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Brucellosis in dairy herds: Farm characteristics and practices in relation to likely adoption of three potential private–public partnership (PPP) vaccination control strategies in West and Central Africa

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Abstract

Brucellosis is regarded as one of the highest burden zoonotic diseases to persist in many regions globally. While sustained vaccination against *B. abortus* in an endemic setting can markedly reduce the prevalence of large ruminant and human brucellosis and benefit local livelihoods, the implementation of effective and sustainable control programmes has often failed in the worst affected areas. In a cross-sectional study of 728 peri-urban dairy farmers in nine areas of six West and Central African countries, levels of commercialization and farm characteristics were examined alongside *B. abortus* seroprevalence estimates to hypothesize the most appropriate

Science and Technology Laboratory (DSTL), Department for International Development (DFID), Economic and Social Research Council (ESRC), Medical Research Council (MRC) and Natural Environment Research Council (NERC). This project represents one of 11 programmes funded in total and was funded under the title, 'Establishment of a multi-sectoral strategy for the control of brucellosis in the main peri-urban dairy production zones of West and Central Africa'. The funders had no input in the design, collection, analysis and interpretation of data, the writing of the report or the decision to submit the article for publication.

model for brucellosis vaccination delivery in each country. Demographic and economic data were collated and used to describe the farming systems currently in place. Furthermore, these data were utilized in a likelihood assessment to generate a quantitative score to hypothesize which of three private-public partnership (PPP) vaccine delivery models, that is 1) transformative, 2) transactional or 3) collaborative, would be most appropriate in each setting. The study sites had substantial differences in their levels of dairy commercialization and the farming practices employed; the heterogeneity across the study sites was evident in the conclusions of which models would be appropriate for vaccination delivery. While Lomé (Togo) had a strong indication for a transformative PPP model, Burkina Faso had strong indication for the collaborative PPP model. Of the remaining study sites, the scores were less dominant for any one model with Cameroon and Ivory Coast sites only just scoring highest on the transformative model and Senegal and Mali sites only just scoring highest on the collaborative model. Interestingly, none of the countries included in the study scored highest on the transactional model which currently is the most commonplace delivery model in the majority of sub-Saharan African countries.

KEYWORDS

brucellosis control, cattle, dairy herds, private-public partnership, vaccination, West and Central Africa

1 | INTRODUCTION

Many endemic diseases in sub-Saharan Africa hinder the development of the livestock sector. Of these diseases, zoonotic infections are amongst those with the highest social and economic burden due to the cross-cutting effects they have on human health in the general population and livelihoods of the poorest livestock keepers due to decreased productivity (McDermott & Arimi, 2002). Amongst these zoonotic diseases, brucellosis is often cited as the disease posing highest burden despite there being vaccines effective at reducing the frequency of infection in the animal host (Franc et al., 2018; WHO/DFID, 2006).

Brucellosis is a zoonotic disease caused by gram-negative coccobacilli bacteria belonging to the *Brucella* genus. Four of the twelve *Brucella* species are recognized to be responsible for the vast majority of human cases, these being *B. abortus*, *B. melitensis*, *B. suis* and *B. canis* (Corbel, 2006). Vaccines against brucellosis are available for domestic ruminant species (cattle, sheep and goats) and are considered the main tool for both reducing prevalence in livestock and preventing zoonotic transmission (Moriyon et al., 2004). Ruminant brucellosis has been successfully eliminated in Australia, New Zealand, Canada, Japan and several European countries through the vaccination of susceptible animals, followed by a test-and-slaughter policy (OIE, 2020).

The disease, however, is still found globally, and its impact is often most acutely felt in endemic settings in parts of Africa, Asia and Central and South America (Akakpo et al., 2009; Maleki et al., 2015). In humans, brucellosis causes flu-like symptoms and chronic debilitating illness. It often manifests as recurrent bouts of fever, which can be misdiagnosed as drug-resistant malaria and lead to underestimation of its incidence (Chabasse et al., 1983; Dean et al., 2012). The main routes for human infection are consumption of contaminated dairy products and contact with infected ruminants (Charters, 1980). In livestock, brucellosis decreases productivity by causing abortions, reducing fertility and decreasing milk yield (Corbel, 1988).

It is widely accepted that sustained vaccination of animals in an endemic setting can markedly reduce the prevalence of ruminant and human brucellosis and benefit local livelihoods. The vaccine endorsed by the World Organisation for Animal Health (OIE) for the prevention of brucellosis in cattle is *B. abortus* S19, which remains the reference vaccine with which any other vaccines must be compared (OIE, 2018). It is used as a live vaccine and is normally given to female calves aged between 3 and 6 months as a single subcutaneous dose. A reduced dose can be administered subcutaneously to adult cattle but is often avoided as animals can develop persistent antibody titres and may abort following vaccination and excrete the vaccine strain in the milk posing a human health risk. Alternatively, the vaccine can be administered to cattle of any age as either one or two doses, given by the conjunctival route, which induces immunity without a persistent antibody response and reduces the risks of abortion and excretion in the milk when vaccinating adult cattle (OIE, 2018).

There is historical serological evidence of widespread brucellosis infection in cattle in the West and Central African region (Akakpo & Ndour, 2013), but there is limited availability or use of brucellosis vaccination (Craighead et al., 2018). Extensive human population growth and high rates of urbanization mean this region is globally one of the most rapidly evolving (Craighead et al., 2018). This changes food consumption practices, and therefore, farming systems which are becoming increasingly intensive (Ducrotoy et al., 2015). In a recent study in the region, herds still practising transhumance were found to be at lower risk of being brucellosis seropositive than those that were sedentary; it was suggested that a decrease in transhumant herds is occurring in evolving peri-urban settings (Musallam et al., 2019). It is important to consider the nature and speed at which these farming systems are evolving in order to evaluate the impact on the epidemiology of disease. This in turn will facilitate a better understanding of what control strategies are warranted, feasible and sustainable. As challenges and demands on dairy production evolve, farmers' practices and behaviours will alter accordingly. Understanding and incorporating these changes into planning is paramount for efficient and effective policy development which will be fit for purpose.

Health service utilization is a well-studied area. Since its first inception some sixty years ago, multiple theories, models and frameworks have been developed and expanded to investigate factors that affect personal and societal use of particular services for both preventative and curative medicine in the human and veterinary service (Batista Ferrer et al., 2015; De Vries et al., 1988; Hardaker & Lien, 2010; Hopman et al., 2011; Looijmans-van den Akker et al., 2009; Rat-Aspert & Fourichon, 2010; Sok et al., 2014, 2016; Velde et al., 2018). Commonly used theories in healthcare utilization research are the theory of planned behaviour which is an expansion of the reasoned action approach (Ajzen & Fishbein, 1980) and the health belief model (Rosenstock, 1974). There has been extensive work developing social psychological decision models within these theories, but one major criticism is that they do not fully account for the broader impacts of extrinsic factors such as political, economic or environmental or inter- and intrapersonal influences (Velde et al., 2018). In their theoretical framework, Andersen and Newman (1973) addressed this problem to a degree; they identified three important areas to consider when assessing health service utilization these being (1) characteristics of the health services delivery system, (2) changes in medical technology and social norms, and (3) individual determinants of utilization. To assess the third area, they developed a behavioural model under the assumption that a sequence of conditions contributes to the type and volume of health service a person uses. In their model, Andersen and Newman identified factors in three categories (predisposing factors, enabling factors and need level) which they deemed influential on people's utilization of human health services in America. Although not extensively used in veterinary healthcare research, we propose that this framework is appropriate to investigate vaccine uptake by cattle farmers.

Many sub-Saharan African countries were placed under structural adjustment programmes (SAPs) in the 1980s as a pre-condition of the International Monetary Fund and the World Bank providing debt relief and loans. These programmes involved adjustment of many government services and legislation to enhance economic performance by allowing unbridled market forces to drive the economy (Amoako-Tuffour et al., 2018; Hollinger & Staatz, 2015). Combinations of different policies were adopted such as privatization, fiscal austerity, free trade and deregulation. These policies and changes were indeed successful in some circumstances where often government provision of livestock services came under increasing criticism for high costs and limited effectiveness. However, it was often only the high potential areas and market-orientated systems such as intensive dairy farming that were adequately served by these markets while marginalized areas and poorer livestock keepers continued to lack adequate access to animal health services (David, 2003; Ilukor et al., 2015; Magnani et al., 2019). In many sub-Saharan African countries, these negative effects coupled with high burdens of endemic diseases means that the resources to carry out effective brucellosis control and surveillance are frequently lacking. When disease control programmes are entirely managed and funded by government or NGOs, they often become unsustainable when competing demands on resources arise and may suffer from inadequate execution or abruptly come to a halt when funds end (Angba et al., 1987; Camus, 1995; Thys E. et al., 2005). Through the effects of SAPs and in response to limited resources of government bodies, privatization and decentralization of animal health services have occurred to varying degrees in many countries. While in some circumstances this has led to more consistent and accessible services there are many examples where certain livestock keepers are disadvantaged as they experience high transaction costs to access such services and less profitable regions or health issues are neglected in a profit-driven private sector (Pica-Ciamarra, 2005).

Looking at inadequacies of past programmes and considering the widespread effects of urbanization on demand and consequently production practices as well as the penetration of Internet technologies and commercial suppliers, the need for design and implementation of new delivery models for brucellosis control in livestock is becoming evident. There are many examples of different models for service delivery in both agricultural and livestock systems globally where the need to align public and private partnerships has been recognized as a corner stone for effective and sustainable delivery of services and goods (Holden, 1999). Indeed, the promotion of public-private partnerships (PPP) by organizations such as the Food and Agriculture Organization of the United Nations (FAO) and OIE has been at the forefront of both animal health provision and agricultural development globally (OIE, 2019). In relation to veterinary services a PPP is defined as 'a collaborative approach in which the public and private sector share resources, responsibilities and risks to achieve common objectives and mutual benefits in the field of veterinary services in a sustainable manner' (Thevasegayam et al., 2017). Recently, Galière et al., (2019) defined a typology for PPPs in the veterinary field; they proposed three types of PPP by performing multiple correspondence analysis (MCA) on data gathered from PPP programmes running globally. They found two factors to be highly significant in defining the types, namely (1) the category of the main private partner collaborating with the public sector and (2) the type of interaction between the partners. They define transactional

PPPs as those often seen as the traditional understanding of PPPs which are initiated and funded by the public sector who contract out certain service delivery to private veterinarians under a client/private provider contract agreement. Collaborative PPPs were defined as partnerships between consortia or producer associations and the public veterinary services and driven by trade interests. The last type was the transformative PPP which represents joint programmes initiated and funded by private companies, often large aid donors or NGOs, to establish sustainable capability to deliver otherwise unattainable major programmes. Examples of transactional PPPs are found in many sub-Saharan African countries such as in Mali where for more than 20 years the veterinary services have delegated certain service provision such as peste des petits ruminants and contagious bovine pleuropneumonia vaccination through the Animal Health Mandate to private veterinarians. This has resulted in improved vaccine coverage, better animal health and therefore food security (OIE, 2019). For the last 10 years, a transformative PPP has been in place between the Ethiopian Ministry of Agriculture and its private partner Ethiochicken. This agreement has increased chicken production in Ethiopia; the private partner produces quality chicks, affordable feed and provides robust farm management training for rural farmers, their agents reach smallholder farmers by partnering with government extension workers, while the public sector provides the necessary vaccines and financial loans for start-up investment for youth and woman to become involved in the chicken production value chain (OIE, 2019). An emergency animal health fund was set up through a collaborative PPP in Namibia; the fund was mobilized during an FMD outbreak in 2015. The private partner, the Meat Board of Namibia (MBN), was able to assist immediately the Directorate of Veterinary Services to set up control measures. The MBN also took responsibility for country-wide awareness campaigns, the appointment of expert consultants, appointing and coordinating veterinarians to conduct post-vaccination sero-surveys, provision of rations to temporary staff manning roadblocks and coordinating via the farmer's associations, the assistance of farmers bordering the Veterinary Cordon Fence to patrol, maintain and repair the fence where necessary (OIE, 2019). The OIE has now adopted this typology of PPP and authored a handbook to describe the set up and running of such agreements (OIE, 2019).

The aim of this study was to describe the commercialization and farming practices in peri-urban dairy cattle farms in six West and Central African countries where cattle brucellosis is endemic and to evaluate the appropriateness of brucellosis vaccination programmes through the three different delivery models outlined above.

2 | METHOD

2.1 | Study sites and data collection

Data for this study were collected in conjunction with a wider study to estimate brucellosis herd seroprevalence in cattle in the region; details of the full methodology are described elsewhere (Musallam et al., 2019) and a short summary is provided here. Cross-sectional studies were conducted in nine peri-urban dairy production zones across six West and Central Africa countries between February 2017 and January 2018, namely in Burkina Faso (Ouagadougou), Cameroon (Bamenda and Ngaoundere), Ivory Coast (Abidjan), Mali (Bamako), Senegal (Dakar, Thies and Niakhar) and Togo (Lomé) (Figure 1).

The target population was defined as 'all bovine dairy herds present in the predefined peri-urban zone'. The study unit was defined as 'any herd where lactating cows are managed together as a unit regardless of herd size'. The boundaries for each 'peri-urban zone' were defined through consultation with personnel from the veterinary and livestock production services, dairy farm associations and private veterinarians in each zone.

A structured questionnaire was designed under the principles of the Andersen–Newman behaviour model (Andersen & Newman, 1973) applied to the utilization of cattle vaccination by farmers (Table 1). In the behavioural model, three categories are identified as being important contributors to an individual's utilization of a service. The first category was defined as predisposing factors, stating 'Some individuals have a propensity to use services more than other individuals, where propensity toward use can be predicted by individual characteristics which exist prior to the onset of specific episodes of illness'. We suggest that the type of farm and the farmer's current behaviour around biosecurity and preventative care fit into this category (Table 1) and would identify if a farmer is more likely to uptake vaccination for brucellosis. The second category encompasses enabling factors under the assumption that 'even though individuals may be predisposed to use health services, some means must be available for them to do so'. Under this category, there are three factors associated with finance as a farmer must have available cash flow to fund vaccination unless it is under a free service; breeding practices have also been included here under the assumption that those farmers who are utilizing artificial insemination will have suppliers/technicians visiting them which could be utilized as an important information and vaccine delivery component under a collaborative model (Table 1). The -third category is defined as need (or illness level) which broadly covers the level of illness either in perception by individuals or the probability of its occurrence. Here, we include the seroprevalence level as a proxy for the threat of brucellosis infection, and we also include dairy output assuming that farmers who have a higher output and more reliance on dairy income will have more need to maintain or improve their production through control of the production limiting effects of brucellosis. The questionnaire data were utilized to provide summary statistics and to perform logistic regression to evaluate the theoretical reasoning for including certain variables in the behavioural model and likelihood assessment.

The questionnaire was administered using Open Data Kit (ODK) on Android tablets in a choice of English or French (see Appendix 1).[1] Herd name, location, composition (number of lactating cows, bulls and heifers), husbandry and management practices as well as economic data were recorded. A pilot questionnaire was administered in ten herds in the study area of Dakar and then modified accordingly to form the final version. Local enumerators in each of the sites who were experienced in quantitative data

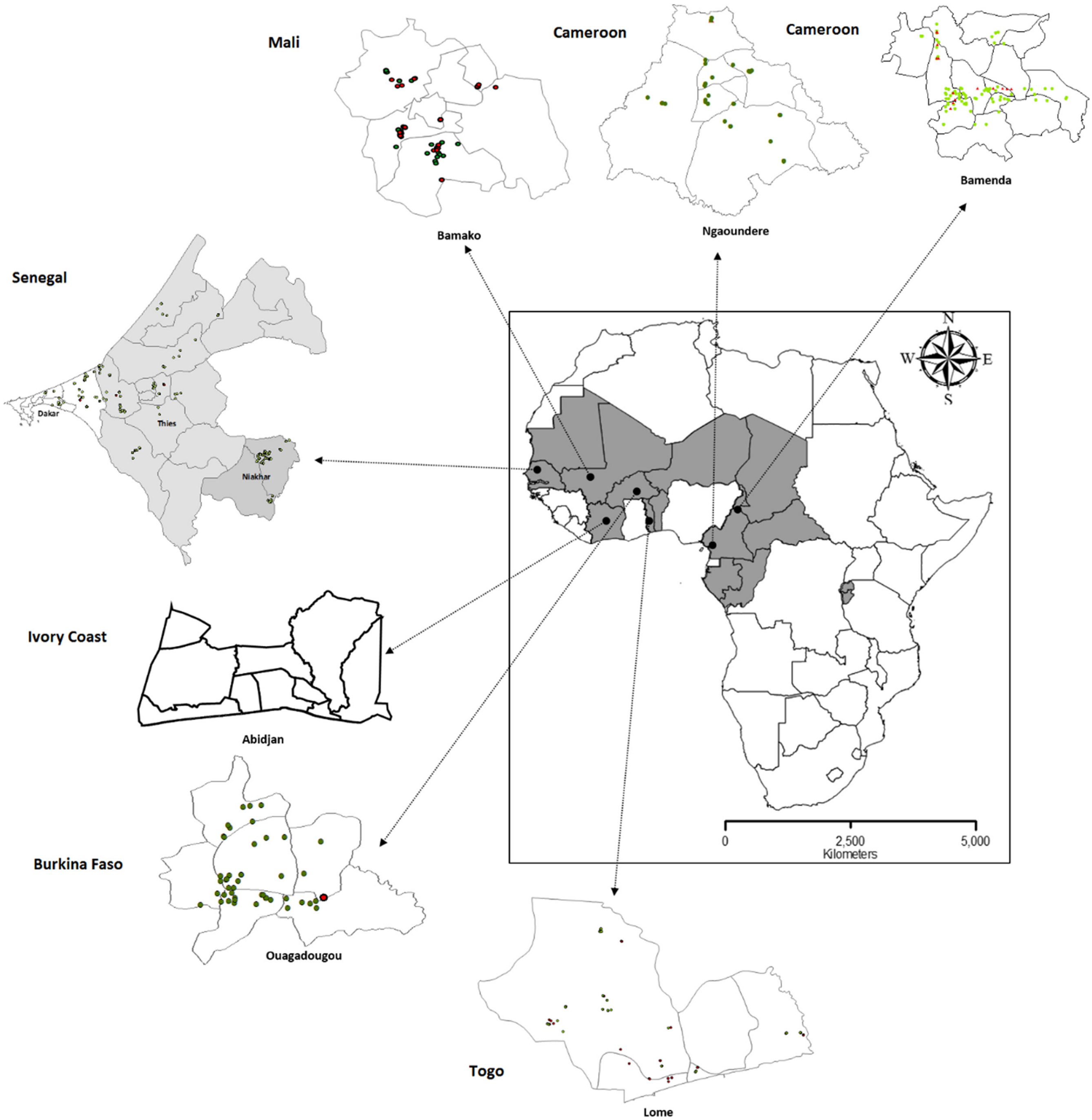

FIGURE 1 Study locations within Africa

TABLE 1 Andersen-Newman behavioural model categories (column headings) and variables selected from logistic regression modelling of questionnaire data and included in the likelihood assessment

Predisposing factors	Enabling factors	Need (illness level)
Farm classification	Breeding practices	Dairy output
Breed type	Dairy income	Seroprevalence level
Quarantine	Input spend	
Vaccine use	Milk price	

collection were employed and trained by project staff from the Interstate School of Veterinary Science and Medicine of Dakar (EISMV). Enumerators followed written guidelines which were provided in French and questions were posed using the appropriate local language. A bulk milk sample was collected from the herd at the same time as the questionnaire was completed for the seroprevalence study.

Ethical approval was granted by the Ethics and Welfare Committee of the Royal Veterinary College (RVC) and the Ethics Committee at the Interstate School of Veterinary Science and

Medicine of Dakar (EISMV) (URN 2015 1347). Informed consent for questionnaire administration and collection of biological samples was obtained verbally from herd owners before sampling and interviewing. Each study was conducted using the same protocol, and any departures from protocol were recorded.

2.2 | Data analysis

All questionnaire data were uploaded to Stata 12.2 in order to produce summary statistics and perform logistic regression (see below). Monetary values are given in Communauté Financière Africaine francs (XOF) as of October 2018; 1 USD = 569 XOF.

2.2.1 | Private-public partnership models

Three PPP types were used to hypothesize potential vaccine delivery models for brucellosis vaccination in the study areas. We did not include a fully public service as in the setting of our study all government services would require the private sector at some point in order to deliver a full coverage of service nationally.

The three model types for vaccination delivery were defined as follows based on OIE (2019):

1. Transformative: Initiated by the private sector but sanctioned by, and working with the public sector to establish an otherwise unattainable major programme. Funded initially by international development assistance or national/international philanthropic or charitable organisations. Joint governance such as a Memorandum of Understanding between the private and public partners.
2. Transactional: Government procurement of vaccination services from private veterinary service providers (veterinarians/paravets). Initiated and funded by the public sector with further payment from the farmers for service. Governance is a client/private provider relationship. The private provider is contracted and trained/monitored by the public sector. The activities and intended outcomes are primarily defined by the public sector and contracts set out effective monitoring and evaluation mechanisms for remedial action if needed.
3. Collaborative: Joint commitment between the public sector and beneficiaries, for example producer associations, consortia or mutual societies. Jointly resourced between the public sector and private entities including dairies, milk associations, feed merchants, artificial insemination companies, agricultural suppliers and supermarkets. Governance may range from legislative to light touch and decision making is shared between the collaborating parties.

2.2.2 | Likelihood assessment

The likelihood assessment was conceptualized to give a quantitative output score for each PPP vaccine delivery model in each country. Guided by the three categories of the Andersen–Newman behavioural model, we hypothesized what farm and farmer characteristics could be expected to influence a farmer's utilization of a paid-for brucellosis vaccination service. These assumptions were further investigated by means of univariate logistic regression of the data testing the association between individual variables and a farmer's reported use of any vaccination in their cattle accounting for aggregation of observations within study areas by stratification. Consideration of the regression output (effect and strength of evidence) combined with the rationale for a variable's inclusion based on Andersen–Newman principles led to the inclusion of 9 questionnaire variables in the likelihood assessment (Table 1). Additionally, the seroprevalence levels (Musallam et al., 2019) from the wider project were included as a variable in the need category of the behavioural model. For each setting and factor, a three-point score (0 = not conducive to model, 1 = moderately conducive, 2 = most conducive) was awarded individually for each of the three vaccine delivery models (Table 2). To define the level for each variable, assessment of the distributions of questionnaire data was first performed and three levels were proposed. These levels were presented to regional veterinary researchers from the Veterinary School of Dakar who gave their expert opinion on both the level and rationale. The three-point score for each study setting and variable was then awarded on the basis of the data analysed from the questionnaire. The total score for each setting and vaccine delivery model was summed, and the model with the highest total score was deemed as most likely to succeed in that setting.

3 | RESULTS

3.1 | Participant demographics and farm characteristics

In total, 728 farmers agreed to participate in the study by answering the questionnaire and allowing bulk milk from their cattle to be sampled (Table 3). In all sites other than Ouagadougou (Burkina Faso), the majority of respondents were the household head or the farm owner. Nearly all respondents were male with only a few females in the Cameroon and Senegal sites (Table 3). All seroprevalence estimates referred to were presented by Musallam et al., (2019).

In Lomé (Togo), large subsistence herds of indigenous breeds (Figure 2) with low milk output were predominant (Table 4). The large majority of farmers (96.1%) participated in transhumance and very few in disease control measures such as vaccinating or quarantining new animals. The highest occurrence of brucellosis seropositive herds (over 60% being positive) was found in the Togo site (Figure 4). The study site in Ivory Coast (Abidjan) had many similarities to the one in Togo in that there were mostly traditional farms practicing transhumance (Table 4) with large herds of predominantly local breed cattle (Figure 2). In contrast to the Togo site, most farmers in Abidjan reported receiving some income from dairy farming (Table 6) and there was widespread reporting of vaccine use with 95% saying they used vaccines in their herds (Table 5). The herd

TABLE 2 Likelihood assessment—parameters and levels utilized for assigning scores to indicate best-fit vaccine delivery model

Farm level factors	Level	Transformative PPP score	Transactional PPP score	Collaborative PPP score	Rationale for scoring
Farm classification	>20% of modern farmers*	0	2	2	Farmers practising modern techniques are more likely to use different inputs into their animals to increase productivity and to be driven by profit; the higher the proportion in the population therefore the more likely paid-for inputs are to succeed.
	10%–20% of modern farmers	1	1	1	
	<10% of modern farmers	2	0	0	
Breed type	<50% keeping local breeds only	0	2	4	Farmers keeping imported breed types do so mainly to increase productivity and profit and therefore are more likely to spend on inputs and to be receptive to interventions to increase productivity and profit. Double weight is given in the collaborative model as breeding and buying imported cattle represents a potential market avenue for vaccine delivery.
	50%–90% keeping local breeds only	1	1	2	
	>90% keeping local breeds only	2	0	0	
Breeding practices	>40% use of artificial insemination by farmers	0	2	4	Farmers utilizing artificial insemination technologies are paying for inputs to increase productivity. Double weight is given in the collaborative category as this service also represents penetration of the population which is a possible market route for vaccine delivery.
	10%–40% use of artificial insemination by farmers	1	1	2	
	<10% use of artificial insemination by farmers	2	0	0	
Dairy income	>70% of farmers receive income from dairy activities	0	2	2	The higher the proportion operating in a commercial way the easier it is to drive disease control options which increase productivity or profit.
	50%–70% of farmers receive income from dairy activities	1	1	1	
	<50% of farmers receive income from dairy activities	2	0	0	
Input spend	>8,000 XOF mean spend per cow/month	0	2	2	The amount farmers spend on inputs indicate the willingness to spend on a paid-for input such as vaccination.
	2,000–8,000 XOF mean spend per cow/month	1	1	1	
	<2,000 XOF mean spend per cow/month	2	0	0	
Quarantine	>50% of farmers quarantine newly introduced animals	0	2	2	The higher the proportion of farmers that are aware of and voluntarily undertake disease control measures, the more likely disease control programmes are to succeed.
	10%–50% of farmers quarantine newly introduced animals	1	1	1	
	<10% of farmers quarantine newly introduced animals	2	0	0	
Vaccine use	<10% of farmers using vaccines	2	2	0	The proportion of farmers already aware of and utilizing vaccines indicates the likely success of a vaccination programme. Voluntary or paid-for programmes require the understanding of vaccine use and the intention of farmers to partake. Farmers not using vaccines currently may need to be legislated or encouraged more broadly to utilize vaccines
	10%–80% of farmers using vaccines	1	1	1	
	>80% of farmers using vaccines	0	0	2	
Dairy output	>3 litres per cow/day	0	2	2	The economic gains for farmers with low yielding cattle will be less, meaning less of a drive to control the disease through paid-for inputs.
	2–3 litres per cow/day	1	1	1	
	<2 litres per cow per day	2	0	0	

(Continues)

TABLE 2 (Continued)

Farm level factors	Level	Transformative PPP score	Transactional PPP score	Collaborative PPP score	Rationale for scoring
Milk price	>400 XOF/Litre	0	2	2	The higher the amount the farmer is receiving for milk, the more cash flow there is for spending on input and also the more drive to increase productivity.
	320–400 XOF/Litre	1	1	1	
	<320 XOF/Litre	2	0	0	
Seroprevalence level (herd level)	<5%	0	0	0	The higher the burden of disease the stronger the incentive to implement control. Double weight is given to the transformative model as there is onus on government and donor organizations to tackle priority disease at this level.
	5%–20%	2	1	1	
	>20%	4	2	2	

*Self-reported as practicing modern farming as opposed to traditional practices.

TABLE 3 Descriptive statistics of survey participants

Country	Respondent's Role				Sex		Mean age in years (range)
	Most senior member of household (farm owner) *N* (%)	Other household member (or farm worker) *N* (%)	Technician/ Paravet *N* (%)	Veterinarian managing farm *N* (%)	Male *N* (%)	Female *N* (%)	
Burkina Faso (*N* = 47)	17 (36.2%)	22 (46.8%)	8 (17.0%)	0 (0%)	47 (100%)	0 (0%)	38 (23–53)
Cameroon (*N* = 187)	123 (56.8%)	59 (31.6%)	5 (2.7%)	0 (0%)	176 (94.1%)	11 (5.9%)	39 (36–41)
Ivory coast (*N* = 71)	69 (97.2%)	1 (1.4%)	1 (1.4%)	0 (0%)	71 (100%)	0 (0%)	39 (35–43)
Mali (*N* = 67)	54 (80.6%)	13 (19.4%)	0 (0%)	0 (0%)	66 (98.5%)	1 (1.5%)	43 (25–61)
Senegal (*N* = 278)	218 (78.4%)	58 (20.9%)	2 (0.7%)	0 (0%)	275 (98.9%)	3 (1.1%)	44 (41–46)
Togo (*N* = 78)	41 (52.6%)	37 (47.4%)	0 (0%)	0 (0%)	78 (100%)	0 (0%)	32 (30–34)

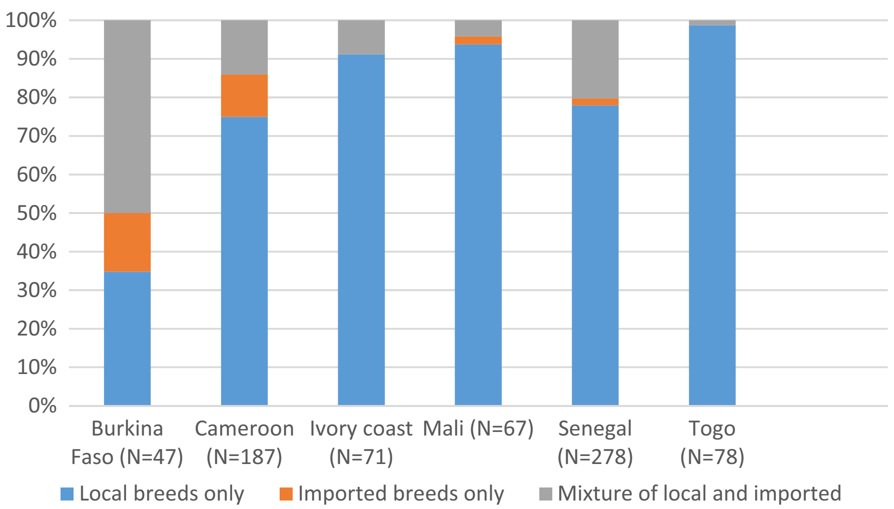

FIGURE 2 Dairy breed types kept by farmers

seroprevalence estimate was lower in Abidjan than in Lomé but still considerable at 23% (Figure 4). In contrast to Lomé, Ouagadougou (Burkina Faso) had a large proportion of farmers who identified as modern[2] - (Table 4), keeping imported high-producing cattle (Figure 2) with relatively smaller herds and higher input spends per cow (Table 6). Artificial insemination was widely used (Figure 3), and all farmers generally partook in some disease control measures already (Table 5). Ouagadougou was the only site where farmers were accessing *Brucella* vaccine (Table 5). Through the private route, approximately a quarter of farmers reported already administering brucellosis vaccine to their cattle. Study sites in Senegal, Cameroon and Mali were comparable on many factors examined although there were some marked differences. There was a very high level of transhumance in Senegal where over 90% of respondents reported this

TABLE 4 Descriptive statistics of farm characteristics

Country	Farm ownership Number of herds (% of herds)		Herding practice Number of herds (% of herds)		Farm type Number of herds (% of herds)		Other livestock keeping Number of herds (% of herds)			Staff number (mean)	Cattle numbers (mean)	Mean milk yield per cow (litres)	Mean milk selling price (per litre) in XOF
	*Mixed**	*Single*	*Not transhumant*	*Transhumant*	*Modern*	*Traditional*	*Farms keeping sheep*	*Farms keeping goats*	*Farms keeping pigs*				
Burkina Faso (N = 47)	3 (6.4%)	44 (93.6%)	7 (14.9%)	40 (85.1%)	28 (59.6%)	19 (40.4%)	42 (89.4%)	29 (61.7%)	10 (21.3%)	3.6	27.4	2.2	387
Cameroon (N = 187)	31 (16.6%)	156 (83.4%)	58 (31.0%)	129 (69.0%)	27 (14.4%)	137 (73.3%)	60 (32.1%)	47 (25.1%)	20 (10.4%)	1.9	36.6	2.2	328
Ivory coast (N = 71)	15 (21.1%)	56 (78.9%)	13 (18.3%)	58 (81.7%)	2 (2.8%)	69 (97.2%)	9 (12.7%)	6 (8.5%)	1 (1.4%)	2.7	41.5	1.3	395
Mali (N = 67)	0 (0%)	67 (100%)	49 (73.1%)	18 (26.9%)	11 (16.4%)	56 (83.6%)	32 (47.8%)	16 (23.9%)	0 (0%)	2.3	33.6	2.3	373
Senegal (N = 278)	174 (63.5%)	100 (36.5%)	16 (5.9%)	256 (94.1%)	29 (10.4%)	247 (88.8%)	130 (46.8%)	145 (52.2%)	37 (13.2%)	2.8	31.7	1.7	525
Togo (N = 78)	19 (24.4%)	59 (75.6%)	3 (3.9%)	75 (96.1%)	3 (3.8%)	75 (96.2%)	17 (21.8%)	18 (23.1%)	0 (0%)	3.6	72.3	1.4	376

*Mixed ownership refers to a herd which is managed by one person but consists of animals belonging to different owners, often within the same household or village.

activity (Table 4) as opposed to only a quarter in both Cameroon and Mali. There was higher use of any vaccines amongst farmers in Cameroon (95%) and Mali (97%) compared to Senegal where only 70% reported such use (Table 5). There was only minimal use of artificial insemination in Cameroon (10%); around a quarter of farmers utilized it in Mali while in Senegal it was slightly higher at around 35% of farmers (Figure 3). While Senegal had low levels of herd seroprevalence in all three areas tested, Cameroon had more moderate levels at 14% in one site and Mali had a higher estimate of 33% herds showing signs of exposure (Figure 4). In all study sites, farmers identified diseases and access to grazing lands as the predominant barriers to farming (Figure 5).

3.2 | Logistic regression and likelihood assessment

In the univariate logistic regression (Table 7), 13 variables were analysed for association with reported use of any cattle vaccination in the past. Following analysis, 8 were included in the likelihood assessment; the variables omitted from the likelihood assessment were farm ownership, respondent age, sex, cattle number and herding practice. Farm ownership was defined as either mixed or single; the mixed ownership model was only prevalent in Senegal with all other locations reporting very few farms under this model. As a result, the p-value for this variable was reasonably large and too little was known about the decision-making power or structure to include it. Age and sex were omitted as, although there was evidence of increased odds of vaccination in the categories, the distribution of these factors in each setting were not significantly different and therefore would have little effect on the score for vaccination models. Farm classification (modern or traditional), herding practices (transhumant or not) and cattle numbers were closely correlated as traditional herds tend to practice transhumance and be much larger in number. It was decided therefore to add only farm type into the assessment as it encompasses the other variables, but also has the important effect in that the more modern farms there are in a setting, the more farmers are likely to adopt inputs to increase productivity. Reported vaccination use was also included in the likelihood assessment as well as the seroprevalence estimates from the wider study. The questionnaire included a section on brucellosis knowledge which started by asking participants if they had heard of brucellosis; if they answered no, the rest of this section was omitted. The answers showed that the majority of participants in each setting had not heard of brucellosis. Consequently, there were not enough data points on brucellosis knowledge to include this in the analysis.

The quantitative scores for the likelihood assessment (Table 8) show that Cameroon, Ivory Coast and Togo score highest for the transformative model of vaccine delivery, while Burkina Faso, Mali and Senegal score highest for a collaborative model. The scores for all three delivery models are very similar in both Mali (11/11/12) and Cameroon (10/8/9).

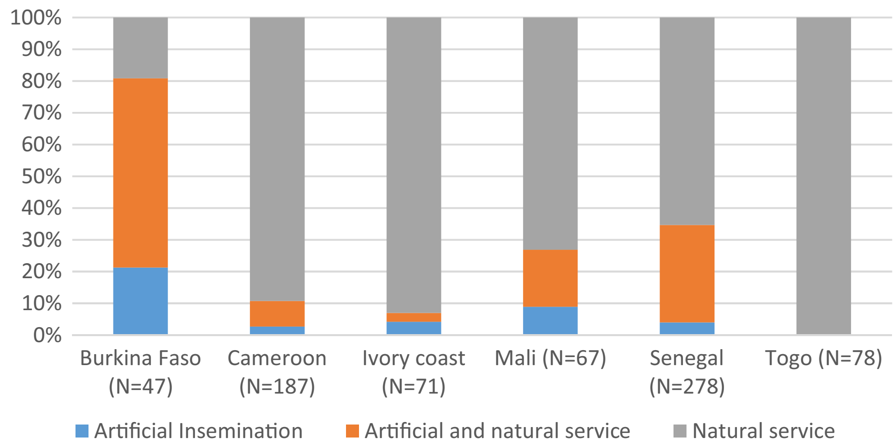

FIGURE 3 Proportions of farmers practicing different breeding methods

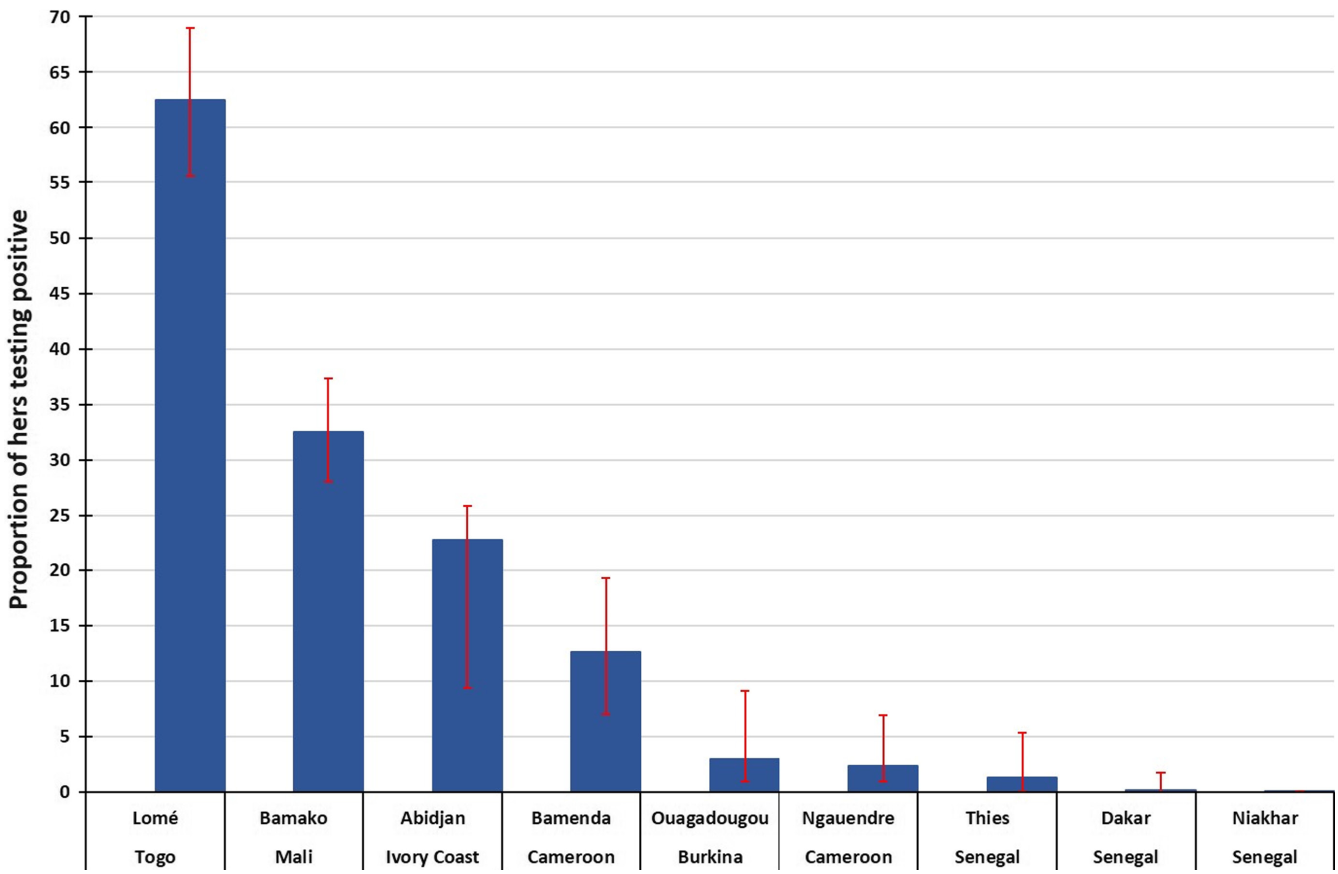

FIGURE 4 Herd-level brucellosis seroprevalence estimate with 95% confidence interval adapted from study by Musallam et al., (2019)

4 | DISCUSSION

In this study, we aimed to characterize the commercialization levels and farming practices in selected peri-urban farming areas in six West and Central African countries and evaluate how these characteristics might influence which PPP delivery models may fit best to implement brucellosis control through vaccination. The results indicate a heterogeneity over the nine study sites in the structure and operation of the peri-urban dairy sector. There is a clear distinction between Lomé (Togo) where the sector seems much less commercially oriented and Ouagadougou (Burkina Faso) where the use of high production breeds and more intensive farming practices are evident. The other sites lie on a spectrum between these two in their level of commercial drive and movement from traditional subsistence farming to business enterprise. Of the three vaccine delivery models proposed, no country scored highest for the transactional PPP model in the likelihood assessment despite this being the most commonplace delivery model for vaccination in the majority of sub-Saharan African countries. Although this model has been widespread since the structural adjustment programmes of the 1980s and 1990s, it has often been criticized for being driven by international development and donor agencies with little input or understanding from local government as to the logic behind or the structural barriers to privatization (Ahuja, 2004). Markets do not function in a vacuum and require strong institutions and appropriate legislation to regulate behaviour and enforce contracts. Equally, demand for such private services often falls short of the level required to sustain profitable private veterinary practice for services such as specific disease control through vaccination. As a result, there are multiple examples where this model has failed to produce the desired outcomes of widespread and affordable coverage of services. Many of the intended end users are alienated from service use due to high transaction costs, and often higher costs are encountered by the public sector to draft and enforce contracts than would be were they to provide the service 'in house'.

The Andersen–Newman behavioural model has been widely used and modified for many settings to assess factors associated with the utilization of services divergent from the initial use of investigating primary human healthcare utilization in America (Ameyaw et al., 2017; Anthony et al., 2007). Despite its great adaption to many human health sectors, there has been very little use of this framework in veterinary medicine utilization research. By modifying and applying the behavioural model to individual farmer factors and farm characteristics, we have been able to hypothesize what characteristics of vaccine delivery systems (Andersen–Newman's first area of consideration) might be the best fit in this particular setting. To realize the full potential of our likelihood assessment and the use of the Andersen–Newman behavioural model in relation to veterinary service utilization, further research is required to establish which variables are most influential on a person's propensity to use a paid-for vaccination service. As can be seen in the output of our logistic regression, the confidence intervals are wide; none of the study settings had established vaccination programmes of a voluntary nature on a large scale. Consequently, participants were asked in general about any vaccination be it compulsory or voluntary for any disease. While this question captures past behaviour, it does not distinguish between the drivers to vaccinate dependent on the type of disease or programme components of importance such as the transaction costs to the farmer or ease of access to a service.

There has been much focus on promoting the use of PPPs to enhance veterinary healthcare service delivery; the OIE in 2019 published a handbook to encourage policymakers to adopt these models as a sustainable way of getting broader and more consistent healthcare coverage to farmers (OIE, 2019). While the three types of PPP outlined by OIE and utilized in this study are very useful to categorize the partners and contract types involved, they are by no means prescriptive. New innovative agreements with partners from different sectors and a mixture of contract types not fitting into these categories may develop and be most appropriate as farming systems and consumer demands evolve. The transactional PPP is commonplace in many countries where, following structural adjustment in the 1980s, many government veterinary services were reduced in size and capacity and encouraged to contract out to private providers by means of health mandates with private veterinarians. For this model to be successful, there has to be adequate commercial gain for the private veterinarians to meet the requirements of the contract and effective monitoring, evaluation and legislation to prevent contract failure between the parties. The infrastructure and institutional arrangements to enable the environment for such arrangements is often lacking which leads to the downfall of appropriate delivery of services (Claire Heffernan & Federica Misturelli, 2001; Nuhu, Mpambiji, & Ngussa, 2020). At present in the study countries, brucellosis vaccine is only available in Burkina Faso; farmers can voluntarily pay to access the vaccine through private veterinarians who have agreements with government for the procurement of vaccines. Only a quarter of farmers utilize this service which highlights either the limited coverage of the service or the limited uptake and demand from the farmer side which may be due to a perceived low risk of disease or lack of awareness about the disease, its consequences or available control options.

In countries such as Togo and Ivory Coast where commercialization of farms is less prominent but disease burden appears to be high, the transformative model scored highest. There is an obvious need to control the disease not least from a public health standpoint. Farmers may not be driven to control the disease on the basis of improving production and they also may not have the financial cash flow to invest in vaccination for their herds; they also have little interaction with other livestock extension workers or suppliers as their systems are low input. A transformative agreement where it is in the government's or NGO's interest to control an important disease could see the employment, training and engagement of private community animal healthcare workers (CAHW). This method of outreach to engage and reach farmers to supply free or heavily subsidized vaccines has proved successful where there is little incentive for private veterinarians to deliver the service (Catley et al., 2004; Ilukor, 2017). In order to engage farmers, it is important to understand the issues they face and incorporate vaccine delivery within other programmes that will lead to eventual self-sufficiency after initial heavy investment from private NGO or government funds. An example of a successful agreement of this nature in Kenya has seen Sidai, a private enterprise, form partnerships with the veterinary services and local government authorities to make a range of animal health products and extension services available to pastoralists as well as providing training on quality products, law enforcement around sub-standard or illegal drugs, cold chain maintenance, job opportunities and diagnostic services (Galière et al., 2019).

Burkina Faso, Mali and Senegal all scored highest for the collaborative model delivery, although they have quite differing characteristics individually. The main factors that influence this outcome in these sites are the level of commercialization and the associated farming practices and access to ancillary services. As this model is defined by shared interests of the end users and providers, there is a large scope to utilize different contractual structures that may be more sustainable as they can be orientated in an incentive-driven

TABLE 5 Practices on farms that relate to disease risks and disease control

Country	Borrowing a breeding bull from others *Number of herds (% of herds)*		Purchasing cattle *Number of herds (% of herds)*			Buying points *Number of herds (% of herds)*		
	Yes	No	Rarely *(most years do not purchase any cattle)*	Sometimes *(most years purchase new cattle at least once)*	Regularly *(purchase cattle several times a year)*	*Market*	*Herders*	*Dealer*
Burkina Faso (*N* = 47)	5 (10.6%)	42 (89.4%)	29 (61.7%)	13 (27.7%)	5 (10.6%)	19 (40%)	37 (79.3%)	6 (12%)
Cameroon (*N* = 187)	27 (14.0%)	160 (86.0%)	65 (34.8%)	48 (25.7%)	11 (5.9%)	159 (85%)	100 (53.2%)	38 (20.5%)
Ivory coast (*N* = 71)	17 (23.9%)	54 (76.1%)	32 (45.1%)	23 (32.4%)	16 (22.5%)	47 (66.7%)	44 (62.5%)	21 (28.9%)
Mali (*N* = 67)	16 (23.9%)	51 (76.1%)	38 (56.7%)	14 (20.9%)	15 (22.4%)	31 (46.9%)	37 (55.4%)	7 (10%)
Senegal (*N* = 278)	46 (15.0%)	232 (85.0%)	99 (35.6%)	119 (42.8%)	36 (12.9%)	220 (79.2%)	173 (62.1%)	91 (32.8%)
Togo (*N* = 78)	13 (16.7%)	65 (83.3%)	41 (52.6%)	37 (47.4%)	0 (0%)	69 (88.3%)	78 (100%)	4 (5.3%)

manner rather than a regulation or penalty manner as is often the case in imposed disease control policy implemented in a top-down style. It is important to consider the context of each setting in terms of the barriers and motivations facing farmers in each area and how this might influence the kinds of partnerships that would be most beneficial in the collaborative model. In areas where access to grazing or affordable inputs are a problem, the power of co-operatives or producer associations may enable group buying power and influence. Membership and benefits of this could come with certain agreements to meet milk quotas and specifications for risk-free milk, and therefore, it would be in the interest of farmers to comply with control and surveillance of important zoonotic disease risks such as brucellosis. In countries already utilizing artificial insemination technologies, mutual gains for both the service provider and the farmer could be achieved if technicians could combine vaccination services at the same time as visiting farms for breeding work. Technicians are a high-risk group for infection with brucellosis due to the close contact with reproductive materials they have. This risk would be reduced if the farms they serve have brucellosis control programmes in place. If these control programmes were offered through the insemination company farmers would then have easy and regular access to vaccines as well as the knowledge that transmission risk from the product and the technician is much reduced when using that company.

With the focus on specific peri-urban settings, the findings from this study are not generalizable to entire countries, but the trends and practices seen in these settings are important when considering the current and future systems in a rapidly evolving sector. Given the disparities often noted between rapidly evolving peri-urban farming and that of traditional rural and extensive farming, it may be more appropriate to address disease control at a more localized level to allow tailored programmes appropriate for the differing settings found nationally. Perhaps different vaccine delivery models may be appropriate within a country for the specific farming systems found across a nation. While we have theorized which vaccine delivery models may be most appropriate using farmer questionnaire data, there are many important aspects that have not been included which warrant further investigation. No data were gathered on consumer demand and expectations, government priorities and capacities for the livestock sector, and we do not have a deep understanding of farmers' awareness or knowledge of brucellosis or its control through vaccination. In our data collection, farmers were only asked if they had heard of brucellosis but we did not offer any other local names or further questioning on awareness of symptoms. Subsequent qualitative work with the same farmers indicated that they used many different local names for signs and symptoms which may be consistent with brucellosis (Craighead et al., 2021). A farmer's reported use of any vaccine in the past was used in the regression model, and no further information on the delivery model of the vaccines accessed by farmers was available. Therefore, the results obtained are extrapolated to represent behaviours associated with a hypothetical brucellosis vaccine programme. The scores awarded for the likelihood assessment are specific to the population distributions in our study settings and ultimately defined by expert opinion. Consequently, further research on a wider study cohort with defined vaccine uptake data would provide a stronger rationale for this novel approach. Despite this, our findings provide a comprehensive analysis of the farm and farmer aspects which have influence over appropriate and sustainable vaccination delivery methods for an important zoonotic disease. By providing a basis of which PPP model would fit best, the further areas of consideration can be investigated on an individual basis.

While the notion of PPPs and evaluation of animal health as either a public or private good is nothing new and indeed well published (Ahuja, 2004), the practice of incorporating these theories and research within the design and research outputs of epidemiological studies is less common. Our study provides a novel approach for assessing healthcare service delivery at the early conception phases and highlights areas for further research. The comparative demographic and production data presented are useful to parameterize cost-benefit models designed on the basis of the proposed vaccine delivery models.

Selling points Number of herds (% of herds)			Quarantine of newly introduced animals Number of herds (% of herds)		Use of vaccines Number of herds (% of herds)			
					Any vaccine		*Brucellosis vaccine*	
Market	*Herders*	*Dealer*	Yes	No	Yes	No	Yes	No
14 (29.3%)	35 (75%)	29 (62.5%)	31 (88.6%)	4 (11.4%)	47 (100%)	0 (0%)	12 (25.5%)	35 (74.5%)
179 (95.7%)	131 (69.8%)	60 (31.8%)	28 (23.5%)	91 (76.5%)	179 (95.7%)	8 (4.3%)	0 (0%)	187 (100%)
37 (52.3%)	32 (45.5%)	31 (43.9%)	19 (36.5%)	33 (63.5%)	68 (95.8%)	3 (4.2%)	0 (0%)	71 (100%)
25 (37.3%)	37 (55.2%)	6 (9%)	18 (26.9%)	49 (73.1%)	65 (97.0%)	2 (3.0%)	0 (0%)	67 (100%)
150 (53.9%)	170 (61%)	177 (63.7%)	100 (42.1%)	150 (57.9%)	219 (78.8%)	59 (21.2%)	0 (0%)	278 (100%)
74 (94.8%)	76 (97.4%)	6 (7.8%)	1 (1.3%)	77 (98.7%)	2 (2.6%)	76 (97.4%)	0 (0%)	78 (100%)

FIGURE 5 Main barriers in farming as identified by farmers and categorized during analysis

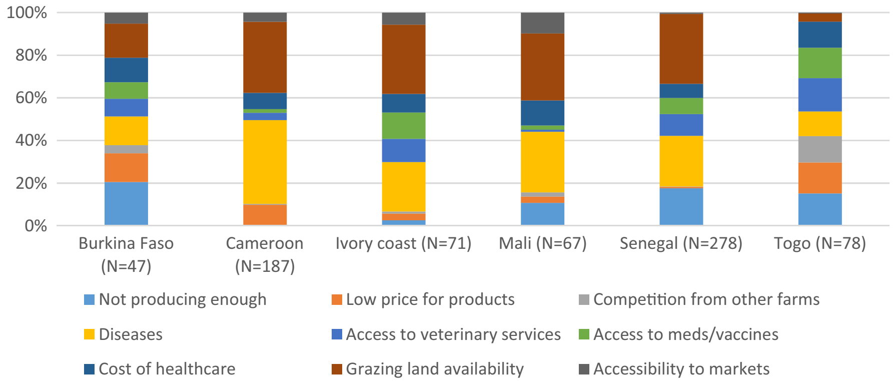

TABLE 6 Financial parameters on farms associated with production

Country	Farmers receiving any income from sales of dairy products *N (%)*	Mean spend per cow/month (XOF) Additional feed	Vitamins/mineral supplements	Medicines/ vaccines
Burkina Faso (*N* = 47)	32 (67.9%)	11,324	2,340	1,380
Cameroon (*N* = 187)	96 (51.5%)	3,246	237	696
Ivory coast (*N* = 71)	64 (89.9%)	6,365	623	2,945
Mali (*N* = 67)	60 (89.5%)	11,558	1,347	1,271
Senegal (*N* = 278)	175 (63.1%)	5,180	2,181	684
Togo (*N* = 78)	42 (53.8%)	0	266	837

5 | CONCLUSION

In this paper, we have examined farmer-specific factors to hypothesize methods of vaccine-based brucellosis control in peri-urban dairy areas where brucellosis is endemic. The findings across sites in the six countries have highlighted the diversity of factors that may hinder or assist in implementing appropriate control strategies in each of these settings. As is evidenced in these findings, each of the study sites examined lies on a spectrum of transformation to more intensive commercially driven systems. The evolving nature of these farming systems provides opportunities for new and innovative routes for animal health services and disease control strategies to be implemented in a successful and sustainable manner. By assessing the current characteristics of each county's dairy sector and considering the future directions, exploration of the suggested delivery models can be undertaken by means of a

TABLE 7 Logistic regression output

Factors potentially associated with vaccinating cattle	Univariate logistic regression with use of any vaccines by farmer	
	Odds ratio (95% CI)	*p*-value
Farm type		0.27
Modern	1	
Traditional	0.5 (0.1–2.3)	
Farm ownership		0.5
Mixed	1	
Single	1.48 (0.3–8.0)	
Breeds		0.2
Local	1	
Exotic	2.1 (0.5–8.2)	
Breeding		0.3
Natural service	1	
Natural and AI	2.4 (0.3–18.1)	
Age		
15–30	1	
31–60	1.9 (1.1–3.1)	0.03
61+	3.1 (0.3–28.7)	0.3
Sex		
Male	1	
Female	4.5 (0.2–100.5)	0.3
Herding practice		0.04
Not transhumant	1	
Transhumant	0.2 (0.1–0.9)	
Cattle number		0.3
Under 50	1	
Over 50	0.4 (0.1–2.4)	
Milk yield		0.2
Less than 2 litres	1	
Over 2 litres	1.2 (0.9–1.6)	
Milk price per litre		
<250	1	
250–350	5.9 (0.9–37.9)	0.06
351–450	5.3 (1.4–19.8)	0.02
451–550	1.7 (0.2–14.6)	0.5
551–650	6.9 (0.3–145.7)	0.2
>650	1.1 (0.1–8.9)	0.9
Quarantine new animals		0.2
No	1	
Yes	3.6 (0.4–30.7)	
Income from dairy		0.7
No	1	
Yes	0.8 (0.3–2.8)	
Spend on inputs per cow		
<2,000	1	
2,000–10,000	5.0 (1.1–22.5)	0.04
>10,000	1.3 (0.2–10.5)	0.7

TABLE 8 Likelihood assessment—scores awarded to each vaccine delivery model by country

Country	Transformative model score	Transactional model score	Collaborative model score
Burkina Faso	2	13	**17**
Cameroon	**10**	8	9
Ivory Coast	**12**	7	7
Mali	11	11	**12**
Senegal	8	9	**11**
Togo	**19**	6	6

The numbers in bold highlight the highest scores for each country.

cost-benefit analysis to inform policy in this important emerging field.

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CONFLICT OF INTEREST

Declarations of interest: none.

DATA AVAILABILITY STATEMENT

Research data are not shared at this time. The data are part of a large and ongoing study, and once complete all data will be published as one data in brief article.

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ENDNOTES

[1] Data from the questionnaire were used for multiple parallel studies, and the sections included in this study were A, B, C, D, E, F, G and J.

[2] The term 'modern' was identified by farmers during qualitative work within the wider project and refers to commercially driven practices such as cross-breeding, artificial insemination and utilizing milk parlours.

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APPENDIX 1

Questionnaire on Risk factors of and KAPs of livestock owners regarding brucellosis in West Africa

Instructions for the interviewer: what to do after arrival at the farm/herd/household:

Ask for the veterinarian-in-charge of the farm or head of the farm/herd/household or most senior person present at that time and:

1. *Explain the objectives of this interview which are: i) to gather information on different methods of cattle management and breeding in order to identify risk factors for some infectious animal diseases ii) to assess the knowledge of the farmers regarding infectious diseases of animals and iii) to address the practices that some farmers do which may expose them to the risk of infection.*
2. *Explain that participation in the interview is entirely voluntary.*
3. *Explain that identification of the farm/herd/household will not be disclosed.*
4. *Explain that the bulk milk sample will be collected and tested for diseases*
5. *Explain that we would like to ask a series of questions to the person in the farm/herd/household who is responsible for rearing the cows most of the time or if this person is not present, the person who regularly looks after them. If none of the farm/herd/household members who regularly look after the animals is available at the time of the visit, please re-schedule the visit.*
6. *Explain that his/her answers and the results of the tested samples will be confidential and we will report the results back to the person. We will report to the veterinary services that there are some positive farms or herds, however the individual herd results will not be disclosed to anyone else.*
7. *If he/she does not agree to participate in the study, make a note indicating that this farm/herd/household declined participation and write the reason why they declined to participate and go to the next farm/herd/household in the list.*

How to proceed with the questionnaire?

8. *Although other farm/herd/household members may be present, remember that the questions are supposed to be answered by interviewee only .*
9. *You should observe and record your observations during the interview, especially when you notice that there is contradiction between what the interviewee says and what you can see.*
10. *The words in italics are some instructions for you, the interviewer, so do not read them to the interviewee.*
11. *The questionnaire includes several types of questions:*
    - *A) Questions in which you will read the participant a number of options from a list*
    - *B) On other occasions you will ask the participant a general question and you will listen to his/her answer and explanations. Based on the answer and explanations provided you will tick the appropriate boxes from a list of options, you will tick the options the participant selects / agrees with.*
    - *C) One of the questions (39) involves presenting some pictures to the interviewee, who will be asked to order them according to a certain criterion. You will record the order in which the pictures have been arranged by the interviewee.*
    - *D) At the end of the questionnaire, you can discuss the answers briefly with the other members of the household who could have been present in the interview and write their comments*

Questionnaire ID : **Date:**

Name of the interviewer :

Country :

Please begin by obtaining GPS co-ordinates after introducing the study to the participant and gaining consent. If you are inside the building, please go outside to record the GPS by pressing 'Record location'

To be completed by the interviewer before the start of the interview:

The person agreed to do the interview is :

☐Senior person in the farm/herd/household/Owner
☐Other farm/herd/household member
☐Technician/Paravet
☐Veterinarian-in-charge of the farm

This person agrees to participate ☐

This person is: Male ☐ Female ☐

The age of this person is …………………… years (if less than 15 years old, please ask his guardian for consent).

The type of the farm is : (*Please fill out based on your observations*)

☐ Modern farm (animals housed in a building with or without milking parlour and milking machine)

☐ Traditional farm (animals kept in an open area or backyard of the house and practice hand milking)

☐ Other, Please describe briefly……………………………

PART 1

SECTION A - FARM STRUCTURE AND TYPE

1. The farm type is; *(tick all those that apply)*
   ☐ Single ownership (all animals are owned by one household)
   ☐Mixed ownership (animals are kept/managed together but belong to people from different households)
2. How will you describe movement of your herd?
   ☐ The cows are always kept around this area (they are never moved to an area that is further away than half a day walking distance or requires staying overnight to find food or water)

   ☐ The animals are sometimes moved to a different area that is too far to be reached and return from within a day.
3. How many people are involved with the farm animals including family members and/or additional staff?
   Family: ……………………
   Additional staff: ……………………………
4. Do your employees work for any other farms?
   Yes, sometimes ☐ Yes, daily ☐ No ☐ I don't know ☐
5. Herd size *(write the number of animals that the farm has at the time of interview)*:

Species		Number		Number
Cows	Bull (un-castrated adult)		Cow (have already given birth)	
	Bull (castrated)		Heifer (not yet given birth)	
	Male calf (still suckling)		Female calf (*still suckling*)	

Sheep	Male (adult)		Female (adult)	
Goat	Male (adult)		Female (adult)	

6. Do you also have pigs? ☐ Yes No ☐
7. Do you also have poultry? ☐ Yes No ☐
8. What are the cattle breeds present in your herd?

……………………………………………………………………………………………

SECTION B - MIXING WITH OTHER ANIMALS

9. Do your cattle come in contact with cattle owned by other farms during vaccination, grazing, veterinary treatment etc.?

   Regularly ☐ Occasionally ☐ Never ☐

10. Do your cattle share pastures/ feeding areas/pens/paddocks with the following? *(Tick one box per row)*

	Regularly	Occasionally	Never
Sheep			
Goats			
Pigs			
Horses			

SECTION C - BREEDING

11. Which of the following best describes the use of service practices for both cows and heifers on your farm/herd? *(Tick one box per row)*

	Use of artificial insemination only	Artificial insemination and natural service	Natural service only
Cows			
Heifers			

12. Do you borrow breeding bulls for breeding from other herds/ farms/ households?

    Always ☐ Sometimes ☐ Never ☐

SECTION D - REPLACEMENT AND PURCHASING

13. How frequently do you purchase new animals in your herd?

	Rarely (most years I don't buy any)	Sometimes (most years I buy new animals at least once)	Regularly (I buy new animals several times a year)
Bovins			
Ovins			
Caprins			

14. How do you introduce newly purchased animals?

    ☐ New animals are allowed to mix with the herd soon

    ☐ I normally keep newly introduced animals totally separated

15. Where do you purchase new animals from? (*Tick all that apply*)

	Markets			**Breeders / Butchers**			**Middle men/Livestock dealers / intermediaries**		
	Regularly	*Sometimes*	*Never*	*Regularly*	*Sometimes*	*Never*	*Regularly*	*Sometimes*	*Never*
Bovins									
Ovins									
Caprins									

16. Do you ever sell animals? (*Tick all that apply*)

	Markets			**Breeders / Butchers**			**Middle men/Livestock dealers / intermediaries**		
	Regularly	*Sometimes*	*Never*	*Regularly*	*Sometimes*	*Never*	*Regularly*	*Sometimes*	*Never*
Bovins									
Ovins									
Caprins									

SECTION E - VACCINATION

17. Do you vaccinate your cattle? *In the table below, please indicate whether the cows in the herd are vaccinated against different diseases and at which frequency. (Note that we are asking about vaccination and not treatment.)*

	Frequency of vaccinations					
	Every year	*Only new animals*	*Only if there is an outbreak*	*Have in the past but not for at least 3+ years*	*Never*	*I don't know*
Anthrax						
FMD						
Brucellosis						
Lumpy Skin Disease						
Rift Valley Fever						
Pasteurellosis						
Enterotoxaemia						
Others						

18. Which diseases do you think are present in your herd? *(Please remember to use local names of the diseases)*
Anthrax☐ FMD☐ Enterotoxaemia☐ Lumpy Skin Disease☐ Rift Valley Fever☐
Pasteurellosis☐ Other (Please specify) ……………………….

SECTION F - CALVING & ABORTION

19. How many of the cows in your herd/ household became pregnant last year?
No. of cows: ……………………………
20. How many of these cows aborted last year?
No. of cows: ……………………………

21. How many of these cows gave birth last year?
    No. of cows: ……………………………
22. How many of the cows in your herd/ household are currently pregnant?
    No. of cows: ……………………………
23. Do abortions in your herd occur:
    Throughout the year ☐ Concentrated during some period ☐

If they are concentrated:

24. Which month in the year did you have the highest number of abortions *(please write the number of animals aborted in the cell corresponds to the month).*

Month	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Number												

25. How often do you assist with parturition of cows by pulling the calf or removing the membranes from it? *(Please tick one box only depending on the answer of the interviewee.)*
    ☐I never assist with calving of cows, cows are always left on their own, unassisted when calving
    ☐Most of the time I do not assist with the calving of cows
    ☐Most of the time I do assist with the calving of cows
    ☐I always assist with the calving of cows
26. When you help in the parturition of cows, do you wear protective gloves? *(Please tick one box only depending on the answer of the interviewee).*
    Never ☐ Sometimes ☐ Always ☐
27. When you help in the parturition of cows, do you wear protective mask? *(Please tick one box only depending on the answer of the interviewee).*
    Never ☐ Sometimes ☐ Always ☐
28. What do you do if one of your cows has aborted? *(Please tick one box only for each raw depending on the answer of the interviewee)*

Action	Never	Sometimes	Always	Only if more than 1 cow aborts
Separate the cow(s) that has aborted from the others for some time				
Call the local veterinarian				
Butcher the cow(s) that has aborted at the farm/herd/household for consumption.				
Sell the cow(s) that has aborted in the market				
Sell the cow(s) that has aborted to the butcher				
Give medications				
Vaccinate animals				
Do nothing				

❖ Are there other actions, not mentioned in the list, that you do if cows abort?
……

29. How do people in your area dispose placenta and aborted foetuses? *(Please tick one box only for each raw depending on the answer of the interviewee)*

Action	Never	Sometimes	Always
Throwing them in water bodies (rivers/streams/canals)			
Throwing them in the street			
Giving them to dogs			
Burying them			
Burning them			
Do nothing			

❖ Are there other actions not mentioned in the list that people do to dispose of placenta and aborted foetuses? ____

30. When disposing of placenta from parturition/abortion, do people in this area wear protective gloves? *(Please tick one box only depending on the answer of the interviewee).*

Never ☐ Sometimes ☐ Always ☐

31. When disposing of placenta from parturition/abortion, do people in this area wear a protective mask? *(Please tick one box only depending on the answer of the interviewee).*

Never ☐ Sometimes ☐ Always ☐

If veterinarian-in-charge is answering the questions then go to section I, if not proceed to section G

SECTION G - KNOWLEDGE OF BRUCELLOSIS

32. Have you ever heard about a disease in animals called Brucellosis?

Yes ☐ No ☐

If the answer to question 32 is "No", then go to section I. if the answer to question 32 is "YES", continue to question 33

33. Could you please tell me which animal species can have brucellosis? (*Please do not tell anything else to the interviewee, simply read the question, listen and tick below on the basis of what the participant has said you can tick as many options as the interviewee answers):*

Cow ☐ Sheep ☐ Goats ☐

Donkeys ☐ Poultry ☐ Others (please specify) ……………………….

34. For each of the following species, please tell me whether you are very confident if this species can have brucellosis, or very confident that this species cannot have brucellosis, or whether you are not sure this species can have brucellosis *(tick one cell for each animal species as the interviewee answers):*

Animal	sure that this animal can have brucellosis	sure that this animal cannot have brucellosis	not sure whether this animal can have brucellosis or not
Poultry			
Sheep			
Donkey			
Goats			
Cattle			
Pig			

35. Could you please tell me what are the problems that animals with brucellosis typically have? *(Please do not tell anything else to the interviewee, simply read the question, listen and tick below on the basis of what the participant has said; you can tick as many options as the interviewee answers):*

Respiratory problems ☐ Die suddenly ☐ Diarrhoea ☐

Produce less milk ☐ Lameness ☐ Abortions ☐

Weight loss ☐ Skin disease ☐ Inflammation of the testicles ☐

Difficulties to become pregnant ☐

Others *(please indicate any other clinical signs of the disease mentioned by the interviewee and not listed above)* ……………………………………………………………………

In the next question you need to use the animal pictures that have been provided

36. *Please pass the animal pictures to the interviewee and ask him/her:* Could you please order the pictures from the species that are most likely to have brucellosis to the species that are least likely to have brucellosis? (*Do not interfere with the interviewee, let the interviewee arrange the pictures as he / she wants and register below the position of each species, from the first one; number 1: the one that is more likely to have the disease called brucellosis, number 5: the one that is least likely to have the disease called brucellosis*).
    Cattle: _____________ (write position number)
    Sheep: _____________ (write position number)
    Goats: _____________ (write position number)
    Donkeys: ___________ (write position number)
    Poultry: ____________ (write position number)
37. Do you think brucellosis can be transmitted from animals to people? *(Please choose one option only, depending on the interviewee answer).*
    ☐ (a) Yes, I am sure this disease can be transmitted from animals to people
    ☐ (b) I am not sure whether this disease can be transmitted from animals to people
    ☐ (c) No, I am sure this disease cannot be transmitted from animals to people

If the answer to question 37 is "c", then go to question 40.

38. In your opinion, which ways brucellosis can be transmitted from animals to humans? *(Please do not tell anything else to the interviewee, simply read the question, listen and tick below on the basis of what the interviewee answers; you can tick as many options as the interviewee answers).*
    Contact with animals ☐
    Contact with infected people ☐
    Contact with foetus or foetal membranes ☐
    Consumption of milk ☐
    Consumption of meat ☐
    Consumption of dairy products ☐
    Contact with faeces ☐
    Others (Please specify)……………………………..
39. In your opinion, how likely it is that a person acquires brucellosis in the following situations? *(Please tick one box only for each row depending on the answer of the interviewee)*

Situation	High	Moderate	Low
contact (touching, walking with, entering pens etc.) with infected animals			
Assisting the parturition of infected animal			
Drinking raw (non-boiled) milk from infected animals			
Eating dairy products (cheese, cream etc.) made from milk of infected animals			
Eating meat of infected animals			
Contact (eating together, being in the same room etc.) with infected person			
Contact with foetuses or foetal membranes of infected animals			

40. In your opinion, what would most people in this area do if they suspect or find out that some of their animals may have brucellosis? *(Please tick one box only for each row depending on the answer of the interviewee)*

Action	Never	Sometimes	Always
Ask the local veterinarian/ paravet/pharmacy for advice			
Buy vaccine			
Try to treat infected animals			
Sell suspected animals directly to neighbours			
Sell suspected animals in the market			
Sell suspected animals to the butcher			
Do nothing			

- Are there other things, which are not in the list, that most people would do if they suspect or find out that some of their animals may have brucellosis? ………………………………………………

SECTION I - MILKING AND MILK HYGIENE

41. Do you routinely wash the udder before milking?
    Yes, with antiseptics ☐ Yes, with warm water ☐ Yes, with cold water ☐ No ☐
42. What is the source of water used for farm practices (farm cleaning, cleaning tools and machinery etc.? *(tick all that may be used even if not always).*
    Community water tanks ☐ Community water pumps ☐
    Own water tanks/piped water ☐ Own well ☐
    Natural sources (rivers and streams) ☐
43. What type of utensil do you use to collect milk?
    Plastic buckets ☐ Metal containers (eg: aluminium, Steel) ☐
    Wooden ☐ Clay containers ☐
    Other ………………………………………………………………
44. How many times do you daily milk cows?
    Always once ☐ Always twice ☐ Once or twice depending on the cow ☐
45. Do you use a milking machine for milking?
    Yes, only milking machine ☐ Yes, milking machine and hand milking ☐
    No, only hand milking ☐

If the answer to question 45 is "No", then go directly to part I.2) Hand milking. if the answer to question 45 is "Yes, continue to question 46.

SECTION I.1 - MILKING MACHINE

46. Do you have a separate milking parlour?
    Yes, I always use it ☐ Yes, but I use it occasionally ☐ No ☐
47. Do you examine milk of each animal for any changes (eg: colour change, clots etc...) by stripping first few drops before attaching the milking machine?
    Yes, always ☐ Yes, Only when I suspect mastitis ☐ No, never ☐
48. How often do you clean milking machine?
    Once daily ☐ Twice daily ☐ Once weekly☐
    Twice weekly☐ Thrice weekly ☐ More than thrice weekly☐
49. How do you clean milking machine?
    With cold water ☐ With warm water☐ With cold water and soap ☐
    With warm water and soap ☐

SECTION I.2 - HAND MILKING

50. Do you/the milker normally wash your hands before milking?
    Yes, with cold water ☐ Yes, with warm water ☐
    Yes, with cold water and soap ☐ Yes, with warm water and soap ☐ No ☐
51. Have you/the milker received any training on milk hygiene?
    Yes, on hygienic milking ☐ Yes, on hygienic milk handling ☐ Yes, on both ☐ No ☐

SECTION I.3 - UDDER HEALTH

52. Do you isolate sick animals from others?
    Yes ☐ No ☐
53. Do you dip teats in antiseptic solutions before milking?

Yes, always ☐ Yes, sometimes ☐ No, never ☐

54. Do you dip teats in antiseptic solutions after milking?
    Yes, always ☐ Yes, sometimes ☐ No, never ☐
55. Do you inject antibiotics into udder when you dry out cows (dry cow therapy)?
    Yes, always ☐ Yes, only for cows with history of mastitis No ☐
56. Do you have regular udder infections/mastitis (when milk has visible changes in appearance or udder is enlarged) in animals?
    Yes ☐ No ☐
57. In a typical month what is the usual number of udder infections/mastitis you see in your farm/herd?
    1-2 ☐ 3-5 ☐ 5-10 ☐ 10-20☐ More than 20 ☐
58. Do you cull/sell for slaughter animals with frequent mastitis?
    Yes, always ☐ Yes, only low producing animals ☐ No ☐

SECTION J - PRODUCTION VALUES

59. In the last month how much did you spend on additional feed for your cows? ....
60. How much do you spend on additional feed for your cows in a;
    Typical month ....
    High spend month ....
    Low spend month..................
61. In the last month how much did you spend on vitamin/mineral supplements for your cows? ....
62. How much do you spend on supplements for your cows in a;
    Typical month ....
    High spend month ....
    Low spend month ....
63. In the last month how much did you spend on medicines and vaccines for your cows?............................
64. How much do you spend on medicines and vaccines for your cows in a;
    Typical month ....
    High spend month ....
    Low spend month............

65. What proportion of your total family income is derived from the sale of dairy products?
    None (self-consumption only) ☐ Always Less than half ☐
    More than half all or most of the year ☐ All of it, through out the year ☐
    Some months more than half of the income but normally less ☐ Do not know ☐

66. How many cows are currently milked in your herd? ....
67. Of the cows being milked, what is the milk yield:
    On average...............
    Highest......................
    Lowest......................
68. How often (on average) do your cows produce calves?
    Every 12 months ☐ Between 12-15 months ☐ Between 15-18 months ☐
    Between 18-24 months ☐ Approximately every second year ☐
    Approximately every third year ☐
69. How long do you milk your cattle for after calving? .... months
70. What is the peak level of daily production for the majority of your cattle? .... Litres/day
71. For how long do they maintain this peak level? ....months
72. How long are the cows dry for (*stop producing milk before the next calving*)? ....months
73. In the last month what did you get as the average price for:
    1 L lait cru...... 1L Lait caillé .... 1L Lait fermenté ....

74. In the last year what did you get as the average price for:
1 L lait cru...... 1L Lait caillé .... 1L Lait fermenté ....

75. In your opinion what is the main problem you face in dairy farming?
☐ not producing enough ☐ particular diseases ☐ cost of healthcare
☐ low price for products ☐ access to veterinary services ☐ transport to markets
☐ competition from other ☐ access to meds/vaccines ☐ land availability for pasture
☐ other...........

PART 2: MILK

1. Do you chill milk as soon as collected (using fridge, ice box, or anything similar) ?
Always ☐ Sometimes☐ Never ☐
2. Do you consume milk produced by your own animals?
Regularly (some days a week during most of the year) ☐
Sometimes (some days during part of the year) ☐
Never ☐
3. Of the milk produced from your animals, do you ever sell any raw milk?
Regularly (some days a week during most of the year) ☐
Sometimes (some days during part of the year) ☐
Never ☐
4. Who do sell milk produced from your animals to (*tick all that apply*)?
Neighbours☐ Local restaurants☐ Kiosks☐ Individual milk collector/vendor☐
Industrial milk collectors☐ Sell it in the nearby market☐ Processing plant☐
Nobody, it is processed by family members☐
Nobody, as there is a processing plant in the farm☐
Other☐ ....
5. How do you preserve milk when transporting to selling point?
Chilled☐ Ambient temperature☐ Sold at farm gate at ambient temperature☐
Chilled and sold at farm gate☐ Milk is processed at the farm☐
6. How do you transport milk to selling point?
Cycle☐ Walking☐ Lorries/Cars☐ Motorcycle☐ Horse/donkey cart☐ Sold at farm gate☐
7. How long does it take to travel to the milk selling point?
Less than 15 minutes ☐ 15-30 minutes ☐ 30minutes – 1 hour☐
1-2 hours ☐ More than 2 hours ☐
8. What is the container you use to transport milk?
Plastic buckets ☐ Metal containers (eg: aluminium, steel) ☐ Clay pots or similar☐
Other ....
9. Do people in your village boil milk in the following cases? *(Curdled milk = milk fermented at room temperature without adding any lactic acid bacteria and/or enzymes, Fermented milk = milk fermented by adding lactic acid bacteria and/or enzymes.)*

Situation	Frequency			
	Always	Most of the times	Only occasionally	Almost never
When consumed as raw milk				
When used to make curdled milk				
When used to make fermented milk				
When used to make other products (butter,yoghurt&cream)				

10. How frequently do you consume the following products in your household?
Curdled milk = milk fermented at room temperature without adding any lactic acid bacteria and/or enzymes,
Fermented milk = milk fermented by adding lactic acid bacteria and/or enzymes.

Product	Frequency			
	Regularly (every week or most weeks during the whole year or most of the year	Sometimes (some weeks but not all or during part of the year)	Occasionally / Rarely	Never
Curdled milk				
Fermented milk				
Other (butter, yoghurt, cream)				

11. Do you produce the following products in your house from milk produced by your animals?
Curdled milk = milk fermented at room temperature without adding any lactic acid bacteria and/or enzymes,
Fermented milk = milk fermented by adding lactic acid bacteria and/or enzymes.

Product	Frequency			
	Regularly (every week or most weeks during the whole year or most of the year	Sometimes (some weeks but not all or during part of the year)	Occasionally / Rarely	Never
Curdled milk				
Fermented milk				
Other (butter, yoghurt cream				

12. Do you produce the following products in your household from milk purchased from other farmers?
Curdled milk = milk fermented at room temperature without adding any lactic acid bacteria and/or enzymes,
Fermented milk = milk fermented by adding lactic acid bacteria and/or enzymes.

Product	Frequency			
	Regularly (every week or most weeks during the whole year or most of the year)	Sometimes (some weeks but not all or during part of the year)	Occasionally / Rarely	Never
Curdled milk				
Fermented milk				
Other (butter, yoghurt, cream)				

13. Do you purchase the following products produced by other farmers?
Curdled milk = milk fermented at room temperature without adding any lactic acid bacteria and/or enzymes,
Fermented milk = milk fermented by adding lactic acid bacteria and/or enzymes.

Product	Frequency			
	Regularly (every week or most weeks during the whole year or most of the year	Sometimes (some weeks but not all or during part of the year)	Occasionally / Rarely	Never
Curdled milk				
Fermented milk				
Other (butter, yoghurt, cream)				

Please note the milk sample ID and use the same to label the bottle.
Milk sample ID:

<<<<<<<<<<<<< THANK YOU >>>>>>>>>>>>>>