percentage of households in all sections practiced slashing and burning (74.6%, 1,270/1,702), with the highest percentage observed in Fallay (, 95.7%, 67/70) and Sei (87.7%, 64/73). Slashing and burning involves clearing land by cutting down and burning trees and bushes. This activity can attract rodents that carry the LF virus, thereby increasing the risk of exposure to the virus for households involved in farming activities. Furthermore, the table shows that most households in all sections left their farms to fallow for 1–2 years (55.2%, 940/1,702) with the highest percentage observed in Fallay (62.9%, 44/70) and the lowest in Sei (23.3%, 17/73). These findings imply that land-clearing practices such as slashing and burning, when combined with short fallow periods, may contribute to habitat disturbance and environmental degradation that support rodent proliferation.

Livelihood activities

In Table 12, amongst all the livelihoods of household members across sections, farming (53.9%, 1,685/3,129) and petty trading (22.0%, 689/3,129) were the most dominant livelihood activities. Mining (9.7%, 303/3,129), other livelihoods (5.4%, 169/3,129), and harvesting of palm fruits for palm oil production (3.2%, 100/3,129) were also fair contribution of household livelihoods practiced across sections. Nevertheless, charcoal burning (2.8%, 88/3,129), okada riding (1.9%, 58/3,129), palm wine tapping (0.7%, 22/3,129), and hunting (0.5%, 15/3,129) represent the smallest of household livelihoods. These findings

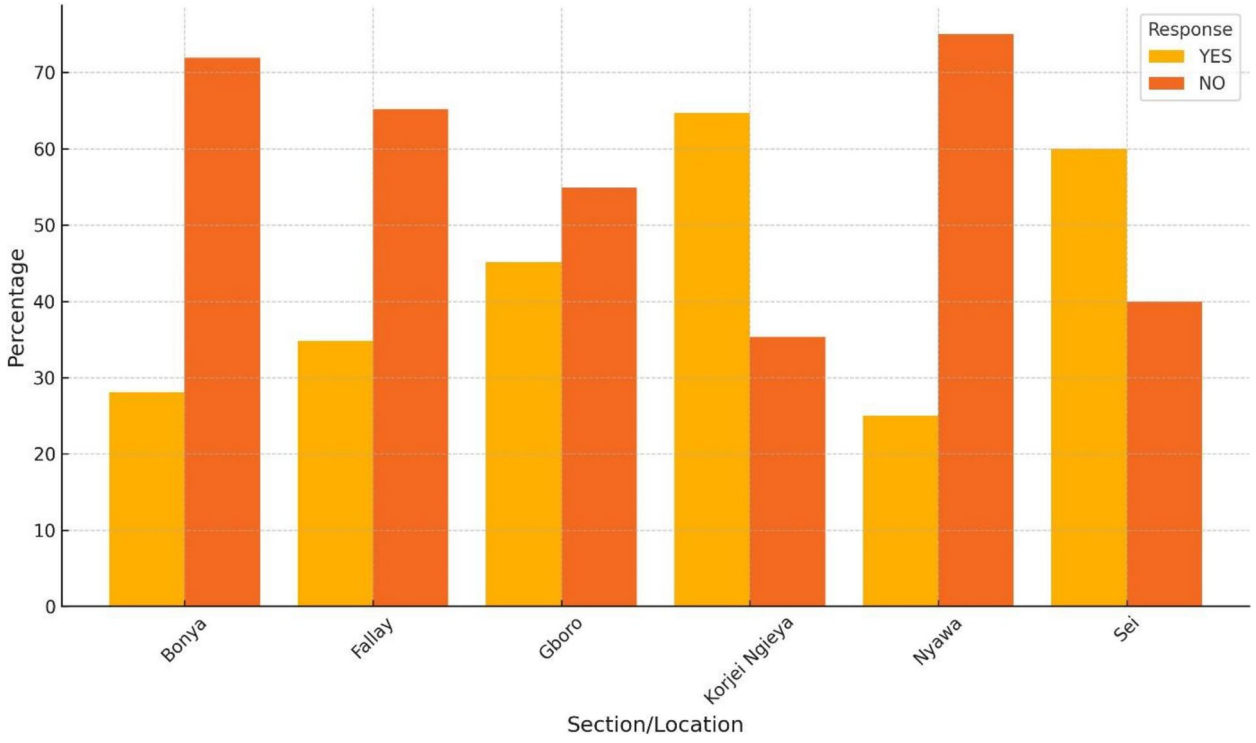
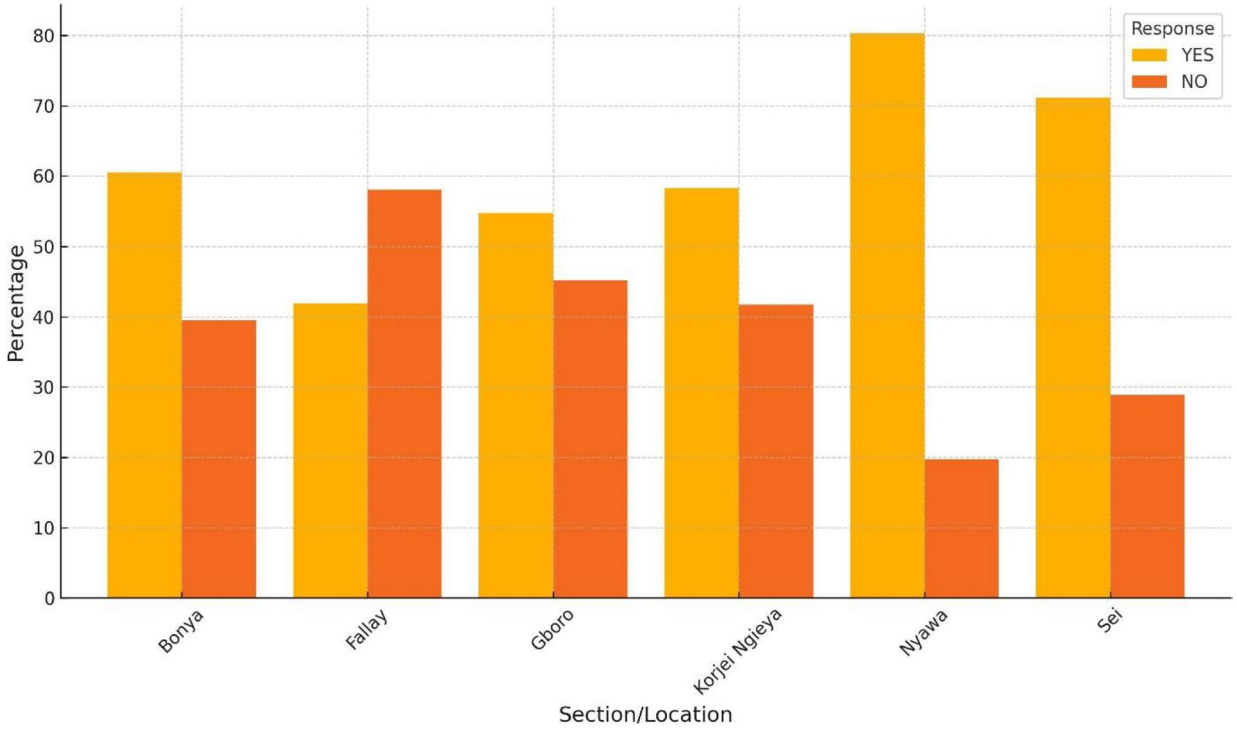


Fig. 3 Proportion of palm fruit harvesting across sections in Lower Bambara Chiefdom



$P < 0.0001$

Fig. 4 Storage of palm fruits across sections in lower Bambara Chiefdom

Table 11 Proportion of households that practice slashing and burning across sections in lower bambara chiefdom

Farming practice		Bonya n (%)	Fallay n (%)	Gboro n (%)	Korjei Ngieya	Nyawa n (%)	Sei	Total
Do you practice slashing and burning	No	200	3	51	28	141	9	432
		29.1	4.3	34.2	23.9	23.3	12.3	25.4
	Yes	487	67	98	89	465	64	1270
		70.9	95.7	65.8	76.1	76.7	87.7	74.6
Total		687	70	149	117	606	73	1702
		100.0	100.0	100.0	100.0	100.0	100.0	100.0
Number of years Farm Left to Fallow	1–2 yrs	369	44	81	62	367	17	940
		53.7	62.9	54.4	53.0	60.6	23.3	55.2
	2–3 yrs	119	4	20	24	85	14	266
		17.3	5.7	13.4	20.5	14.0	19.2	15.6
	3–4 yrs	98	3	20	14	39	14	188
		14.3	4.3	13.4	12.0	6.4	19.2	11.0
	4–5 yrs	47	13	17	9	40	20	146
		6.8	18.6	11.4	7.7	6.6	27.4	8.6
	Other	54	6	11	8	75	8	162
		7.9	8.6	7.4	6.8	12.4	11.0	9.5
Total		687	70	149	117	606	73	1702
		100.0	100.0	100.0	100.0	100.0	100.0	100.0

*$P < 0.0001$; $N = 1702$; n = frequency, % = percentage

Table 12 Household livelihood activities

Livelihood	Section						Total
	Bonya n (%)	Fallay n (%)	Gboro n (%)	Korjei Ngieya n (%)	Nyawa n (%)	Sei n (%)	n (%)
Mining	61	7	19	8	194	14	303
	6.7	7.9	11.7	5.9	24.5	18.7	9.7
Farming	707	76	142	130	556	74	1685
	77.5	85.4	87.7	95.6	70.1	98.7	53.9
Petty-trading	333	41	37	33	233	12	689
	36.5	46.1	22.8	24.3	29.4	16.0	22.0
Charcoal burning	60	8	4	11	5	0	88
	6.6	9.0	2.5	8.1	0.6	0.0	2.8
Okada riding	35	3	1	3	14	2	58
	3.8	3.4	0.6	2.2	1.8	2.7	1.9
Hunting	9	2	0	0	4	0	15
	1.0	2.2	0.0	0.0	0.5	0.0	0.5
Palm-wine taping	15	0	1	0	6	0	22
	1.6	0.0	0.6	0.0	0.8	0.0	0.7
Harvesting palm fruits for palm-oil production	48	2	17	15	15	3	100
	5.3	2.2	10.5	11.0	1.9	4.0	3.2
Others, specify	61	5	5	1	91	6	169
	6.7	5.6	3.1	0.7	11.5	8.0	5.4

$N = 3167$; n = frequency, % = percentage

have important implications for disease surveillance and risk mitigation. The predominance of farming and palm-related activities suggests continued close interaction with the natural environment particularly forested and rodent-prone areas thus increasing the likelihood of exposure to zoonotic diseases such as LF. Additionally, livelihoods like charcoal burning, mining, and hunting, though practiced at lower rates, may also involve ecological disruption and extended time in high-risk environments.

Discussion

This study examined the socioeconomic and environmental factors influencing LF transmission in Lower Bambara Chiefdom, Sierra Leone. Significant associations between LF markers and variables such as household size, educational status, farming practices, waste disposal methods,

housing construction materials, and proximity to logging activities. Larger household sizes were common in the study area, reflecting cultural and economic dynamics common in rural Sierra Leone. Such living arrangements can facilitate close contact among individuals, increasing exposure to LF vectors. The observed associations largely correspond with the studies in Nigeria and other West Africa nations [44, 50] which showed that extended household size, low education, mixed farming, and bushy surroundings is link with increased LF transmission. In contrast, other African regions, particularly North and South Africa, typically have smaller household sizes due to different socioeconomic conditions and urbanization rates [51, 52]. Lack of education can have significant impacts on individual health outcomes and community health in general [53]. The association between low educational attainment and increased LF risk underscores the role of health literacy in disease prevention. Limited education may impede access to vital health information and the adoption of preventive measures, thereby elevating vulnerability to LF [54]. Similar findings have been reported in Nigeria, where low awareness and knowledge of LF were prevalent among communities [55, 56]. These findings highlight the importance of considering regional socioeconomic and cultural factors in designing effective public health interventions [57, 58].

Furthermore, similar gender patterns which aligned a Tanzanian study found that women were less likely to participate in household surveys due to gender roles and lack of decision-making power, which aligned with the latest study which reported more males in the survey [59]. This gender imbalance is particularly relevant in the context of LF, as men in rural Sierra Leone are more likely to engage in outdoor activities such as farming and logging occupations that increase exposure to rodent habitats and, by extension, to LF virus reservoirs [48]. Similarly, a China study reported older adults were more likely to be included in household surveys due to their higher rates of non-migration and stable residency [60] and they often have more stable household roles and may be primary decision-makers, influencing environmental hygiene, waste disposal, and food storage factors known to affect LF transmission risks. This was consistent with the current study, in which about 60% of respondents were above 33 years that reflect an increasing age of household heads in Africa [61], which can have implications for household composition, socioeconomic status, and exposure risks similar to a study carried out in Singapore [48].

A study conducted in Nigeria also agreed with the present finding highlighting the age range of household heads (41-50years) [62], unlike an Ethiopia report which depicts contrasting results [63]. Moreover, the high proportion of married individuals and subsistence farmers in the study population mirrors results from similar studies [44, 49] and is particularly significant, given that farming practices, land use patterns, and household size are all critical determinants of LF exposure in endemic communities. Therefore, the observed sociodemographic characteristics in this study are not merely descriptive but have direct implications for understanding population-level vulnerability to LF.

Environmental markers, notably bushy surroundings and inadequate waste management emerged as significant risk factors for LF transmission and transmission. Dense vegetation and unmanaged grass around homes provide conducive habitats for Mastomys rodents, the primary LF vectors [64, 65]. This finding is consistent with Nigerian research which indicated that poor housing quality and environmental hygiene increase the risk of rodent infestation and LF [66]. Additionally, improper waste disposal practices, such as open burning, burying garbage and inadequate storage can advertently attract rodents, further amplifying transmission risks [67, 68]. For example, mismanaged waste provides food and shelter for rodents, facilitating their proliferation near human dwellings. This proximity increases the risk of LF transmission as humans come into contact with environments contaminated by infected rodent excreta. Effective waste management strategies, and community engagement in promoting proper food and water storage and waste management has been implemented in interventions to combat LF [69]. Furthermore, the presence of bushy environments though less common in the study area aligned with public health concerns in West Africa regarding the spread of vector-borne diseases like LASV [70].

Socioeconomic activities like logging and farming were also linked to LF transmission. Logging near residential areas disrupts natural rodent habitats, leading to increased human-rodent interactions. Similarly, mixed farming practices can interest rodents, heightening exposure to LF vectors [71–73]. These findings underscore the need for targeted interventions addressing the environmental consequences of such livelihood activities. A study in Nigeria highlighted that poor housing conditions and hygiene practices contribute to increased rodent presence, aligning with our observations [74].

Socioeconomic factors along with environmental management policies, also play a significant role in LF transmission. Different communities in Africa and West Africa maintain their surroundings based on traditional practices, economic conditions, or environmental conservation policies [75]. Moreover, the study's findings highlight critical environmental and infrastructural factors contributing to LF transmission in Lower Bambara Chiefdom, Sierra Leone. These factors include water sources, waste management practices, and urbanization trends, all of which influence the prevalence and transmission

dynamics of LF. In the study area, primary drinking water sources such as surface water, unprotected wells, and standpipes are susceptible to contamination. This contamination can attract rodents, particularly Mastomys natalensis, the primary reservoir for LASV [76]. Rodents are drawn to accessible water sources, increasing the likelihood of human exposure to the virus through contact with rodent excreta [77]. This situation is exacerbated by inadequate sanitation infrastructure, a common issue in many parts of Africa, including West Africa and Sierra Leone [64]. Ensuring clean and protected water sources is essential to reduce rodent attraction and subsequent LF transmission.

On the other hand, research from Nigeria, specifically in Ondo State, has shown a shift in LF incidence from rural to urban areas [78]. This study showed that environmental factors such as elevation, evening light, and reduced precipitation levels are associated with a higher incidence of LF include which is not common with the current report that highlighted bushy surroundings, proximity to marketplaces and logging sites, waste disposal practices and the vulnerability of water sources linked to LF transmission. Additionally, it emphasised the importance of urbanization, population density, and specific ecological factors like light pollution and vegetation index as major risk factors for LF demonstrating a deeper understanding of how ecological factors can affect the disease's ability to spread [78].

Farming, a key livelihood activity in Lower Bambara according to the latest report is consistently identified across various regions as an increasing LF socioeconomic marker due to enhanced rodent-human interactions [79, 80]. However, the type and method of farming may vary regionally, affecting LF transmission differently and further impacting community health education and disease awareness [81, 82]. For instance, mixed farming identified in the current report combines crop cultivation and livestock rearing [49, 83]. This type of farming entices rodents, the primary carriers of the LASV, increasing human-rodent interactions, a trend consistent with findings in Africa [84]. Finally, the practiced of slashing and burning in agriculture is noted in other regions as an LF risk [85, 86] as rodent habitat are disrupted allowing them to rush into homes.

Furthermore, the research study investigated the influence of household building materials on the risk of contracting LF. Housing conditions were identified as critical factors impacting LF transmission. The common use of mud walls in house construction and zinc roofing was associated with increased rodent habitation and nesting sites within homes [65, 87–89] aligning with the present study emphasising the need for improved housing designs and materials to mitigate LF risks. Research in Sierra Leone has shown that poor housing quality increases the risk of rodent infestation and LF transmission [90]. Unlike some rural areas in Sierra Leone and West Africa where thatch roofs are common, most households use zinc roofs which might offer better protection against rodents [91, 92]. More so, the use of wooden materials for doors and windows in Lower Bambara though common, was not significantly linked to LF risks which contrast a West African study [93]. Additionally, the widespread use of pit latrines in the study is also a noted risk factor, aligning with findings from other African regions where such facilities can attract rodents [16, 94].

Furthermore, the study suggests a possible link between palm wine consumption and LF spread which was a common finding in LF studies elsewhere [79, 95]. Nevertheless, it is important to note that this study was conducted in an LF-endemic area, and while the results provide insights into the high consumption of palm wine, further research is needed to determine the specific role of palm wine consumption in the transmission of LF. Nonetheless, no study has directly linked palm wine with LF disease transmission though a study has pinpointed that ethanol found in palm wine may serve as a risk factor to the immune system. Nevertheless, in some parts of Nigeria, it is used as a malaria prophylaxis [96]. Logging and timber activities were also identified as risk factors in the current Lower Bambara chiefdom research and vary in impact and prevalence in other studies [97, 98]. In some areas, these activities are less disruptive to rodent habitats, influencing LF transmission risk differently [99, 100].

The proximity of economic activities to residential areas is a crucial factor in LF transmission in and is also recognized in other studies [2, 64, 78]. However, the degree of proximity and its impact on LF risk can differ across regions evidenced in Guinea [64] and Nigeria [101]. Overall, the study highlights both common and unique aspects of LF transmission risk, underscoring the need for tailored approaches to LF prevention and control that consider local socioeconomic and environmental conditions.

Limitations and strengths

The study has several potential limitations. One major concern is potential biases, such as recall bias, where respondents may have difficulty accurately recalling past behaviors or experiences related to LF. This can lead to inaccuracies in their responses. Another issue is selection bias; the study relied on household heads or knowledgeable members as respondents, which might exclude less knowledgeable or less involved individuals, skewing the data towards more informed perspectives.

Regarding the geographic scope, the research was conducted in only 26 out of 112 EAs within the Lower

Bambara Chiefdom and lacked house-level LF data. This limited coverage means the findings may not fully represent the entire population, as a significant portion of the community did not have the opportunity to participate. Furthermore, the findings are specific to the Lower Bambara Chiefdom and may not be generalizable to other regions in Sierra Leone or other countries with different socio-demographic and cultural contexts.

The study also faced challenges during data collection. The high illiteracy rate among the studied population required enumerators to administer the questionnaire verbally, which could introduce errors in the interpretation and recording of responses. In addition, the study experienced limited resources and logistical challenges in reaching remote or difficult-to-access areas might have restricted the study's ability to include a more diverse and representative sample.

Despite these limitations, the study has several strengths. It employed a descriptive cross-sectional quantitative approach, providing a snapshot of community predictive markers to LF transmission at a specific point in time. The use of a large sample size (2,167 respondents) enhances the reliability of the findings. Additionally, the rigorous data collection process, including the use of a pre-tested questionnaire and trained enumerators, ensured high data quality. The study's focus on a high LF endemic area allows for a detailed understanding of community-driven prevention and control measures, which can inform targeted public health interventions.

By acknowledging these limitations and strengths, future research can aim to address these gaps by expanding the geographic scope, employing strategies to mitigate biases, and recommending longitudinal studies to enhance the robustness and generalizability of the findings.

Conclusion

In conclusion, this study underscores the complex interplay of socioeconomic and environmental factors in shaping LF transmission in Lower Bambara Chiefdom. While some interventions exist, our findings suggest the need for enhancements particularly in environmental hygiene education and rodent-proof housing strategies. Addressing livelihood practices such as logging and farming through policy and community-based initiatives can further reduce transmission. Policy measures should consider establishing buffer zones for logging near residential areas, implementing rodent control programs, promoting rodent-proof palm storage, and enforcing improved sanitation standards. Future research should evaluate the effectiveness of such interventions and explore additional cultural and ecological factors contributing to LF transmission.

Abbreviations

EA Enumeration Area
LF Lassa fever
VHF Viral Haemorrhagic Fever

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Authors' contributions

A.B.S.K. conceived and designed the study, supervised data collection, and provided critical revisions to the manuscript. A.M. contributed to the study design, data analysis, and manuscript writing. He was responsible for the interpretation of the statistical findings and contributed to drafting and editing the manuscript. P.F. assisted in the collection of data, performed statistical analysis, and contributed to manuscript drafting. J.M.L. was involved in the data collection and contributed to the methodological framework. O.A.S. provided expertise in environmental health and reviewed the manuscript for technical content. M.K.R. contributed to the literature review, and manuscript writing, and critically reviewed the manuscript for intellectual content.

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Data availability

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. Data sharing is subject to compliance with ethical guidelines and participant consent.

Declarations

Ethics approval and consent to participate

This study received ethical approval from the Njala University Institutional Review Board (NU-IRB), Sierra Leone, and was conducted in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from all participants before data collection. For illiterate participants, consent was obtained via thumbprint in the presence of an impartial witness, and where applicable, legal guardians provided consent on their behalf.

Consent for publication

Not applicable. This manuscript does not contain any identifying images or other personal or clinical details of participants that compromise anonymity.

Competing interests

The authors declare no competing interests.

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