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RESEARCH

Seroprevalence and Risk Factors for Bovine Brucellosis in *Polonnaruwa* District, Sri Lanka

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ABSTRACT

Purpose: *This study aimed to determine the seroprevalence of bovine brucellosis and identify key risk factors contributing to its transmission in dairy cattle in the Polonnaruwa district, where abortion-related reproductive losses had been reported.*

Research Method: *A cross-sectional study with a two-stage sampling procedure was employed. The blood samples were collected from 180 cattle across 38 farms that had reported abortions between August 2022 and August 2023. Serological testing was done using the Rose Bengal Plate Test (RBPT) and confirmed with the Complement Fixation Test (CFT). A pre-tested structured questionnaire was used to collect data on demographics, management practices, and reproductive history of cattle. Data were analyzed using SPSS (version 25), applying descriptive statistics, chi-square tests, and multivariate logistic regression.*

Findings and Values: *The study reported a high seroprevalence of 35.5% at the animal level and 63.15% at the herd level. Abortion history, poor hygiene, and larger herd size were identified as significant independent predictors of bovine brucellosis seropositivity. Females, crossbreeds, and older animals showed higher seropositivity. The findings suggest that bovine brucellosis may be endemic in the region and underline the potential value of targeted control measures such as improved biosecurity, reproductive screening, and farmer education to help reduce the disease burden and protect both animal and public health.*

Keywords: *Bovine brucellosis, Reproductive indicators, Risk factors, Seroprevalence, Sri Lanka, Zoonotic disease.*

INTRODUCTION

Brucellosis, a significant zoonotic disease caused by bacteria of the genus *Brucella*, continues to affect livestock production systems globally, especially in low- and middle-income countries. These gram-negative, facultative intracellular coccobacilli (Quinn *et al.* 2002) infect various species, including cattle and buffaloes (*Brucella abortus*), sheep and goats (*Brucella melitensis*), and pigs (*Brucella suis*) (Khurana *et al.* 2021).

In cattle, transmission commonly occurs through ingestion or contact with contaminated feed, water, uterine discharges, fetal membranes, or aborted fetuses (Radostits *et al.* 2007). Clinical manifestations include late-term abortions, retained placenta, orchitis, epididymitis, infertility, and a notable decline in milk yield (Radostits *et al.* 2007, OIE 2009, McDermott *et al.* 2013). Complicating control efforts, many infected animals exhibit subclinical infections,

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facilitating silent transmission within herds. Globally, brucellosis remains endemic in regions such as South Asia, sub-Saharan Africa, and Latin America (Mohammed *et al.* 2013, McDermott *et al.* 2013). In South Asia, inadequate veterinary services, poor awareness, and the predominance of traditional mixed-farming systems hinder effective disease control (Kothalawala *et al.* 2017). Economically, the disease imposes substantial losses on smallholder dairy farmers by reducing milk production by up to 20%, and increasing infertility, culling, and veterinary care costs (McDermott *et al.* 2013). Furthermore, brucellosis carries profound public health implications due to its zoonotic potential. Human brucellosis, often acquired through direct contact with infected animals or consumption of unpasteurized dairy products, manifests as undulant fever, fatigue, and joint pain; it can lead to chronic debilitating illness (Pappas *et al.* 2006, Dean *et al.* 2012). Hence, both economic and clinical dimensions compound the burden on public health systems in endemic areas (Corbel 2006, Mantur & Amarnath 2008).

Brucellosis remains a persistent problem within the dairy sector in Sri Lanka; *Brucella abortus* is identified as the primary causative agent in bovine populations (Bandara & Mahipala 2002). The disease is believed to have been introduced during World War II via the British Army, with the first confirmed local case in 1956 at the *Polonnaruwa* Livestock Research Station (Bandara & Mahipala 2002). Despite national-level control efforts, including test-and-slaughter programs and limited vaccination, sporadic outbreaks and persistently infected herds continue to challenge eradication. While national-level studies report an animal-level prevalence of approximately 4.7%, some regions show higher localized burdens.

For instance, a study in the Northern Province reported seroprevalence at 2.7% in animals and 9.6% at the herd level (Kothalawala *et al.* 2017), reflecting persistent transmission in endemic pockets. The *Polonnaruwa* district, a major dairy-producing area in Sri Lanka, comprises diverse herd sizes and management systems, ranging from smallholder farms to more intensive operations. Historic data from this region documented a prevalence of 7.7%, with risk levels influenced by herd size, reproductive management, and hygiene practices (Wickramasuriya *et al.* 1983).

Polonnaruwa also holds strategic importance in the national dairy development agenda due to its robust agricultural infrastructure and livestock-based livelihoods. Farmers in this district rely heavily on cattle for milk as well as for meat and manure, making livestock health a key determinant of rural income and food security. Despite the known presence of the disease, updated epidemiological data from the North Central Province are scarce. Moreover, there is a lack of clarity regarding how current farm management, biosecurity practices, and reproductive health indicators interact to influence brucellosis prevalence and transmission.

Therefore, this study was designed to fill this critical knowledge gap by assessing the seroprevalence of bovine brucellosis and evaluating associated risk factors in the *Polonnaruwa* district. It aims to generate locally relevant evidence to support improved disease control programs. The insights gained are expected to contribute to more targeted veterinary interventions, guide farmer education efforts, and inform national policy development for brucellosis mitigation in Sri Lanka.

MATERIALS AND METHODS

The study area

The research was conducted in *Polonnaruwa* District in the North Central Province of Sri Lanka, located within the Mahaweli River plain. The district extends over 3,338 km^2, comprising 3,077 km^2 of land and 216 km^2 of water, at elevations ranging from 50 to 500 m above mean sea level. It lies between 7°40'–8°21' N latitude and 80°44'–81°20' E longitude. *Trincomalee, Batticaloa, Ampara, Matale*, and *Anuradhapura* districts border the *Polonnaruwa* District (Fig. 1).

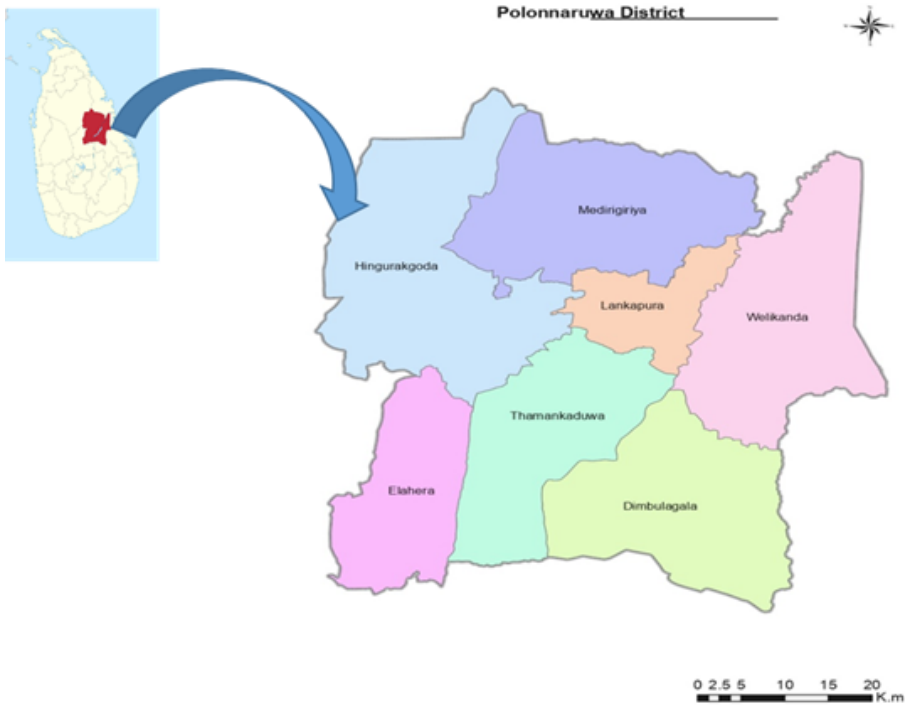

Figure 1. The geographic location of *Polonnaruwa* District, North Central Province, Sri Lanka, where the present study was conducted (Source: Department of Census and Statistics, Sri Lanka, 2023).

Sampling procedure

The study included all veterinary ranges in the *Polonnaruwa* District (*Lankapura, Polonnaruwa, Medirigiriya, Minneriya, Walikanda, Dimbulagala, and Bakamuna*). A two-stage sampling procedure was employed to select the study population (Fig. 2).

Stage 1: Selection of farms: Eligible farms were purposively identified in consultation with records maintained by the District Veterinary Investigation Center, *Polonnaruwa*. The selected farms met the following criteria: (i) at least one abortion case reported between August 2022 and August 2023, (ii) registration with the respective veterinary office, and (iii) at least one lactating cow present at the time of data collection. Farms that did not fulfill these conditions were excluded.

Stage 2: Selection of cattle: Approximately 50% of the cattle were chosen using simple random sampling from the purposively selected farms. This yielded a total of 180 animals distributed across seven veterinary ranges (Fig. 2). The district consists predominantly of small and medium-scale dairy farms operating under extensive, semi-intensive, and intensive systems. Farms were categorized based on herd size as small ($\leq$ 10 cows), medium (11–50 cows), and large ($>$ 50 cows). Management systems were defined as follows: farms practicing zero-grazing (animals housed and fed for 24 hours) were classified as intensive, while those where cows were tethered in the morning (around 08:00 h) and returned to sheds by 14:30 h were classified as semi-intensive (Bandara *et al.*, 2011). The study population comprised local, Indian, and crossbred cattle. The sample included milking and non-milking cows, heifers, and bulls over six months of age. The body condition of each animal was assessed using Body Condition Scoring (BCS) through visual inspection and palpation, and categorized as poor, average, or good.

Blood sample collection

About 10 mL of blood sample was collected aseptically from the jugular vein of each selected healthy cattle using plain vacutainer tubes, yielding a total of 180 blood samples. The blood samples were left at room temperature for 30 minutes to allow clot formation, and centrifuged at 3,000 rpm for 10–15 minutes to separate the

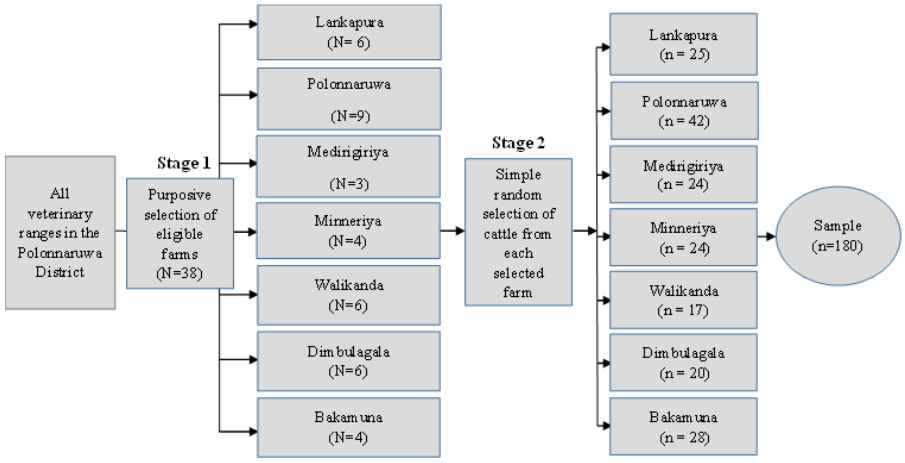

Figure 2. Two-stage sampling procedure showing the selection of farms and cattle across veterinary ranges in *Polonnaruwa* District, Sri Lanka (n = 180).

serum.

The serum was carefully harvested using sterile pipettes, transferred into labeled cryovials, and stored at -20°C until tested by the Rose Bengal Plate Test (RBPT) and Complement Fixation Test (CFT).

Serological test procedure

RBPT: The serum samples were screened using RBPT antigen (VLA Weybridge, UK). Both the test serum and the antigen were maintained at room temperature for 30 minutes before the test. A volume of 30 µL of RBPT antigen and 30 µL of test serum were placed alongside on a clean plate and thoroughly mixed. The plate was gently shaken for 4 minutes before recording the degree of agglutination reaction. Samples were considered positive if any agglutination was observed and negative if no agglutination occurred. Positive serum samples were then retested using CFT. Only the samples that tested positive on both RBPT and CFT were considered positive for brucellosis.

CFT: This test was performed on all sera that tested positive by RBPT for further confirmation. *Brucella abortus* antigen for CFT was used to detect the presence of anti-*Brucella* antibodies in the serum, similar to RBPT. The test was conducted according to the protocol recommended by the OIE at the Veterinary Research Institute (VRI), Gannoruwa, Sri Lanka.

Questionnaire survey

The primary data were collected through structured individual interviews using a pre-tested questionnaire on individual animal data and farm-level details. The questionnaire included both open-ended and closed-ended questions. It was distributed to the participants for completion.

A pilot test involving 15 dairy farmers was conducted before the primary survey to identify potential challenges in the survey process. Insights from the pilot study were utilized to refine and improve the structured questionnaire design, thus enhancing its clarity and reliability.

Data analysis

Data collected during the study were entered into Microsoft Excel (Version 2016) and analyzed using SPSS version 25. Descriptive statistics were employed to summarize these data. Frequencies were used to check the overall prevalence of brucellosis. The cattle that tested positive on both the RBPT and the CFT were classified as *'Brucella seropositive'*. Associations between variables and seropositivity of brucellosis were assessed using the Chi-square. A binary logistic regression model helped to identify the factors influencing the likelihood of being positive for brucellosis. The dependent variable was brucellosis serostatus, coded 1 for seropositive

and 0 for seronegative. Independent variables included key predictors derived from animal- and farm-level data. The general form of the binary logistic regression model is expressed as follows:

$$\log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \cdots \quad (1)$$

where,

p	probability of the outcome (e.g., disease presence = 1)
$\frac{p}{1-p}$	odds of the outcome
$\log\left(\frac{p}{1-p}\right)$	logit (log-odds) of the outcome
β_0	intercept
β_i	regression coefficient for predictor X_i

RESULTS AND DISCUSSION

Study population

Demographically, the majority were females (91.1%); over three years old (91.1%), and crossbreeds (70.6%), reflecting typical regional herd structures (Table 1). A significant proportion (65.6%) of animals had poor body condition scores, which could predispose them to infections due to immune compromise. Extensive management system was predominant (67.8%), attributable to dry zone ecology, abundant grazing lands, and traditional, and low-cost livestock rearing practices in *Polonnaruwa*. Further, smallholder farmers in the region often lack infrastructure for intensive systems and rely on free-range grazing to sustain their herds. However, extensive system likely increases cattle exposure to environmental pathogens due to grazing, communal watering points, and less structured biosecurity. Terefe *et al.* (2017) have reported similar associations between extensive systems and increased disease exposure.

Seropositivity of Bovine Brucellosis

Seropositivity confirmed by CFT was 35.5% at the animal level, with the highest noted in *Lankapura* (56.0%) and *Minneriya* (54.2%). No positives were recorded in *Welikanda* (Table 2). These spatial differences may reflect heterogeneity in farm management practices, cattle movement, and surveillance sensitivity across the district. The elevated prevalence in *Lankapura* and *Minneriya* could be attributed to several interconnected factors. These areas include a mix of small- and medium-scale farms with frequent animal exchanges through communal grazing and limited veterinary lapse, conditions that can facilitate horizontal transmission.

Additionally, experiences from officers in veterinary offices indicate a higher incidence of unregulated breeding practices and poor waste disposal methods in these regions, both identified as risk factors in this study. In contrast, zero seroprevalence in *Welikanda* may not necessarily indicate the true absence of infection. Instead, it could reflect underreporting of abortion cases, improved farm-level biosecurity, or sampling limitations. Previous regional surveillance studies have also reported variability in brucellosis prevalence between districts and divisions, highlighting the importance of localized disease monitoring (Kothalawala *et al.* 2017).

The herd level seropositivity was 63.15%, with 100% positivity in *Lankapura, Madirigiriya, Minneriya*, and *Bakamuna* (Table 3). These rates are substantially higher than national averages reported by Silva *et al.* 2000 and Kothalawala *et al.* 2017, suggesting a localized outbreak or persistent endemicity in these divisions. This situation also denotes that even if individual animal-level prevalence varied, the disease was likely circulating within the majority of farms in those ranges, underscoring the importance of district-wide vaccination, targeted biosecurity interventions, and farm-level screening, particularly in high-risk divisions.

Association between demographic characteristics and seroprevalence

A significant association was detected between age and seropositivity (p=0.004) (Table 4), with higher prevalence in animals over 6 years

Table 1. Distribution of tested cattle by demographic and management factors in *Polonnaruwa* District, Sri Lanka (n = 180).

Factor	Variables	Frequency	Percentage
Age	6 months – 3 years	16	8.9
	> 3 years	164	91.1
	Total	180	100
Sex	Male	16	8.9
	Female	164	91.1
	Total	180	100
Breed	Local	29	16.1
	Indian	24	13.3
	Cross breed	127	70.6
	Total	180	100
Body condition status	Good	19	10.6
	Average	43	23.9
	Poor	118	65.5
	Total	180	100
Herd size	Small (< 10)	84	46.7
	Medium (11–20)	44	24.4
	Large (> 20)	52	28.9
	Total	180	100
Management	Intensive	13	7.2
	Semi intensive	45	25.0
	Extensive	122	67.8
	Total	180	100

(49.3%). The probable reason could be the prolonged exposure to infectious environments and accumulated reproductive events (Al-Majali *et al.* 2009, Terefe *et al.* 2017). Older cattle are more likely to have encountered contaminated materials or infected herd mates during their productive lifespan, thereby increasing their susceptibility. Crossbreeds showed significantly higher infection rates (40.2%) than local breeds (5.6%) (p=0.016), aligning with findings from Indonesia (Yanti *et al.* 2021).

Crossbreeds are often raised under semi-intensive or intensive systems with more frequent human-animal interactions and movement between farms. These systems, while aiming to improve milk yield, may inadvertently elevate brucellosis transmission if biosecurity is insufficient (Silva *et al.* 2000, Yanti *et al.* 2021). Females were more frequently infected than males (37.8% vs. 12.5%, p=0.044), consistent with previous

Table 2. Animal-level seroprevalence of bovine brucellosis in different veterinary ranges of *Polonnaruwa* District, Sri Lanka (n = 180).

Veterinary range	Number of samples collected	RBPT positive		CFT positive	
		Frequency	Percentage	Frequency	Percentage
Lankapura	25	18	72.0	14	56.0
Polonnaruwa	42	26	61.9	20	47.6
Madirigiriya	24	20	83.3	11	45.8
Minneriya	24	18	75.0	13	54.2
Welikanda	17	4	23.5	0	0.0
Dimbulagala	20	9	45.0	3	15.0
Bakamuna	28	19	67.9	3	10.7
Total	180	114	63.3	64	35.5

Table 3. Herd level seroprevalence of bovine brucellosis in different veterinary ranges of Polonnaruwa District, Sri Lanka (n = 180).

Veterinary range	Number of farms	RBPT positive		CFT positive	
		Frequency	Percentage	Frequency	Percentage
Lankapura	6	6	100	6	100
Polonnaruwa	9	8	88.8	8	88.8
Madirigiriya	3	3	100	3	100
Minneriya	4	4	100	4	100
Welikanda	6	2	33.3	0	0
Dimbulagala	6	4	66.6	1	16.6
Bakamuna	4	4	100	2	50
Total	38	31	81.57	24	63.15

literature emphasizing susceptibility due to reproductive tract involvement (McDermott *et al.* 2013).

This pattern is also supported by Sagamiko *et al.* 2018 and Khurana *et al.* 2021, who observed that females were at greater risk due to their reproductive physiology and longer retention within the herd. Female cattle are more frequently exposed to risk factors such as pregnancy, parturition, and retained fetal membranes, all of which contribute to Brucella transmission and persistence.

Surprisingly, body condition was not significantly associated (p=0.670), though the majority of positives were in poorly conditioned animals, suggesting a possible relationship between chronic infection and declining nutritional status. However, further studies are needed to establish causality. Herd size also emerged as a significant factor (p=0.019), with medium and large herds showing greater risk likely due to increased animal contact, difficulty

Table 4. Association between demographic characteristics of cattle and seroprevalence of bovine brucellosis in *Polonnaruwa* District, Sri Lanka (n = 180).

Factor	Variables	Number of animals tested	Number of CFT positive animals	Percentage	χ^2	P-value
Age	6 months – 3 years	40	8	20.0	11.207	0.004
	3 < 6 years	67	20	29.9		
	> 6 years	73	36	49.3		
Breed	Local	18	1	5.6	8.268	0.016
	Indian	35	12	34.3		
	Cross breed	127	51	40.2		
Sex	Male	16	2	12.5	4.074	0.044
	Female	164	62	37.8		
Body condition	Good	19	5	26.3	0.800	0.670
	Average	43	16	37.2		
	Poor	118	43	36.4		
Herd size	Small (< 10)	84	21	25.0	7.964	0.019
	Medium (11–20)	44	21	47.7		
	Large (> 20)	52	22	42.3		
Management	Intensive	13	2	15.4	2.499	0.287
	Semi intensive	45	17	37.8		
	Extensive	122	45	36.9		

in maintaining hygiene, and greater animal movement.

Similar observations have been reported in Tanzania and India, where herd size was positively correlated with Brucella exposure (Ducrotoy *et al.* 2014, Pathak *et al.* 2016). This finding also aligns with Sagamiko *et al.* 2018, who stated increased transmission in larger groups due to higher animal contact rates.

Further, Terefe *et al.* 2017 reported that farms with large herd size ($>$ 20 animals) have brucellosis 9.13 times higher than smaller size herds ($<$ 20 animals). Large farms often face challenges in isolating aborting animals or implementing rigorous biosecurity, increasing the probability of pathogen circulation.

Management system was not statistically significant (p=0.287); yet, similar results were observed by Shirima *et al.* 2018, who reported that grazing patterns (free range, semi-intensive and zero grazing) did not show to be associated with Brucella seroprevalence in urban settings of Tanzania. However, higher seroprevalence among animals reared under extensive and semi-intensive systems (36.9%–37.8%) was observed in this study. This trend suggests that open grazing and shared water sources may contribute to higher exposure to Brucella organisms, as noted by Swai & Schoonman 2010.

Table 5. Association between reproductive characteristics of cattle and seroprevalence of bovine brucellosis in *Polonnaruwa* District, Sri Lanka (n = 180).

Factor	Variables	Number of animals tested	Number of CFT positive animals	Percentage	X^2	P-value
Reproductive status	Lactating	81	32	39.5	17.546	0.002
	Dry cow	28	7	25.0		
	Pregnant	29	18	62.1		
	Heifer	26	5	19.2		
	Bull	16	2	12.5		
	Total	180	64	35.5		
Number of services per conception	1	27	6	22.2	12.965	0.011
	2	67	19	28.4		
	3	4	3	75.0		
	> 3	4	2	50.0		
	Total	102	32	31.37		
Calving interval	1 year	29	13	44.8	15.934	0.000
	1 – 2 years	58	13	22.4		
	> 2 years	50	30	60.0		
	Total	137	56	40.9		
Retention placenta	Present	60	31	51.7	5.143	0.023
	Absent	77	25	32.5		
	Total	137	56	40.9		
Abortion history	Present	87	52	59.8	41.624	0.000
	Absent	71	7	9.9		
	Total	158	59	37.3		
Number of abortions	No	58	10	17.2	17.213	0.001
	1	86	41	47.7		
	2	17	10	58.8		
	3	3	1	33.3		
	Total	164	62	37.8		
Still births	Yes	105	52	49.5	12.590	0.000
	No	30	4	13.3		
	Total	135	56	41.5		
Aborted fetal age	1 – 3 months	2	2	100	3.929	0.140
	4 – 6 months	18	6	33.3		
	> 6 months	85	43	50.6		
	Total	105	51	48.6		
Breeding method	Natural	86	36	41.9	1.381	0.501

Factor	Variables	Number of animals tested	Number of CFT positive animals	Percentage	X^2	P-value
	Artificial insemination	55	19	34.5		
	Both	23	7	30.4		
	Total	164	62	37.8		

Association between reproductive characteristics and seroprevalence

Reproductive parameters were strongly associated with brucellosis seropositivity in this study (Table 5). The most notable finding was the significantly higher prevalence among animals with a history of abortion (59.8%, p<0.001). This observation is consistent with numerous studies that have established abortion, particularly during the third trimester, as a hallmark clinical sign of Brucella abortus infection in cattle (Corbel 2006, Radostits *et al.* 2007, Shirima *et al.* 2018).

The bacterium has a strong tropism for the gravid uterus due to the presence of erythritol. This sugar alcohol enhances Brucella replication in the placenta, leading to placentitis and subsequent abortion (Anderson *et al.* 1986, Yin *et al.* 2023). Animals that had experienced stillbirths were also significantly associated with seropositivity (p<0.001), reinforcing the known impact of brucellosis on fetal viability and intrauterine infection (Ali *et al.* 2013, Jilo *et al.* 2023). Animals that had experienced retained placenta showed higher seropositivity (p=0.023), consistent with previous findings linking Brucella infection with uterine inflammation and delayed fetal membrane expulsion (Mantur *et al.* 2008, Khurana *et al.* 2021).

Prolonged calving intervals (>2 years) were another significant risk indicator (p<0.001), which may be explained by repeated conception failures and abortions in Brucella-infected animals, which extend the time between successful calvings. The highest seropositivity was observed among pregnant (62.1%) and lactating cows (39.5%), respectively. Pregnant animals are especially susceptible due to hormonal changes and reduced immune surveillance that allow latent infections to reactivate (Neta *et al.* 2010).

Despite the higher number of animals bred through artificial insemination (AI), no significant association was detected between the breeding method and seropositivity (p=0.501). Shirima *et al.* 2018 observed similar results and reported that no significant statistical difference exists between herd owners who practice natural mating (80%) and those who practice artificial insemination (20%) in Brucella seroprevalence. However, the risk of transmission via contaminated semen or equipment has been documented, and remains a biosecurity concern in endemic settings (Al-Majali *et al.* 2009).

Association between hygienic practices, farm-level biosecurity measures, and seroprevalence of bovine brucellosis

Farms with poor hygiene status displayed a notably higher seropositivity (45.9%) compared to farms rated as having “good” or “very good” hygiene ($p < 0.001$) (Table 6).

Moreover, farms that practiced open dumping of animal waste or fed aborted materials to dogs exhibited significantly higher seropositivity levels. In contrast, regular use of disinfectants and proper waste management were strongly protective, with zero seropositivity reported on farms using effective disinfectants. According to Corbel (2006) and Dadar *et al.* (2021), contaminated environments, including manure,

Table 6. Association between hygienic practices, farm-level biosecurity measures, and seroprevalence of bovine brucellosis in *Polonnaruwa* District, Sri Lanka, based on CFT results and chi-square analysis (n = 180).

Factor	Variable	Number of animals tested	Number of CFT positive animals	Percentage	X^2	P-value
Waste disposal method	Burying	82	14	17.1	22.456	0.000
	Open dump	61	31	50.8		
	Feeding to dogs	37	19	51.4		
Manure disposal	Very good	3	0	0.0	7.169	0.028
	Good	18	2	11.1		
	Poor	159	62	39.0		
Hygienic status of the farm	Very good	14	0	0.0	25.520	0.000
	Good	31	2	6.5		
	Poor	135	62	45.9		
Usage of disinfectants	Yes	10	0	0.0	7.932	0.019
	Sometimes	18	4	22.2		
	No	152	60	39.5		

Table 7. Final multivariable logistic regression model predicting the likelihood of bovine brucellosis seropositivity in cattle from *Polonnaruwa* District, Sri Lanka (n = 180).

	B	S.E.	Wald	df	Sig.	Exp(B)
Step 5[a]						
Sex (male)	-2.332	1.491	2.447	1	0.118	0.097
Herd size			11.378	2	0.003	
Small	-2.687	0.866	9.624	1	0.002	0.068
Medium	-0.904	0.915	0.976	1	0.323	0.405
Abortion history (yes)	3.143	0.686	20.996	1	0.000	23.169
Hygiene status			35.253	2	0.000	
Very good	-4.780	0.916	27.211	1	0.000	0.008
Good	-4.853	0.859	31.952	1	0.000	0.008
Constant	2.569	1.036	6.145	1	0.013	13.056

aborted fetuses, and placental membranes, serve as significant sources of *Brucella* transmission in livestock. These materials can persist in soil and bedding and may infect other animals through ingestion or mucosal contact. Open dumping in shared grazing areas or near water sources intensifies the risk of environmental contamination and community-level disease spread (Abo-Shehada *et al*. 2013). Additionally, the practice of feeding aborted material or placenta to dogs perpetuates the infection within farms and introduces a potential zoonotic risk. Dogs may become infected and serve as mechanical vectors or reservoirs, further complicating eradication efforts (Ron-Román *et al*. 2014).

Disinfectant use and strict hygiene protocols have been shown to reduce brucellosis risk significantly. A study by Khalafallah *et al*. (2023) demonstrated that certain disinfectants, such as Virkon® S and Dettol, were highly effective against *Brucella melitensis*, which is closely related to *Brucella abortus*, suggesting their potential role in controlling the spread of brucellosis in veterinary settings. Al-Majali *et al*. (2009) also observed that the use of disinfectants and the presence of adequate veterinary services were protective factors for brucellosis.

These findings underscore the urgent need to strengthen biosecurity education among smallholder farmers, particularly in extensive and semi-intensive systems. Practical interventions, i.e., designated waste disposal sites, use of chemical disinfectants, avoidance of feeding contaminated tissues to dogs, and regular cleaning of animal housing, should be prioritized.

Multivariable logistic regression analysis of risk factors for bovine brucellosis

The final logistic regression model identified three significant predictors of brucellosis seropositivity: (1) Herd size, (2) Abortion history, and (3) Farm hygiene status (Table 7). Specifically, cattle from smaller herds had lower odds of infection compared to those in larger herds, while animals with an abortion history were far more likely to be seropositive. Farms with good or very good hygiene practices showed a markedly reduced risk compared to those with poor hygiene. These findings highlight the central role of reproductive history and biosecurity in the occurrence of bovine brucellosis, consistent with previous reports by Currò *et al.* (2012) and Li *et al.* (2019).

The final logistic regression model can be expressed as follows:

$$\begin{aligned}\text{Logit}(P) = 2.569 - 2.332\,(\text{Male}) - 2.687\\ (\text{Small herd}) - 0.904\,(\text{Medium herd}) + 3.143\\ (\text{Abortion history}) - 4.780\,(\text{Very good hygiene})\\ - 4.853\,(\text{Good hygiene})\end{aligned}$$

where P is the probability of seropositivity for brucellosis.

CONCLUSIONS

This study extensively examined the vulnerability of farming households to livelihood insecurity in both urban and rural areas. The key findings indicate that rural farming household heads tend to be older than their urban counterparts are, while they also cultivate larger expanses of land. Both urban and rural areas face various forms of livelihood insecurity, including climate change, biological hazards, socio-infrastructural challenges, economic instability, and political threats. Among these, drought, kidnapping, and cattle encroachment on farmland emerged as the most severe stressors, with rural areas experiencing a higher level of vulnerability, particularly to kidnapping and cattle-related damages on their farmland.

The regression analysis revealed that age, farming experience, and household size were significant predictors of kidnapping vulnerability in rural areas. Specifically, younger farmers, those with more farming experience, and larger households were more likely to be vulnerable to kidnapping. For cattle encroachment, years of schooling significantly reduced vulnerability in urban areas, while in rural areas, age, education, experience, and household size were all

significant factors influencing vulnerability. These findings underscore the importance of tailored interventions based on demographic and socio-economic characteristics.

To reduce vulnerability to kidnapping and cattle encroachment, pragmatic policy actions should include strengthening rural security systems, enforcing the Ekiti State anti-grazing law, and promoting community-based surveillance initiatives. Targeted support should also focus on increasing security-related awareness among urban and rural households, providing extension services on conflict-sensitive farming practices, and empowering farming households, particularly those with limited experience or large household sizes. Enhancing farmers' resilience through non-farm income opportunities to augment agricultural earnings, adoption of climate-smart practices through planting of drought-resistant crops, and affordable agricultural insurance schemes is crucial. These efforts should be supported by effective information dissemination to farming households, and backed by coordinated action from government, and local authorities to mitigate sustainably livelihood insecurity in both urban and rural areas of Ekiti State.

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