Preventive Veterinary Medicine 215 (2023) 105919

Contents lists available at ScienceDirect

Preventive Veterinary Medicine

journal homepage: www.elsevier.com/locate/prevetmed

Access to vaccination services for priority ruminant livestock diseases in Ghana: Barriers and determinants of service utilization by farmers

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ARTICLE INFO

Keywords:
Livestock
Livestock diseases
Livestock farmers
Vaccination access

ABSTRACT

Introduction: Livestock diseases are a major constraint to agricultural productivity, frequently causing significant livelihood losses for farmers, and negatively affecting public food safety and security. Vaccines provide an effective and profitable means for controlling most infectious livestock diseases, but remain underutilized. This study sought to assess the barriers and determinants of vaccination utilization for priority livestock diseases in Ghana.

Methods: We conducted a mixed-method study involving a quantitative survey with ruminant livestock farmers (N = 350) and seven focus group discussions (FGD) involving 65 ruminant livestock farmers. The survey data were analyzed, and distribution of barriers to vaccination access described. We evaluated the determinants of vaccination utilization (any use of vaccination against contagious-bovine-pleuropneumonia (CBPP) and peste-des-petits-ruminants (PPR) in 2021) using logistic regression analyses at the 0.05 significance level. FGD transcripts were analyzed deductively. We used triangulation to achieve convergence across the different datasets and analyses.

Results: The farmers kept an average (median) of 5 tropical livestock units (TLUs) of ruminant livestock (IQR=2.6–12.0) that were on average 8 kilometers (IQR=1.9–12.4) away from veterinary officers (VOs). Only 16% (56/350) of herds were vaccinated against the diseases. Most farmers (274/350) had limited knowledge on vaccines against CBPP and PPR infections, 63% (222/350) perceived low risk of these diseases to their herds. About half of farmers reported experiencing outbreaks of either disease in the study year (2021). Farmers scored on average 80.5 out of 98 (IQR=74–85) on the RS-14 resilience scale. After adjusting for farmers' livestock rearing experience, herd size, sex, wealth status, distance to VOs, previous disease outbreaks, and perceived risk of the diseases, vaccination utilization was negatively associated with limited knowledge (aOR=0.19, 95% CI=0.08–0.43), and positively associated with personal exposure to outbreaks in the study year (aOR=5.26, 95% CI=2.01–13.7) and increasing resilience (aOR=1.13, 95%CI=1.07–1.19). FGDs revealed farmer misconceptions about vaccines, costs of vaccines, and timely access to vaccines from VOs as additional barriers.

Conclusions: Acceptability, affordability, accessibility, and availability of vaccine services represent the main barriers to vaccines utilization by ruminant livestock farmers in Ghana. Given that limited knowledge regarding the value of vaccination and shortfalls in veterinary service supply are of central importance for both the demand and supply side, more collaboration between the different stakeholders in a transdisciplinary manner to effectively address the low vaccination utilization problem is needed.

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https://doi.org/10.1016/j.prevetmed.2023.105919
Received 16 February 2023; Received in revised form 3 April 2023; Accepted 9 April 2023
Available online 11 April 2023

1. Introduction

The production in the livestock sector accounts for about 40% of the agriculture sector's gross domestic product in West Africa; the main species reared being ruminants (cattle, sheep, and goats) and poultry (OECD and ECOWAS, 2008). Ruminants are mostly domesticated mammals with digestive systems that depend on pre-gastric retention of digesta associated with fermentation of plant materials by symbiotic microorganisms (Stover et al., 2016). Mobility in search for optimal grazing resources for the animals, known as transhumance, is an essential part of livestock farming, particularly for cattle farmers. Although these animal movements can be predicted due to their seasonality, the national borders have not been able to adequately prevent unapproved animal movements in the region. Thus, there is a high level of interaction between the transhumance and local herds, leading to the frequent introduction and spread of pathogens across borders (Motta et al., 2017; Apolloni et al., 2019).

Livestock diseases impose significant costs on the livestock sector through animal deaths, disease control costs, and restrictions on animal trade (Grace et al., 2015; Nuvey et al., 2022a). At the individual farmer level, the diseases cause significant livelihood losses for households (Pradère, 2014; Huntington et al., 2021), affecting their domestic food security (Dominguez-Salas et al., 2019; Nuvey et al., 2022b), and psychosocial wellbeing (Mort et al., 2005; Nuvey et al., 2020). While the public is affected potentially unsafe food, due to misuse of antimicrobials in livestock production entering the food chain (Kimera et al., 2020; Mshana et al., 2021), and heightened food insecurity from a reduction in the productivity of diseased animals (Herrero et al., 2013). For the most part, the livestock diseases with the most severe impact are transboundary in nature (Islam et al., 2013; Clemmons et al., 2021). These transboundary diseases are highly contagious animal diseases, whose epidemiology may differ across countries; they occur mainly as epidemics, but could also become endemic in the ecosystems of affected countries (Otte et al., 2004). In the West African region, the diseases with the highest impact on countries includes Newcastle disease (ND) in poultry, peste-des-petits-ruminants (PPR) in sheep and goats, contagious bovine pleuropneumonia (CBPP) in cattle, and African swine fever (ASF) in pigs (Otte et al., 2004; Fadiga et al., 2013).

In Ghana, the livestock sector provides employment for about 10% of the country's population, with about 20% of livestock holders being women. About 80% of livestock farmers are rural dwellers, who keep 60% of the 18 million heads of livestock (GSS, 2021). Livestock production is dominated by smallholder farmers practicing the extensive system of rearing. Aside from poultry (74%), ruminant livestock rearing constitute the other significant proportion (21%) of livestock holdings of households engaged in livestock production (GSS, 2020a). The livestock sector in Ghana similar to other countries in the West African region, faces challenges with transboundary animal diseases. In a previous study, the livestock farmers and veterinary service providers identified FMD and CBPP in cattle, and PPR and Mange in sheep and goats as priority diseases affecting ruminant livestock productivity, causing an average of 10% (and up to 70%) of herd losses per year. The farmers mainly use treatment services for managing diseases, most of which service is provided by informal persons who are not supervised by the veterinary system or the treatment is done by farmers themselves. In addition, the medicines applied by the farmers are not useful for the conditions treated in most cases (Nuvey et al., 2023). An effective control of these priority livestock diseases is therefore critical to sustaining the livelihoods and wellbeing of farmers on one hand, and the food safety and security of the population on the other hand.

Preventive veterinary services particularly vaccination have been shown to be both effective and profitable in controlling livestock diseases (Charlier et al., 2022; Nuvey et al., 2022a). However, vaccines supply and utilization rates by farmers in many sub-Saharan African countries including Ghana remain very low (Donadeu et al., 2019; OIE, 2019). Among the reported priority diseases; FMD and CBPP in cattle, and PPR and Mange in sheep and goats based on previous research in Ghana (Nuvey et al., 2023), only CBPP in cattle and PPR in sheep and goats have approved vaccines by the veterinary system in Ghana for their control (Diop et al., 2011). We therefore sought in this study to identify ways to improve the utilization of these vaccines by farmers to mitigate the occurrence and impact of these priority diseases. Identifying the barriers and determinants of farmers' utilization of vaccination services in the Ghanaian context is needed, to inform policy actions towards achieving this goal.

2. Materials and methods

2.1. Description of study area

The study was conducted in the Mion, Pru East and Kwahu Afram Plains South (KAPS) Districts, which are representative of the northern, middle and southern farming belts of Ghana. The three districts lie in the Guinea Savannah, Transition and Deciduous forest Vegetation zones respectively that are the main livestock production zones in Ghana (GSS, 2014a; b, c) (Fig. 1). Ghana has a population of 31 million people; with a sex ratio of 97 males for every 100 females, of which about 60% are economically active. A higher share of males (64%) than females (53%) engage in economic activity in the country. Unemployment rate is 13% among the economically active population (GSS, 2021). The annual average household per capita income is GHC 11,694 (USD 1949) [GHC is Ghanaian Cedis: USD 1 ≈ GHC 6 at the time of the survey (Bank of Ghana, 2021)]; with significantly higher per capita income for urban dwellers [GHC 16,373 (USD 2729)] compared to rural dwellers [GHC 5880 (USD 980)] (GSS, 2019). The agricultural sector contributes about 20% to the country's gross domestic product. For most households, agricultural activity mainly entail the cultivation of crops and livestock rearing (GSS, 2020b).

The selected districts are mainly rural and agrarian, with about one-third of the livestock holdings of households being ruminant species. The primary ruminant livestock species reared by farmers are cattle, sheep, and goats. The primary non-ruminant livestock species reared are poultry, pigs, and rabbits. The majority of the livestock rearing (53%) is for income generation – the rest is directly consumed by the household. The livestock production system is largely extensive and dominated by small-scale farmers (GSS, 2020a). In Ghana, vaccination services for livestock are provided mainly by government employed veterinary officers (VOs), and is usually done from farm to farm. The VOs providing veterinary services including vaccination in rural areas, where livestock are usually reared, are mainly veterinary paraprofessionals with a diploma degree (equivalent to three years of training) in animal health as a minimum qualification. The VOs work under the direct supervision of district or regional veterinarians (usually with a doctor of veterinary medicine qualification) (Diop et al., 2011).

2.2. Study design

This was a cross-sectional study which employed a convergent parallel mixed-method research approach. This study design enabled us to conduct both quantitative and qualitative elements of the research project during the same phase of the research process. Although the analysis of data is conducted separately for each method, the results have equal weighting and are interpreted jointly (Creswell and Clark, 2018). We conducted a cross-sectional survey involving 350 ruminant livestock farming households, as well as seven focus group discussions (FGDs) involving 65 ruminant livestock farmers purposively selected within the study area. A household refers to a person or group of persons who normally live together and are catered for as one unit; members may or may not be related. Any member of the household who takes responsibility for the upkeep of the livestock kept by the household was eligible to participate in the study.

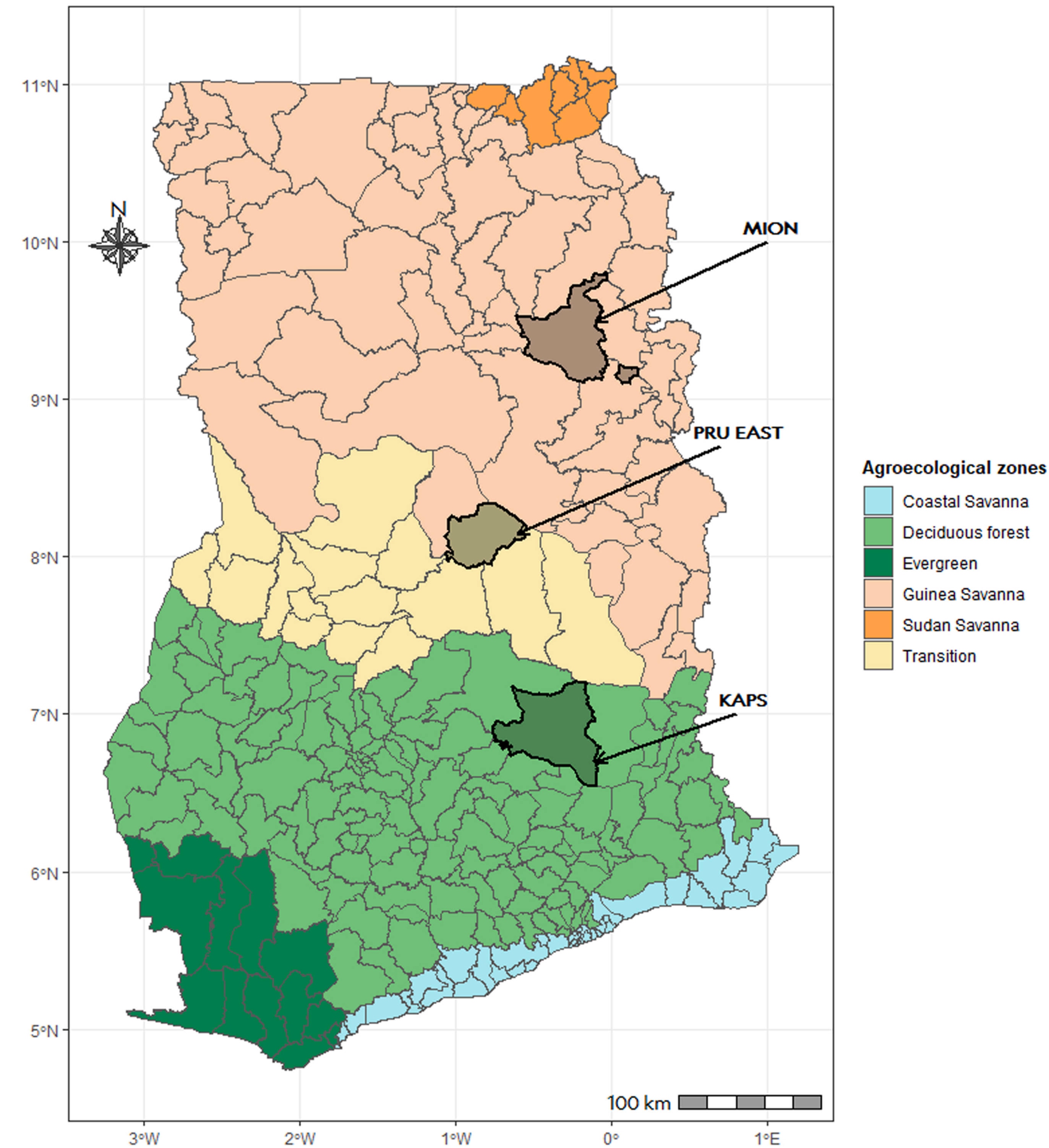

Fig. 1. Administrative map of Ghana showing the agro-ecological zones and study districts. (The figure shows the district-level administrative and ago-ecological map of Ghana. It presents the distinct locations of the study districts (shaded areas to which arrows point) within the main agro-ecological zones. MION, PRU EAST, and KAPS denote the Mion, Pru East and Kwahu Afram Plains South Districts respectively.)

2.3. Study population

In the survey, we firstly obtained district maps and created a sampling frame of villages within the study area to be sampled for data collection. Based on the population and housing census data available prior to the study, there were about 80880, 54694, 47230 tropical livestock units (TLUs) of ruminant livestock species in the KAPS, Mion and Pru East Districts respectively, with an average of about 10 holdings per household. We randomly drew 15 villages in the KAPS District, and 10 villages each in the Pru East and Mion Districts, proportional to the number of livestock farming households per district (GSS, 2014a; b, c). From the selected villages, at least two persons were approached per village to participate in FGDs organized after the surveys in each study district. Seven FGDs were conducted involving 65 participants in the study area.

2.4. Sample size and sampling technique

The sample size was determined using Epi Info version 7 (Dean et al., 2011) with the following assumptions: Expected vaccination utilization rate of 10% was estimated based on previously reported vaccination utilization rates in the West African region (Dione et al., 2017; ElArbi et al., 2019). The acceptable margin of error was 5%, at a 95% confidence level. With an assumed average of eight subjects per cluster (m) and an intra-cluster correlation coefficient (ICC) of 0.2, the design effect of the study was 2.4 To reach a margin of error of 5%, a sample size of 350 livestock farmers was required. We recruited 350 livestock farmers from 38 villages using random segmentation. In villages where sufficient households were not realized, the adjoining village was selected for sampling of the remainder of households missed. For the FGDs, we used a purposive sampling approach to recruit farmers during the survey in each district. The farmers who consented to participate in FGDs in the three districts were 65.

2.5. Data collection and data management

The enumeration team visited the households rearing ruminant livestock in their homes to conduct the survey between November 2021 and January 2022. The survey questionnaires were administered to the respondents' face-to-face using tablets with Open Data Kit (ODK) application. The survey instruments collected data on farmers' previous and current history of experiencing outbreaks of the priority diseases (CBPP and PPR) in herds, perception of the risk of the diseases to herds, utilization of vaccination services, barriers to service utilization, knowledge of vaccines to protect herds against the diseases, and other socio-demographic characteristics of the participating farmers. Knowledge level was assessed based on farmers' responses to questions on the vaccines' functions and effectiveness, required frequency of use, protection offered to animals, and places to acquire the vaccines when needed. Correct responses yielded a score of 1 while wrong responses yielded a score of zero (0). Perception of the diseases risk to herds was assessed on a five-item Likert scale with responses ranging from 1 to 5; higher scores denote higher risk perception of the diseases to a herd, one item's score (Q4) is reversed to achieve a similar direction of perception score (**Additional file 1**).

The FGDs were conducted during the same period at designated venues in the study districts using a paper-based interview guide, and the FGD sessions were recorded using an audiotape. The farmers discussed in the FGDs their experiences with the outbreaks of the priority diseases, awareness of vaccines for protecting herds against the priority diseases, vaccine utilization and effectiveness in protecting livestock, main constraints of vaccination access and utilization, and the potential measures to improve vaccine uptake.

The survey data were downloaded in Microsoft Excel format from ODK and imported into Stata version 16 (StataCorp, 2019) for analyses. The interview audio recordings from the FGDs were transcribed verbatim, and the transcripts were imported into NVivo software version 12 (QSR International Pty Ltd, 2018) for analysis.

2.6. Data analyses

We performed descriptive analyses of the survey data, comparing the distribution of farmers' responses by study district. The farmers' herd sizes were converted to tropical livestock units (TLU) to standardize livestock holdings as follows: 1 TLU corresponds to 1 cattle or 5 small ruminants (sheep and goats) (Njuki et al., 2011). We determined the relative wealth of households using an index of a household's ownership of selected assets, such as televisions, refrigerators and bicycles (ICF, 2019). Resilience was assessed using the Resilience scale (RS-14) (Wagnild, 2009). The RS-14 is a 14 item Likert-scale with scores ranging between 1 and 7, and higher scores indicative of higher resilience. We used the median split approach to categorize knowledge and perception scale scores (Iacobucci et al., 2015), with scores above the median corresponding to good knowledge and good perception respectively, and lower scores otherwise. We adapted the access framework proposed by (Obrist et al., 2007), for each of the reported barriers to vaccination utilization, to determine the applicable dimension of access they fit. Based on the observed distribution in each dimension, we could determine the access dimension(s) to be prioritized for interventions to improve vaccination utilization by ruminant livestock farmers. We compared the access dimension distribution among the households by study district.

In a pre-specified model, we evaluated the relationship between vaccination use (any use of vaccination in the past 12 months) to protect livestock against contagious bovine pleuropneumonia (CBPP) and peste-des-petits-ruminants (PPR), and farmers' sex, herd size, wealth status, resilience level, experience with livestock rearing, distance to VOs, perception of the diseases risk to herds, previous and current history of outbreaks of the diseases in herds, and knowledge level of vaccination against the diseases, adjusting for clustering at the village level, at the 95% confidence level in a logistic regression model. We presented crude (cOR) and adjusted odds ratios (aOR) with their respective 95% confidence intervals (CI) for univariable and multivariable analyses respectively.

The analysis of FGD transcripts was performed from a social constructivism viewpoint, as we understood agricultural (livestock) production to entail the social and cultural creations of those involved. We sought to find convergence on farmers' perception of the risk of the priority diseases to their herds, level of knowledge on vaccination against the diseases, the challenges that farmers face in accessing vaccination services, and to identify ways to address these challenges to improve vaccination uptake. We conducted thematic analysis of the transcripts deductively, by generating codes and categories from the raw transcript texts, based on the study objectives. We present the results as narratives supported by verbatim quotes with clarification phrases where required for quotes, placed in square brackets.

3. Results

3.1. Characteristics of the study respondents

Table 1 presents a summary of the obtained household survey data in the study area. On average (median), farmers participating in the survey (N = 350) were 45 years old (IQR = 35–54). The farmers reported rearing livestock for an average 9 years (IQR = 6–15), with households keeping on average of 5 TLUs of ruminant livestock (IQR = 2.6–12); including cattle, goats, and sheep in their herds. More than two-thirds (71%) of the farmers were male. The farmer households were 8 kilometers (IQR = 1.9–12.4) away from their veterinary service providers (VOs) on average. Households' wealth index differed significantly between study districts ($p < 0.001$), with Mion (59%) and Pru East (69%) Districts having the highest proportion of the poorest and least poor households respectively. Furthermore, the farmers scored an average resilience score of 80.5 out of 98 (IQR = 74–85), with the average resilience scores highest in the Mion District (82.5), and lowest in the KAPS District (78.0).

Table 1 also shows that the farmers scored an average of 19 out of 25 (IQR = 17–21) on the perception scale, and 3 out of 5 (IQR = 2–3) on the knowledge scale. Only 22% (76/350) of the farmers had good knowledge of vaccines (score above the median knowledge score) to protect their herds against contagious bovine pleuropneumonia (CBPP) and/ or peste-des-petits-ruminants (PPR) infections. Also, only 37% (128/350) of the farmers perceived a high risk of CBPP and/or PPR infections to their herds. About 47% (164/350) of households experienced either CBPP (49%, 43/87) or PPR (46%, 155/338) outbreaks in the study year.

The farmers participating in the focus group discussions (FGDs)

Table 1
Summary of data collected from household survey by study district (N = 350).

Characteristic Socio-demographic characteristics	n	KAPS Median (IQR)	MION Median (IQR)	PRU EAST Median (IQR)
Livestock farming experience (years)		9 (5.0 – 16.0)	10 (6.0 – 17.0)	9 (5.0 – 15.0)
Distance to veterinary service (km)		12.0 (8.0 – 14.4)	6.9 (1.6 – 12.7)	1.9 (0.6 – 5.6)
Resilience level		78 (73.0 – 84.0)	82.5 (78.0 – 87.0)	81 (75.0 – 86.0)
Knowledge of CBPP and/or PPR vaccines		3 (2.0 – 4.0)	3 (3.0 – 3.0)	3 (3.0 – 4.0)
Perception of CBPP and/or PPR disease risk		19 (17.0 – 21.0)	18 (17 – 20)	18 (16.0 – 21.0)
		% (n/N)	**% (n/N)**	**% (n/N)**
Sex				
Female	102	38% (57/149)	16% (16/98)	28% (29/103)
Male	248	62% (92/149)	84% (82/98)	72% (74/103)
Wealth status quintiles				
Poorest	70	14% (21/149)	42% (41/98)	8% (8/103)
Below average	74	28% (41/149)	26% (25/98)	8% (8/103)
Average	66	24% (36/149)	14% (14/98)	15% (16/103)
Above average	70	25% (37/149)	10% (10/98)	22% (23/103)
Least poor	70	9% (14/149)	8% (8/98)	47% (48/103)
Herd size (Tropical Livestock Units)				
Small (1st tertile: 0.6 – 3.2 TLUs)	127	42% (62/149)	43% (42/98)	23% (24/103)
Medium (2nd tertile: 3.4 – 8.2 TLUs)	107	31% (46/149)	25% (25/98)	34% (35/103)
Large (3rd tertile: 8.4 – 249.8 TLUs)	116	27% (41/149)	32% (31/98)	43% (44/103)
Utilization of CBPP and PPR vaccination[a]				
Past herd vaccination against CBPP and/or PPR	65	29% (43/149)	13% (13/98)	9% (9/103)
Current herd vaccination against CBPP and/or PPR	56	4% (6/149)	14% (14/98)	35% (36/103)
History of CBPP and/or PPR outbreak in herds[b]				
Previous history of CBPP and/or PPR outbreak	159	35% (52/149)	48% (47/98)	58% (60/103)
Present history of CBPP and/or PPR outbreak	164	31% (46/149)	41% (40/98)	76% (78/103)

Percentages (%) are the proportion of ruminant livestock farmers within each characteristic explored per study district sub-sample (N). Numbers (n) of households, falling into each sub-category of assessed characteristics within the study districts; KAPS: households from the Kwahu Afram Plains South District, MION: households from the Mion District and PRU EAST: households from the Pru East District in Ghana. For continuous variables, the median with corresponding lower and upper quartile values are reported in parentheses. CBPP denotes contagious bovine pleuropneumonia infection in cattle, and PPR denotes peste-des-petits-ruminants infection in sheep and/ or goats. [a]For the utilization of CBPP/PPR vaccinations, non-use of the vaccines by a household in the past years (before 2021) and non-use of the vaccines in the study year (2021) were the reference categories respectively in each case. [b]For the herd history of CBPP/PPR outbreak, non-experience of an outbreak in herd in the previous years (before 2021) and non-experience of an outbreak in the study year (2021) were the reference categories respectively.

(N = 65) reared on average 5.2 TLUs (IQR = 32.4 TLUs) of ruminant livestock per herd. Most of the participating farmers were male (85%), and about (60%) of the farmers had at least some basic formal education.

3.2. Utilization of vaccination services against priority diseases

We found that only 18% (65/350) of households had ever vaccinated their herds against CBPP and/or PPR before the study year. In the study year (2021), only 16% (56/350) of farmers had vaccinated their herds against these priority diseases (Table 1). The previous and present vaccination utilization rates were significantly different between the study districts ($p < 0.001$).

We present the determinants of current vaccination utilization by the farmers in Table 2. In our pre-specified univariable models, we found positive associations between farmers utilizing vaccination and years of experience with livestock rearing (cOR = 1.04, 95% CI = 1.01 – 1.08, p = 0.02), farmers' resilience (cOR = 1.12, 95% CI = 1.06 – 1.18, p < 0.001), herd size (cOR = 2.34, 95% CI = 1.59 – 3.44, p < 0.001), male sex (cOR = 2.10, 95% CI = 1.01 – 4.33, p = 0.04), wealth status

Table 2
Determinants of livestock farmers' utilization of vaccination services against priority ruminant livestock diseases in Ghana (N = 350).

Variables	Unadjusted model		Adjusted model	
	cOR (95% CI)	P-value	aOR (95% CI)	P-value
Livestock farming experience (years)	1.04 (1.01, 1.08)	0.02	1.02 (0.97, 1.08)	0.40
Distance to veterinary service (km)	0.90 (0.86, 0.95)	< 0.001	0.93 (0.85, 1.01)	0.08
Resilience level	1.12 (1.06, 1.18)	< 0.001	1.13 (1.07, 1.19)	< 0.001
Herd size (TLU)				
Small (1st tertile)	ref		ref	
Medium (2nd tertile)	2.01 (0.83, 4.85)	0.12	0.94 (0.35, 2.52)	0.90
Large (3rd tertile)	5.26 (2.39, 11.6)	< 0.001	1.34 (0.45, 3.99)	0.60
Sex				
Female	ref		ref	
Male	2.10 (1.01, 4.33)	0.04	1.43 (0.63, 3.24)	0.39
Wealth status				
Poorest	ref		ref	
Below average	0.94 (0.31, 2.83)	0.91	1.61 (0.47, 5.77)	0.45
Average	1.07 (0.35, 3.23)	0.91	1.26 (0.35, 4.53)	0.73
Above average	1.33 (0.47, 3.79)	0.60	1.03 (0.27, 3.94)	0.96
Least poor	5.32 (2.12, 13.3)	< 0.001	2.51 (0.84, 7.51)	0.10
Herd history of CBPP/PPR outbreak*				
History of CBPP/PPR outbreak in herd	3.68 (1.96, 6.87)	< 0.001	1.16 (0.48, 2.81)	0.74
Present (2021) CBPP/PPR outbreak in herd	5.32 (2.70, 10.5)	< 0.001	5.17 (1.96, 13.7)	0.001
Knowledge of CBPP and/or PPR vaccines				
Good	ref		ref	
Limited	0.18 (0.10, 0.33)	< 0.001	0.18 (0.07, 0.42)	< 0.001
Perception of CBPP and/or PPR disease risk				
High	ref		ref	
Low	0.47 (0.27, 0.84)	0.01	1.76 (0.95, 3.24)	0.07

Variables included as predictors of the current utilization of professional veterinary services by livestock farmers in Ghana. Crude odds ratio (cOR) with 95% Confidence Intervals (CI) and the associated *p*-values for the unadjusted model and adjusted odds ratio (aOR) with 95% CI and the associated *p*-values for the adjusted model, accounting for clustering during sampling of respondents. 'ref' denotes the reference category. * For the herd history of CBPP/PPR outbreak, non-experience of an outbreak in a household's herd in the past years (before 2021) and non-experience of an outbreak in the study year (2021) were the reference categories respectively in each case.

(cOR = 1.58, 95% CI = 1.27 – 1.98, $p < 0.001$), and previous (cOR = 3.68, 95% CI = 1.96 – 6.87, $p < 0.001$) and current history (cOR = 5.32, 95% CI = 2.70 – 10.5, $p < 0.001$) of disease (CBPP and/or PPR) outbreak in a herd. There was a negative association between vaccination use and distance between the livestock farming households and VOs (cOR = 0.90, 95% CI = 0.86 – 0.95, $p < 0.001$), perception of low risk of CBPP and/or PPR infection to herds (cOR = 0.47, 95% CI = 0.27 – 0.84, $p = 0.01$), and limited knowledge of CBPP and/or PPR vaccines (cOR = 0.18, 95% CI = 0.10 – 0.33, $p < 0.001$).

After adjusting for the covariates described above, we found positive associations between vaccination use and farmers' resilience (aOR = 1.13, 95% CI = 1.07 – 1.19, $p < 0.001$), and personal experience of an outbreak of the diseases (CBPP and/or PPR) in the study year (aoR = 5.17, 95% CI = 1.96 – 13.7, $p < 0.001$). While vaccination use was negatively associated with farmers' limited knowledge of vaccines to protect their livestock herds against diseases (aOR = 0.18, 95% CI = 0.07 – 0.42, $p < 0.001$).

In the FGDs we similarly found that farmer knowledge of vaccination against these priority diseases and self-conviction or willingness to protect assets (resilience), influences greatly the utilization of vaccination services. Thus, mere provision of information about vaccination availability to the farmers is not sufficient. There are also significant misconceptions about vaccine effectiveness, particularly during an active disease outbreak. Thus, farmers generally only seek to protect their animals when they hear about or experienced the disease outbreaks.

> "For me I have only heard about the vaccine that prevents CBPP. I know that it will be good for us to take that CBPP vaccine, but if the disease [CBPP] is already in the kraal [an enclosure or pen where the farmers' animals or herd is kept] and you go ahead to vaccinate them, it would kill most of them. So, for me, I have stopped vaccinating my cattle, because if they are already infected and you vaccinate [them], some may die." **(Male farmer, 46 years old, KAPS District)**

> "Some time back, the veterinary officer reached out and explained to us about the vaccine that could protect our animals before the disease [PPR] comes. During that time when he [veterinary officer] said that, I also vaccinated my animals…, it protected them against the disease [PPR]." **(Male farmer, 40 years old, Pru East District)**

> "I also do similar as she [another farmer participant] said. If the disease doesn't infect your animals…, even if the veterinary officer is talking about vaccinating them against the disease, you are not too worried about it. But when you see the infection with your own eyes [pauses]. For me, I don't normally do it unless I see that the disease has infected them… Even when he [veterinary officer] brings the vaccines and asks us to vaccinate the animals, most of the farmers don't take it seriously. We'll hear the announcement that we should mobilize ourselves to come and vaccinate our animals, but we don't take it seriously… So, we the farmers; we do not have that spirit [willingness] to vaccinate our animals." **(Male farmer, 59 years old, KAPS District)**

Despite the low patronage of vaccination services, we found that many of the farmers that utilize the vaccination services mostly had positive outcomes of protection for their animals, comparing those with and without vaccination use. Few farmers reported negative outcomes.

> "With that medicine [vaccine], if you inject the animals before the disease [PPR] comes, it [vaccine] protects them from being infected by the disease, and also from dying from it. But now that we don't inject them with that medicine [vaccine] before it [PPR] comes, it kills many of our animals." **(Male farmer, 54 years old, KAPS District)**

> When he [veterinary officer] vaccinates them [sheep and goats] against the diarrheal disease [PPR], and there is an outbreak, to be honest, even if the animal is infected, it won't die. And the phlegm [mucous discharge] that comes out of their head [via nostrils], is reduced. At times, when the disease comes, it often doesn't affect them. And even if they get infected by it, it takes only about two to three days and then it resolves. So, it [vaccine] protects them [sheep and goats] against the different kinds of diseases that we mentioned. So, as for the vaccination, it is very very important, ahaa." **(Female farmer, 46 years old, KAPS District)**

> "Vaccinations are usually very helpful; they protect the animals very well against those diseases [CBPP and PPR]. Even when you're doubtful whether there is an outbreak among your animals or not, and you call for vaccination, only those animals which have already contracted the disease are badly affected, and those vaccinated before contracting the disease are usually safe." **(Male farmer, 41 years old, Mion District).**

> "What I observed is that the older ones [bucks, does, ewes, and rams] that I vaccinated were not affected by the disease [PPR] when it came. But the young ones [kids and lambs] that were given birth to afterwards, it was not yet time for them to be vaccinated, so they were the ones that the disease normally infected." **(Male farmer, 32 years old, Pru East District)**

3.3. Barriers to the utilization of vaccination services

We applied the access framework proposed by Obrist et al. (2007), to identify the barriers to farmers accessing vaccination services against infectious livestock diseases in general. Our results showed that the main bottlenecks were in the acceptability (59%), affordability (53%), accessibility (42%), and availability (34%) dimensions of the access framework (Table 3). The barriers were somewhat district specific. The proportion of households reporting challenges for each dimension was highest in the KAPS district in all the dimensions except for affordability (Fig. 2). Affordability as a barrier was highest for farmers in the Pru East

Table 3
Barriers to households' access to vaccination against ruminant livestock diseases.

Access dimension	Measure	Prevalence
Acceptability	Information on service is unaligned with values and practices of users	59% (210/350)
	Service is not perceived by users as valuable to livestock farming	
Affordability	Users had inadequate funds (money) to use the service when provided	53% (187/350)
	Users had inadequate time to participate when services were provided	
Accessibility	Service provider is distant (far) from the users	42% (148/350)
	Service provider is unreachable to users when service was needed	
Availability	Service is unavailable with the provider when required by the user	34% (119/350)
	Service offered by the provider is insufficient to meet the user's needs	
Adequacy	Quality of service provided did not meet the user's expectation	4% (17/350)
	User is dissatisfied with the attitude of service provider	

Measures depict the indicators obtained in survey as barriers to service utilization. Service refers to vaccination against contagious bovine pleuropneumonia (CBPP) in cattle, and/or peste-des-petits-ruminants (PPR) infection in sheep and/ or goats. Service providers are public employed veterinary officers delivering veterinary services in study districts. Users are ruminant livestock farming households (rearing any of cattle, sheep and or goat) in the study districts. Prevalence denotes the proportion of households reporting at least one of the indicators as barriers to their access to vaccination in any given farming year.

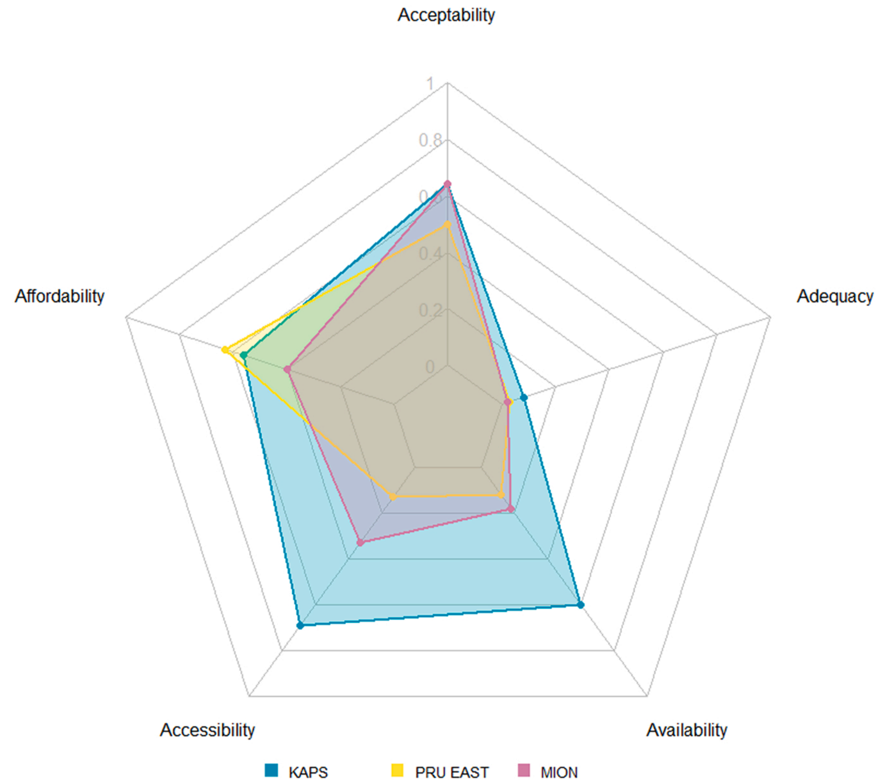

Fig. 2. Access dimensions influencing vaccination utilization by livestock farmers in Ghana by district. (The figure shows the access dimensions influencing farmers' utilization of vaccination services against infectious diseases in livestock in Ghana. The color differences depict each study district. The point positions on the radar chart corresponds to the proportion of farmers reporting barriers that fall within each of the access dimensions.)

District (63%), compared to the other districts. The Mion District had acceptability as the main barrier (64%). In the KAPS District, accessibility was the main barrier (69%), followed by acceptability (64%), availability (60%), and affordability (56%). Adequacy was not much of a barrier for the farmers. We also found the barriers to vaccination access to be gendered; whereby the proportion of female farmers reporting barriers to access was higher in all dimensions compared to males. We did not find marked differences in barriers to access stratified by age categories and marital status of the farmers (**Additional file 2**).

The discussions with the farmers similarly affirm the demand side barriers of acceptability and affordability. Farmers frequently do not consider vaccination against infectious diseases as a part of livestock farming. Even when the farmers are informed and willing to utilize vaccination, the requirement by VOs to have sufficient animals per vial of vaccine [100 cattle for CBPP, and 50 sheep or goats for PPR] before vaccine vials are administered, is a disincentive for farmers whose herds are not sufficiently large, unless they can get other farmers to participate or offer to pay for the unused doses of vaccines. There are also farmers who nevertheless, do not consider vaccination a priority enough to spend their resources on it. In the study year, average vaccination cost were GHC 6 (USD 1) and GHC 5 (USD 0.83) for CBBP and PPR respectively.

> "…If the animal is not sick, why should I spend my money to vaccinate the animal? Myself sitting here, I'm sick, and I need money to treat myself [laughs], and to talk of the animal. If the animal gets infected by the disease [PPR] today, I don't have money, so why should I use money to vaccinate an animal that is not ill [diseased]. How about me myself?" **(Male farmer, 40 years old, KAPS District).**

> "Majority of us have no education on the importance of preventive veterinary services like vaccination… Some farmers do think their cattle are healthy and need no treatment. So, when the time comes and the veterinary people [officers] talk about that [vaccination], it appears as though they [veterinary officers] are basically trying hard to make money from us the farmers rather than the intended protection the veterinary officers' vaccination would offer against animal losses. It's a big challenge." **(Male farmer, 41 years old, Mion District).**

> "I remember that some time ago an announcement was made that we should come together as livestock farmers for a vaccination exercise. They said that, when a vial of vaccine is opened, unless he [veterinary officer] uses all [vaccine doses] in a day. We were told that for some of the medicine [vaccine], it must be used to inject hundred (100) animals [cattle] and for others, fifty (50) animals [goats and sheep]. So, as we were thinking about it, whether to participate, someone [a farmer] was saying that the veterinary officer had gone to buy his medicines that he was planning to come and sell…, but because they were about to expire; and he doesn't know what to do with them, that was why he wanted to come and inject our animals. It made some of us who were willing then to vaccinate our animals to have a change of mind. So that is part of the reasons why some [farmers] don't vaccinate their animals before the diseases come." **(Male farmer, 37 years old, KAPS District)**

> "Usually, the veterinary officers come to inform us about these vaccines. But when you go to ask them [veterinary officers], they tell you that after opening the vaccine vial, he needs to inject a lot of the animals at a go, from one animal to another until the vial is finished, so it doesn't go to waste., It can be that on a date [scheduled] we all agreed to inject [vaccinate] our animals, maybe your friend [farmer] does not have the money to do it,…, so he [veterinary officer] would not be able to administer it [vaccine] to your animals" **(Male famer, 60 years old, Pru East District)**

Aside the demand side barriers, some farmers also reported supply side barriers regarding the accessibility, availability, and adequacy of the vaccination services offered.

"Sometimes, even if one [a farmer] gets the money today [for vaccination] but is not able to access the veterinary officers, you will end up spending the money. Later when they [veterinary officers] show up, what can you do? You will not be able to participate in the vaccination for the animals." **(Female famer, 46 years old, Mion District)**

"In times past, the veterinary officers would come around to vaccinate our animals yearly. But nowadays it is no longer so…, in fact because the veterinary officers are few, we don't get them [animals] vaccinated regularly… Because we don't get the vaccines on time… You need access to the vaccine every year to give them [animals], so you can protect them. By the time the next vaccination period is approaching, the veterinary officer would say he is going to Accra [360 km from district] to get the vaccines, so organize yourself and get other people to also take the vaccine. But where am I going to get them? Maybe the other farmer is doing something on his own and I also on my own. But if it was possible that if you have only 20 cattle, the veterinary officer can just vaccinate your animals and do similar for other farmers, then all the time we could vaccinate to protect them [animals]. But we don't get it that way." **(Male farmer, 46 years old, KAPS District)**

"For me I have a veterinary man [officer] who usually treat my animals for me. So maybe on the day the veterinary officers come for a vaccination exercise, I may have already spent the money on treating the animals or the veterinary man who sees my animal is not part of the exercise…, so therefore I would not be able to participate in the vaccination." **(Male farmer, 53 years old, Mion District)**

The farmers argued that increased community engagements by VOs on the value of vaccinations and discounting of vaccination costs, and legislation by local authorities, as well as community mobilization by farmers, would improve vaccination adoption and use.

"When there is a vaccination exercise, we only want to have the information about the exercise in good time. The veterinary officers should give the scheduled times that they would always call on us for education on the vaccination exercises. When veterinary officers organize it and get us involved, then we can spread the message among ourselves… I believe that if the education is done on media platforms like radio and television, it would be great. Because even if a farmer is not able to get the time to listen to the education, at least some people in the community who are fortunate to follow the discussion on the media platform, can share what they heard or learnt for others to benefit as well. If that is done, all the farmers who never paid attention to vaccination would bring back their attention and enhance the patronage…. Because for example, if I know the importance [of vaccination] and I have to vaccinate my animals against a disease and I have 3 animals, I can sell one to cater for [protect] the other two." **(Male farmer, 41 years old, Mion District)**

"Nowadays you can't get the medicine [vaccine] free [like in the past]. But they [veterinary officers] should give us a moderate price. If the price is moderate, we can easily afford. So, if government can help us so that the medicine [vaccine] will come; and if every year, we are supposed to pay a certain amount of money to the government so that they [veterinary officers] will vaccinate our animal for us, that is better. For you to pay money, for your animal to stay healthy, is better than when the diseases infects the animals, and you don't get money to buy medicines to treat them, then they all die. That would mean that we are working in vain. If we are able to pay something small every year, for them to come to inject the animals for us, I think that would help us." **(Male famer, 54 years old, KAPS District)**

"Like he [another farmer participant] said, I think we those livestock farmers living in one area [village], have to form a union or an association. So that when we have this group, then we could say, all those who have these kind of animals, we want to vaccinate the animals this year so that they are not infected by these diseases… When the association meets and decides on a particular date, then we can go and call the veterinary officer, for him to come and vaccinate our animals. When we join and there is understanding, it would help us all… Because when you leave your own animals and someone else vaccinates their own, the disease could infect your animals and could spread to other animals in the area, or in some cases, it could affect all of us." **(Female farmer, 62 years old, Pru East District)**

"I also do support the suggestion that it should be made compulsory that everyone undertakes the vaccination of their animals. I believe if we have a mandatory regulation that it is enforceable in the community,… so that if you don't vaccinate your animals, you would be caught and sanctioned,…, you won't be permitted to keep livestock, and your farm would be closed to serve as a deterrent." **(Male famer, 48 years old, KAPS District)**

4. Discussion

Infectious livestock diseases significantly reduce the productivity in the livestock sector, which negatively affects farmers' livelihoods and wellbeing, and public food safety and security. Although vaccination has been shown to be effective and provide high returns on investment, farmers' utilization of vaccination services for livestock diseases remain very low in many sub-Saharan African countries. In this study, we aimed to identity the barriers and determinants of farmers' utilization of vaccination against priority diseases for the livestock sector in Ghana. We implemented a convergent parallel mixed-method design to achieve this goal. Our results suggest that the utilization of vaccination services by farmers is mainly influenced by the service costs, and farmers' experience of disease outbreaks in herds, knowledge level of vaccines, and resilience to adversity and motivation levels.

Previous studies among livestock farmers in East Africa made similar findings, where factors including cultural norms, farmers' knowledge of disease and vaccines, history of disease occurrence in herds, vaccine costs, and distance to vaccine sources influenced households' utilization of vaccination services (Mutua et al., 2019; Mukamana et al., 2022; Williams et al., 2022). A study also showed that socio-cultural factors including age, sex, ethnicity, marital status, geographic location, physical ability and education influence access to vaccination in Uganda (Acosta et al., 2022). We found similar influences on vaccination access of sex, farmers' experience, wealth status, and distance to veterinary services in our unadjusted model. Although the acceptability, affordability, accessibility, and availability of vaccines mainly constrain farmers' access, the increased engagement of veterinary personnel (VOs) with the farmers on the usefulness of vaccinations and discounting of vaccination costs as well as community mobilization, have been proposed to have the potential to improve uptake and utilization of vaccination services. In addition to these, farmers proposed implementation of legislation to compel participation. This approach however is likely to be counterproductive if awareness and confidence in vaccines are not improved first (Brewer et al., 2017).

Farmers' decision to utilize vaccination could be treated as a discrete choice problem based on the random utility theory (Hensher et al., 2005), whereby the utility a farmer derives from participating in a vaccination exercise would be the sum of the utility derived from the characteristics of the vaccination program. Thus, it is intuitive that all things being equal, improving farmers' awareness on vaccination as an effective and profitable control measure against infectious diseases could address most of the demand side barriers of access (acceptability and affordability). More so, we found the limited knowledge of the effectiveness of vaccines, particularly during active disease outbreaks as the main driver of farmers' misconceptions about vaccines and unwillingness to invest resources in vaccinating their herds during the FGDs. The farmers showed in the survey and FGDs that they were more knowledgeable particularly on where the vaccines for protecting the herds could be accessed and on the concept of herd immunity offered by vaccination.

Government subsidies are often used to incentivize adoption of vaccination in some contexts (Mongoh et al., 2008; China, 2017; Greenville, 2020; Roch and Conrady, 2021; Parliament, 2022). However, given the current resource constraints of the veterinary system in Ghana, we argue that public funding of such subsidies would not be possible currently to achieve optimal vaccination coverage. Moreover, previous research has showed that motivational risk communication strategies that increase farmer awareness and willingness are equally effective in increasing farmer vaccination uptake compared with the provision of financial compensation in the form of subsidies (Sok and Fischer, 2020). Future studies in Ghana could address the costing issue by evaluating farmers' valuation and willingness to pay for vaccines, to inform pricing policy that would incentivize use.

The main supply side barriers were related to availability of vaccines and accessibility of VOs to farmers when required, and could be addressed by increasing budgetary allocation to veterinary services, which would help reduce the human resource gap in the veterinary sector. The recent review of the performance of veterinary services of African countries showed that funding for operationalizing veterinary services was very poor for 78% of countries (OIE, 2019). The public resource allocations to the veterinary system certainly has to be improved if the sector is able to attain its goals, particularly in disease control. In a recent review of the livestock vaccine supply chain, (Acosta et al., 2019) argued that addressing farmer willingness to vaccinate through increased awareness creation alone, without a commensurate effort to address the supply side challenges would be ineffective in optimizing the vaccination coverage. This underscore the need for increased collaborative and transdisciplinary approaches, involving scientists, policy makers and communities, working together to address the key challenges.

The access framework proposed by (Obrist et al., 2007) also enables the evaluation of the equitability of people's access to health services. We found marked differences in the distribution of the barriers to access in the study districts. The Kwahu Afram Plains South (KAPS) District had a higher proportion of farmers reporting challenges in almost all the access dimensions. This could be explained by the relatively large veterinary workload in KAPS, more than two times that of the other districts. The veterinary livestock units, which is calculated by dividing the standardized total number of animal heads in tropical livestock units by the number of VOs was about 30000 in KAPS compared to about 11500 and 9000 in Mion and Pru East Districts respectively. The Veterinary Services Directorate in Ghana should thus endeavor to maintain an equitable distribution of the available staffing resources to districts.

Our study had some limitations. Despite our best efforts to obtain a representative sample of the different agro-ecological zones in Ghana, this study did not account for the two other minority agro-ecological zones namely the Evergreen and Coastal Savannah zones. Even though these zones are not typical areas for livestock production in Ghana, determining the barriers faced in their contexts would have improved the representativeness of our findings. In spite of this omitted perspective, we do not expect the parameters evaluated to be markedly different in these agro-ecological zones. Additionally, even though we relied mainly on reported information in this study, we believe that the triangulation of results from the different methods show validity of our instruments. Our study thus, has provided valuable information on the barriers and determinants of vaccination utilization in a developing country context, which would inform strategies to address low coverage of preventive vaccination in livestock.

5. Conclusion

Our study shows that limited knowledge of the effectiveness and profitability of vaccines, lack of timely access to vaccines and the cost of vaccination services discourage farmers' utilization of vaccination to protect their livestock herds against priority infectious diseases, while increased resilience to adversity as well as the experience of diseases in herds are positively associated with vaccination use. Thus, acceptability, affordability, accessibility, and availability of vaccine services represent the main access dimensions constraining vaccination adoption and use. Misconceptions about vaccines cannot be addressed by information provision of vaccine effectiveness alone. These strategies need to include thorough engagement with community members, and should be sensitive to gender issues relating to vaccination access. Farmer proposals with potential to address the problem would include increased engagement of communities by veterinary service providers on the value and effectiveness of vaccines, discounting of vaccination costs, and farmer community mobilization. Given that limited knowledge of the effectiveness of vaccination and veterinary services supply shortfalls in the districts drive the observed demand and supply side challenges respectively, greater collaboration between the different stakeholders in a transdisciplinary manner to effectively address the low vaccination utilization problem is needed.

Consent for publication

Not applicable.

Ethics approval

The study was reviewed and approved by the Ghana Health Service Ethics Review Committee (approval number: GHS-ERC 006/09/20). In the study districts, permission was obtained from all the relevant authorities prior to field data collection. The study participants provided written informed consent and the data generated are kept as confidential records. All the methods in this study were carried out in accordance with relevant guidelines and regulations (such as Declaration of Helsinki).

Funding

This work was supported by the Royal Society of Tropical Medicine and Hygiene [GT21/14282/GB], and the Afrique One-African Science Partnership for Intervention Research Excellence [Afrique One-ASPIRE/DEL-15-008]. The funders had no role in the study.

Author contributions

Conceptualization, all authors; **methodology**, all authors; **validation**, G.F., J.H., G.I.M., K.K.A., B.B. and J.Z.; **formal analysis**, F.S.N.; **investigation**, F.S.N.; **resources**, B.B., J.H., J.Z. and G.F.; **data curation**, F.S.N.; **writing—original draft preparation**, F.S.N.; **writing—review and editing**, all authors; **visualization**, F.S.N., and J.H.; **supervision**, G.F., G.I.M., K.K.A., B.B. and J.Z.; **project administration**, F.S.N. and B.B.; **funding acquisition**, K.K.A., B.B. and J.Z. All authors have read and agreed to the published version of the manuscript.

Declaration of Competing Interest

The authors declare that they have no competing interests.

Availability of data and materials

All data generated or analyzed during this study are included in this published article, and its supplementary files.

Acknowledgements

We would like to acknowledge the livestock farmers and agricultural department staff in all the study districts for their participation in this study. The corresponding author is grateful to the State Secretariat for Education, Research, and Innovation (SERI) of Switzerland for the scholarship to fund his doctoral studies during which this study was conducted.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2023.105919.

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