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RESEARCH ARTICLE

Knowledge, perception, and adoption of personal biosecurity measures among ruminant veterinarians and farmers in Georgia: A cross-sectional nationwide study

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ABSTRACT

Background and Aim: Zoonotic diseases pose a major global public health and economic threat, particularly in regions with intensive livestock–human interaction. Georgia, in the South Caucasus, faces endemic zoonoses such as brucellosis, anthrax, and echinococcosis, yet limited information exists on the personal biosecurity practices of those most at risk. This study aimed to assess the extent, determinants, and characteristics of personal biosecurity measures (PBMs) among ruminant farmers and veterinarians in Georgia, with emphasis on their knowledge, attitudes, and perceived zoonotic risks.

Materials and Methods: A nationwide cross-sectional survey was conducted between July and September 2024 among 433 ruminant farmers and 114 veterinarians across nine regions and 53 municipalities. Validated, multilingual questionnaires were used to collect data on socio-demographics, zoonosis awareness, risk perception, personal protective equipment (PPE) usage, motivators, and barriers to PBM adoption. Descriptive and non-parametric analyses (Mann–Whitney U and Kruskal–Wallis) were performed using R software.

Results: Among farmers, 41.8% did not believe zoonoses could be contracted from animals, yet paradoxically scored higher in PBM implementation than those who did. Female farmers, those with higher education, and those who had discussed zoonosis prevention with experts demonstrated stronger adherence, whereas longer livestock experience predicted lower compliance. Among veterinarians, 70.2% self-rated their zoonosis knowledge as high, though only four correctly identified all listed zoonoses. Field veterinarians and those working ≥3 days/week scored significantly higher in PPE use ($p < 0.05$). Across all respondents, PPE usage was highest for gloves and farm-dedicated clothing but lowest for face masks and protective glasses during high-risk procedures such as parturition and carcass disposal. Discomfort and hot conditions were the main obstacles to PPE use.

Conclusion: Personal biosecurity adoption in Georgia is widespread yet inconsistent and shaped by gender, education, experience, and perceived vulnerability. The contradiction between perceived knowledge and actual zoonotic awareness underscores the need for targeted, behavior-centered training. Expanding educational leaflets and strengthening farmer–veterinarian communication within the National Animal Health and One Health frameworks could bridge gaps between knowledge, perceptions, and practices.

Keywords: biosecurity, farmers, Georgia, One Health, personal protective equipment, veterinarians, zoonoses.

INTRODUCTION

Humans and animals share an inherently close and interdependent relationship that underpins food security, livelihoods, and companionship. However, this proximity also facilitates the transmission of zoonotic pathogens, estimated to account for approximately 61% of all human infectious disease agents [1, 2]. The One Health concept underscores the critical need for integrated approaches to safeguard public health by preventing zoonoses and

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emerging infections at the interface of human, animal, and environmental systems. The Quadripartite Organizations, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme, the World Organization for Animal Health (WOAH), and the World Health Organization (WHO), jointly lead coordinated efforts at global, regional, and national levels to mitigate such threats [3].

The WHO and WOAH have identified brucellosis, echinococcosis, and rabies as priority zoonoses of significant public health and veterinary concern in Central Asian and Caucasian countries [4]. Georgia, located in the South Caucasus, bears a particularly high zoonotic disease burden [5]. Brucellosis remains endemic, with ruminant seroprevalence ranging from 2.2% to 31% at the herd or village level and around 5.2% at the individual level [6]. In humans, the annual incidence between 2015 and 2019 averaged 4.7 cases/100,000 population [7]. Anthrax is also entrenched; national surveillance between 2008 and 2015 reported numerous human cutaneous cases [8], and a separate study (2000–2012) recorded more than a fivefold increase in incidence in rural–urban interface zones [9]. Rabies persists as a public health challenge, although human cases declined from approximately 5/year (2007–2014) to 1/year (2015–2023), animal cases, especially in dogs, surged to a record high in 2023 [10]. In contrast, data on echinococcosis remain scarce and fragmented [11].

To address these threats, Georgia established the National Animal Health Program Steering Group in 2013 to prioritize zoonoses of public health importance. The program introduced targeted vaccination against brucellosis, anthrax, and rabies in animals, and prophylactic vaccination for high-risk human populations, including hunters and veterinarians [7].

Globally, zoonoses impose major health and economic burdens, incurring high treatment costs, livestock losses, reduced productivity, and trade limitations [12]. In Georgia, brucellosis is among the most prevalent bacterial zoonoses in livestock, leading to severe economic losses, particularly in the regions of Kakheti, Kvemo Kartli, and Imereti [13]. Longitudinal studies over three decades identified shepherds (29%) and farmers (12.3%) as the most affected occupational groups [14]. Anthrax, similarly, poses persistent risks, with epidemiological investigations linking human cases to high-risk behaviors such as livestock slaughter, carcass disposal, caring for diseased animals, and handling contaminated animal products [15, 16].

Recognizing these impacts, the focus of health systems has shifted from curative to preventive medicine, with biosecurity emerging as a cornerstone of animal and public health [17, 18]. Although definitions vary across sectors, biosecurity broadly encompasses measures to prevent the introduction and spread of infectious agents affecting humans, animals, plants, and ecosystems [19]. Traditionally divided into internal and external measures [20], WOAH defines biosecurity as "a set of management and physical measures designed to reduce the risk of disease spread within and between animal populations" [21]. Recent frameworks have expanded this concept through the 5Bs model, bio-exclusion, bio-compartmentation, bio-containment, bio-prevention, and bio-preservation, linking human, animal, plant, and environmental health within a unified One Health framework [17, 21–25].

Effective biosecurity demands context-specific implementation tailored to farm type and production system. At the individual level, personal biosecurity measures (PBMs), including hand hygiene, appropriate use of personal protective equipment (PPE), cleaning and disinfection, and sharp safety, play a key role in minimizing pathogen exposure and interrupting zoonotic transmission chains [26, 27].

Situated between Eastern Europe and Western Asia, Georgia remains a key transboundary zone for infectious disease movement. Although neighboring countries such as Türkiye, Armenia, and Azerbaijan share similar zoonotic profiles, their livestock systems, veterinary structures, and disease control capacities differ, underscoring the need for country-specific assessments. Ongoing national initiatives, including the National Animal Identification and Traceability System (NAITS), the Animal Health Program, and the One Health Action Plan, mark important steps toward modernizing Georgia's veterinary and public health infrastructure and strengthening integrated zoonosis control [28].

Despite Georgia's ongoing veterinary modernization and the implementation of the National Animal Health Program and One Health Action Plan, empirical data on personal biosecurity behavior among individuals in direct contact with ruminants remain largely absent. While previous studies in Europe, Asia, and Africa have described farmers' and veterinarians' biosecurity practices, comparable research in the South Caucasus is scarce, despite the region's heavy burden of transboundary animal diseases and zoonotic infections such as brucellosis, anthrax, echinococcosis, and rabies. Most available data in Georgia focus on pathogen surveillance, vaccination coverage, or disease prevalence, rather than the behavioral and occupational factors influencing zoonotic risk at the human–animal interface. Furthermore, existing literature does not sufficiently address how socio-demographic characteristics (e.g., gender, education, and experience) and professional factors (e.g., field vs. official veterinarians, working frequency, and perceived zoonosis knowledge) shape adherence to PBMs. No comprehensive nationwide study has yet evaluated the determinants of PPE use, hygiene compliance, or risk perception among Georgian livestock stakeholders. This gap limits the design of evidence-based interventions and communication strategies needed to align national programs with the behavioral realities of those most at risk. Therefore, a systematic assessment of farmers' and veterinarians' knowledge, attitudes, and practices (KAP) related to PBMs is essential to bridge the current knowledge deficit and to support a stronger One Health–based response to zoonotic threats in the region.

This study aimed to assess the extent, characteristics, and determinants of PBMs adopted by ruminant farmers and veterinarians across Georgia. Specifically, it sought to:

1. Quantify the level of implementation of key PBMs, such as hand hygiene, cleaning and disinfection, and use of PPE, under various livestock management and veterinary care scenarios.
2. Identify socio-demographic, professional, and perceptual factors influencing adherence to these practices.
3. Demonstrate the knowledge, attitudes, and risk perceptions of farmers and veterinarians toward zoonotic disease prevention.
4. Explore the motivators and obstacles associated with PPE use and other biosecurity behaviors in field conditions.

By providing the first nationwide dataset on PBMs among Georgian ruminant farmers and veterinarians, this study generates baseline evidence to inform policy, guide targeted awareness campaigns, and strengthen farmer–veterinarian communication frameworks within Georgia's evolving One Health and animal health programs.

MATERIALS AND METHODS

Ethical approval

Ethical approval for this study was obtained from the Ethical Committee of the Universitat Autònoma de Barcelona (approval code: CEEAH 7165 2/2/2024). All study procedures were reviewed and approved prior to the commencement of the research and were conducted in accordance with internationally accepted ethical principles for research involving human participants.

Participation in the study was entirely voluntary. All participants were clearly informed about the objectives of the study, the study design, the procedures involved, the potential risks and benefits, and their rights as research participants. It was explicitly stated that refusal to participate or withdrawal from the study at any stage would not result in any penalty or adverse consequences.

Written informed consent was obtained from all participants prior to data collection. For participants recruited through face-to-face interactions, written consent was obtained before administering the questionnaire. For veterinarians recruited through online platforms, informed consent was obtained electronically before access to the survey was provided.

Confidentiality and anonymity of participants were strictly maintained throughout the study. No personal identifiers were collected, and all responses were anonymized and coded prior to analysis. The collected data were stored securely on password-protected devices accessible only to the research team, in compliance with applicable data protection and privacy regulations.

Study period and location

The study was conducted between January and October 2024. Researchers based in Barcelona, Budapest, and Tbilisi communicated and coordinated throughout the study period using online communication tools. Fieldwork and data collection were carried out across Georgia between July and September 2024 under the supervision of FAO Georgia.

Study design

A cross-sectional study design was chosen to obtain a snapshot of ruminant veterinarians and farmers' current personal biosecurity practices and their determinants during the study period. Given the wide geographic scope and large population of interest, it was particularly suitable for efficient data collection across different regions and subgroups within a limited timeframe.

Study area and population

This study was conducted in Georgia, which includes 12 regions and 76 municipalities [29]. The NAITS was established in 2022. At the time of the study, 2,455,408 large ruminants (LR) were distributed across 818,469 holdings, and 600,269 small ruminants (SR), mainly sheep, were distributed across 7,503 holdings in 9 regions and 53 municipalities (Excel file_Georgia livestock data). Approximately 150,000 farmers and 1,000 veterinarians (including 500 field and 500 official veterinarians) were engaged in ruminant farming in the country (D. Angelovski, personal communication, 2024). Official veterinarians are those working primarily at the central or regional administrative level who conduct field visits for audits or specific duties. In contrast, field veterinarians are those whose daily work involves direct contact with animals. Smallholder farms accounted for more than 95% of all farms, with only 5% were commercial. There were three main production types: mixed-breed extensive cattle, dairy cattle, and extensive sheep farming [30].

Development of questionnaires and leaflets

The study questionnaires for farmers and veterinarians were developed collaboratively by researchers from Universitat Autònoma de Barcelona, experts from the FAO Regional Office for Europe and Central Asia, and experts from the FAO Georgia office. The questionnaires were based on a literature review and online guidelines. The drafted questionnaires were sent to experts, who independently reviewed each questionnaire item for relevance, clarity, representativeness, cultural and contextual appropriateness, feasibility, alignment with study objectives, and wording neutrality. Feedback was compiled, discussed in consensus meetings with stakeholders, and incorporated to refine questionnaire items.

The final version of the study questionnaire included sections on farm characteristics, socio-demographic information, veterinarians' professional profiles, awareness of zoonotic transmission, risk perception of zoonoses, knowledge of zoonoses, application of practices to prevent zoonoses and safeguard livestock health, implementation of PBMs, related motivators and obstacles, farmer–veterinarian communication, and education and training needs on the subject. Most questions were multiple-choice, with no open-ended items.

The risk perception of zoonoses, practices to prevent zoonoses and safeguard livestock health, implementation of PPE, and associated motivators and obstacles were assessed using the Likert scale. The perceived level of knowledge of veterinarians and farmers' awareness of zoonotic transmission were evaluated using categorical responses.

After finalizing the English versions (Supplementary File 1), the service provider (Applied Research Company), under the supervision of the FAO Georgia focal point, translated them into Georgian, Armenian, and Azerbaijani given the involvement of those two ethnic groups in Georgian farming. Independent bilingual experts culturally adapted the translations to ensure that the wording and concepts were contextually appropriate and easily understood. The questionnaires were then formatted for the KoboCollect platform v2024.1.3 (Kobo, Inc., Harvard Humanitarian Initiative, Cambridge, MA, USA), and a pilot study was conducted with four farmers and three veterinarians.

Following the pilot, it was found that the use of dedicated farm boots was not a common practice in Georgian farms; consequently, this item was removed from the PPE section. In addition, due to variations in local terminology for certain diseases, the questionnaire was revised to include both the scientific names and the commonly used local names in parentheses. Participants in the pilot study were excluded from the final sample.

Face and content validity were assessed through expert review, and the internal consistency of Likert-scaled sections for PPE use scores was evaluated using Cronbach's alpha, which was 0.92 for farmers and 0.89 for veterinarians. These sections were treated as unidimensional based on the questionnaire's conceptual design. The scoring system used to describe the level of PPE implementation was not intended to serve as an analytical scale or to define categorical thresholds; therefore, formal factor analysis was not performed. Informative leaflets on zoonoses prevention and PPE use were created in English and Georgian with additional contributions from the WHO experts (Supplementary File 2).

Sampling strategy

The sample size was calculated using Cochran's formula [31], assuming a 95% confidence level, 5% margin of error, and an estimated 50% prevalence of biosecurity adherence to ensure maximum variability, resulting in 387 farmers, 100 field veterinarians, and 100 official veterinarians.

Based on the FAO Georgia focal point data on the number of cattle, SRs (mainly sheep), and farms by region and municipality, a stratified proportional sampling approach was applied across municipalities according to livestock holdings (Excel file_Georgia livestock data). Eligible farmers and veterinarians were subsequently recruited within each stratum using convenience sampling. Eligible participants included individuals aged ≥18 years who were actively involved in ruminants care and consented to participate. Those who were not directly responsible for animal handling or veterinary tasks were excluded.

Due to the geographic constraints of conducting fieldwork, including the country's mountainous terrain and the dispersed distribution of livestock farms, a convenience sampling approach was employed. This method allowed for the efficient recruitment of participants who were accessible and willing to engage in the study, ensuring timely data collection while maintaining the safety and feasibility of field operations. Recruitment was stratified by region and livestock type to improve the representativeness of the sample, and efforts were made to include farms of varying sizes and production systems.

Recruitment of farmers

Proportional to the distribution of cattle and sheep holdings across the country, the study aimed to reach a total of 387 farmers to be surveyed face-to-face, including at least 350 farmers engaged in mixed-breed extensive cattle or dairy farming and 37 farmers involved in extensive sheep farming (Figures 1 and 2). Some rules were imposed to avoid multiple interviews from the same village: only one farmer was interviewed from villages with fewer than 10 farms, while villages with 10 farms or more could contribute up to two farmers. Participants were recruited through convenience sampling.

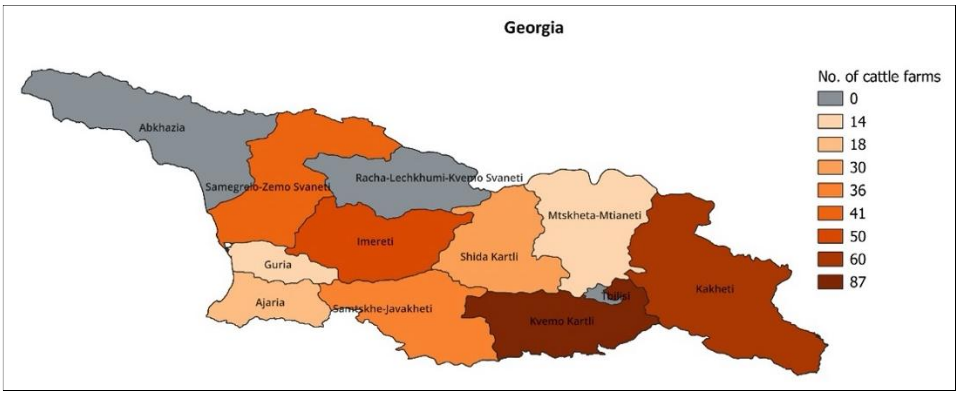

Figure 1: Geographic distribution of cattle farms targeted in the study across regions of Georgia. The map illustrates the spatial coverage of large-ruminant production systems in the study. The map was generated using QGIS Geographic Information System (version 3.34).

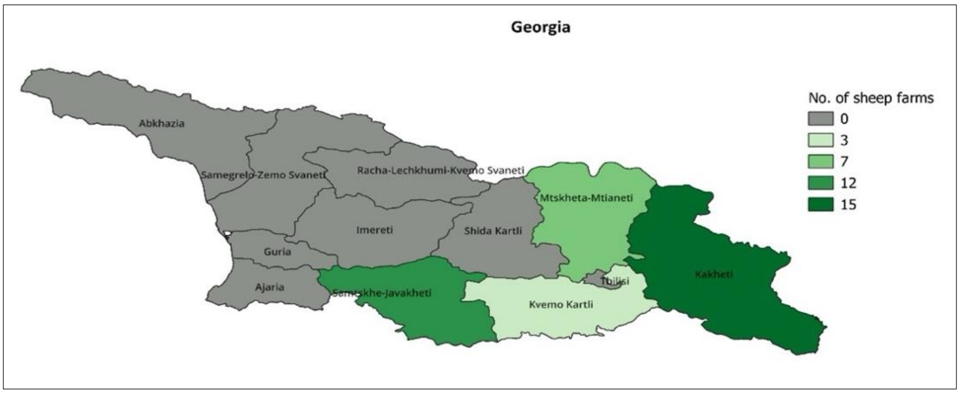

Figure 2: Geographic distribution of sheep farms targeted in the study across regions of Georgia. The map illustrates the spatial distribution of small-ruminant production systems in the study area. The map was generated using QGIS Geographic Information System (version 3.34).

Recruitment of veterinarians

The study aimed to include 200 veterinarians: 100 field veterinarians to be surveyed face-to-face and 100 official veterinarians who responded to the online questionnaire. Approximately two field veterinarians from each municipality were targeted for face-to-face interviews. A maximum of one field veterinarian was selected in municipalities with fewer than 10 farms. Up to two field veterinarians were recruited for municipalities with 10–19 farms, while a maximum of three field veterinarians were included in those with 20 or more farms. Participants were selected through convenience sampling.

A summary of the study protocol is presented in the flowchart, as shown in Figure 3, which was created using BioRender.com.

Field work

We collaborated with a professional data collection company (Applied Research Company, Tbilisi, Georgia) to ensure the quality and consistency of data collection. Before the fieldwork, the staff was provided with a detailed briefing on the objectives and methodology of the study and standardized instructions on how to conduct face-to-face interviews with the participants in an ethical and consistent manner.

For the online questionnaire component, the participants received clear guidance on how to complete the survey. Data entry was monitored daily. Between July 01, 2024, and September 30, 2024, trained personnel conducted face-to-face interviews with farmers and field veterinarians in nine regions and 53 municipalities, obtaining written consent before administering questionnaires. Participants received information leaflets on completion of the interview. The contracted data collection company conducted the fieldwork under the supervision of the FAO Georgia focal point. On completion, the company provided the research team with a data quality report, confirming that all data had been double-checked and documenting any challenges encountered in the field.

Due to logistical reasons, data from official veterinarians were collected online through a questionnaire link, while the consent form and leaflet were sent through the National Food Agency mailing list, with three reminders sent between July and September 2024.

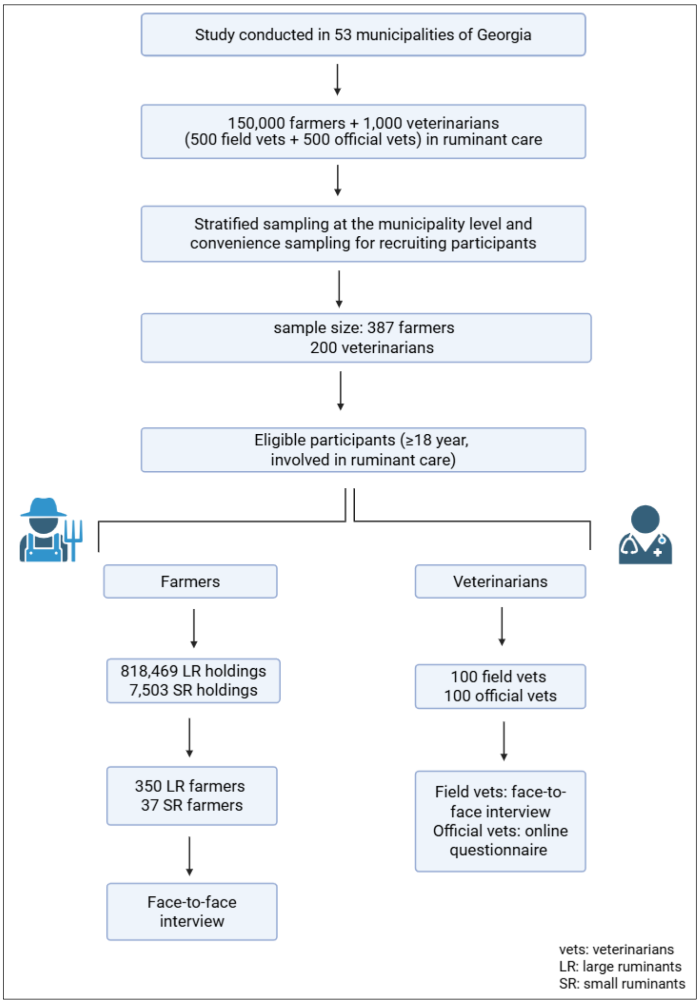

Figure 3: Flow diagram of the study protocol. The diagram summarizes the study design, including sampling strategy, recruitment of farmers and veterinarians, data collection methods (face-to-face and online), and analytical workflow.

Data management and scoring

Data were exported from the KoboToolbox (Kobo Inc., Harvard Humanitarian Initiative, Cambridge, MA, USA) and organized in Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). Three incomplete questionnaires from the online survey were excluded from the final analysis. All face-to-face surveys conducted with field veterinarians and farmers were completed and included in the dataset.

Descriptive analyses were performed to summarize the data with counts and frequencies. The Shapiro–Wilk test was used to assess the normality of the numeric variables. The comparative analysis did not include farm size because the data were highly skewed and not normally distributed, making meaningful categorization impractical. Only one farmer declined to disclose their gender; as 55.4% of participants were female and 44.5% were male, this individual was categorized as female for the purposes of the comparative analysis.

To facilitate comparative analyses, a scoring system was applied to each of the three sections: good general practices for preventing zoonoses; good general practices on farms ensuring healthy livestock; and using four PPE items (i.e., farm-dedicated clothing, gloves, face mask, and protective glasses). The Likert scale assigned points (“always = 2”, “sometimes = 1”, and “never = 0”), resulting in an overall score for each study subject based on the sum of assigned scores for all practices. In the veterinarian questionnaire, the practices to avoid were scored inversely (i.e., 0 assigned to "always" and 2 to "never").

With a maximum possible score of 8, higher scores represented higher levels of adoption of PBMs. The scores were treated as continuous numeric variables rather than being categorized into thresholds (e.g., low, medium, and high adherence). As such, we reported median values to describe central tendencies, allowing for a more nuanced and flexible interpretation of PPE use across participants without imposing arbitrary cutoff points. Treating composite scores as continuous variables is a practice used in behavioral and public health research when multiple Likert items measure a single construct [31–33].

Statistical analysis

Due to the non-normal distribution of score data (Shapiro–Wilk test, $p < 0.05$), non-parametric tests were applied. Chi-square tests compared categorical variables, while Mann–Whitney U and Kruskal–Wallis tests assessed differences in scores, with Dunn's test and Bonferroni correction for *post hoc* pairwise comparisons.

The effect sizes were reported as rank-biserial correlation (r) for the Mann–Whitney U-test, eta squared (η^2) for the Kruskal–Wallis test, and Cramér's V for the Chi-square test. These non-parametric methods are robust for ordinal data and deviations from normality, providing an appropriate analytical approach for the objectives of the study.

Statistical significance was set at $p < 0.05$. All analyses were conducted in R Commander (https://www.R-project.org/) and RStudio (version 4.5.1; https://www.rstudio.com/) with the following packages: dplyr, psych, summarytools, rstatix, dunn.test, boxplot, and ggplot2 (https://www.rstudio.com/).

RESULTS

Overview of study participants

Overall, 547 participants, comprising 433 farmers and 114 veterinarians, were surveyed across nine regions and 53 municipalities across the country. Although not initially targeted, two veterinarians from Tbilisi (capital region), two from Rustavi (Kvemo Kartli region), and two from Batumi (Adjara region) responded to the online questionnaire, and their responses were included in the analysis. Figure 4 shows the total number of participants by municipality. A detailed breakdown of farmers (LR and SR farmers) and veterinarians (field and official veterinarians) by region and municipality can be found in the accompanying Excel file_Georgia Livestock Data.

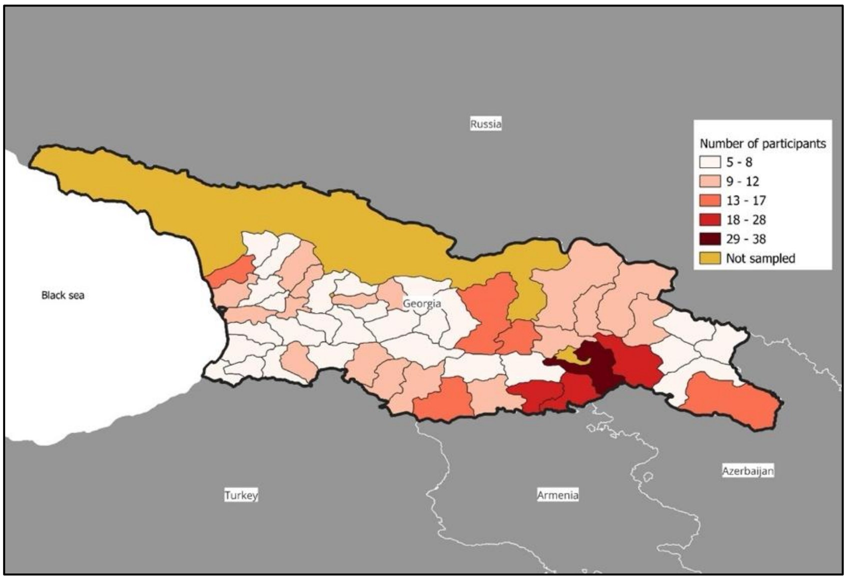

Figure 4: Spatial distribution of study participants across municipalities in Georgia. The figure shows the total number of participants per municipality, including farmers (large- and small-ruminant farmers) and veterinarians (field and official veterinarians). †Numbers represent the total participants per municipality. ‡Tbilisi was not initially targeted; however, responses from two official veterinarians who completed the online questionnaire were included in the analysis. The map was generated using QGIS Geographic Information System (version 3.34).

Farmer survey results

Socio-demographic features

Although the target sample size was 387 farmers (including 350 LR and 37 SR farmers), the service provider ultimately interviewed 433 farmers (388 LR and 45 SR farmers) face-to-face while adhering to the prescribed instructions and guidelines as closely as possible. Over half of the participants were female and older than 50 years, with most being high school graduates. Almost all were farm owners, and two-thirds had over 10 years of experience in livestock care. The majority of respondents reported having no chronic diseases (Table 1).

Farm characteristics

A total of 16.6% of farms kept various combinations of LRs and SRs, while 83.4% focused on a single type of livestock. Of all holdings, 50.6% had dairy cattle, 5.8% raised beef cattle, 16.6% raised cattle for mixed purposes, and 10.4% kept SRs. Dairy cattle farms, which constituted 50.6% of the total holdings, were predominantly small-scale, with 91.3% having ≤10 animals (Supplementary File 3).

Table 1: Socio-demographic characteristics of ruminant farmers participating in the nationwide cross-sectional survey in Georgia.

Variables	n	%†
Age (years)		
15–20	3	0.7
21–30	11	2.5
31–40	59	13.6
41–50	123	28.4
≥51	237	54.7
Gender		
Female	239	55.2
Male	193	44.5
I do not want to answer	1	0.2
Marital status		
Married	387	89.4
Not married	46	10.6
Highest level of education		
Primary school	6	1.4
Secondary school	44	10.2
High school	303	70.0
University degree	25	5.8
Postgraduate degree	55	12.7
Role on the farm		
Farm owner	405	93.5
Salaried employee	13	3.0
Other	15	3.5
Years of experience		
≤5	54	12.5
6–10	93	21.5
11–20	138	31.9
≥21	148	34.2
Number of workers		
0	102	23.6
1–5	324	74.9
6–10	5	1.1
≥11	2	0.5
Medical history of chronic diseases or immune disorders		
Yes	67	15.5
No	364	84.1
I do not want to answer	2	0.5

† Percentages are calculated within each variable column and may not total 100% because of rounding or missing responses.

Knowledge of zoonoses

41.8% of farmers believed that it was not possible to contract a disease from their animals. Those who responded affirmatively were further questioned about which zoonoses they were familiar with. The four top diseases mentioned were brucellosis, anthrax, Crimean-Congo hemorrhagic fever, and ringworm, with several farmers also mentioning rabies. Regarding the history of zoonoses over the past 10 years, 92.6% reported no occurrences (Supplementary File 3).

Cleaning and disinfection practices

48% cleaned and disinfected their farms daily, and 51% washed farm-dedicated clothing weekly, most often separately. Most of the farms had hygiene facilities, including a sink (73.9%), running water (73%), and a soap bar (82.4%) (Supplementary File 3).

Good general practices for zoonosis prevention and healthy livestock

Most farmers consistently practiced proper hand washing, covered cuts, boiled milk, and safely disposed of carcasses. While the majority of participants regularly administered antiparasitic medicines to their pets, about one-third were not always concerned with their pets' feeding on viscera. Over 90% were vigilant in seeking veterinary advice and had their animals vaccinated against zoonoses. Three-quarters of the animals were always isolated (Table 2).

Table 2: Good general practices for zoonoses prevention and ensuring healthy livestock among ruminant farmers (n = 433).

Practices	Always n (%)†	Sometimes n (%)†	Never n (%)†
Preventing zoonoses			
Wash hands before contact with animals	337 (77.8)	83 (19.2)	13 (3.0)
Wash hands after contact with animal body fluids (e.g., blood, abortion materials)	402 (92.8)	27 (6.2)	4 (0.9)
Wash hands after contact with animals even if gloves are used	365 (84.3)	60 (13.9)	8 (1.8)
Wash hands before eating, drinking, or smoking	400 (92.4)	32 (7.4)	1 (0.2)
Wash wound site after a cut or abrasion at the farm	393 (90.8)	37 (8.5)	3 (0.7)
Cover cuts or abrasions with waterproof bandages	379 (87.5)	47 (10.8)	7 (1.6)
Boil or pasteurize milk before consumption	389 (89.8)	39 (9.0)	5 (1.1)
Wash fruits and vegetables thoroughly before eating or cooking	398 (91.9)	35 (8.1)	–
Avoid consuming raw or undercooked meat	402 (92.8)	20 (4.6)	11 (2.5)
Properly manage and dispose of animal waste or carcasses	385 (88.9)	41 (9.5)	7 (1.6)
Ensure a clean and safe water supply for animals and humans	386 (89.1)	44 (10.2)	3 (0.7)
Regularly administer antiparasitic medicines to pets	390 (90.1)	42 (9.7)	1 (0.2)
Do not allow pets on the farm	304 (70.2)	89 (20.5)	40 (9.2)
Do not feed pets with viscera	321 (74.1)	74 (17.1)	38 (8.8)
Ensuring healthy livestock			
Isolate sick animals	326 (75.3)	67 (15.5)	40 (9.2)
Promptly seek veterinary advice when illness is observed	402 (92.8)	27 (6.2)	4 (0.9)
Treat infected animals promptly with recommended medications	418 (96.5)	12 (2.8)	3 (0.7)
Vaccinate animals against zoonotic diseases (e.g., brucellosis)	410 (94.7)	22 (5.1)	1 (0.2)

† Percentages are calculated column-wise.

Implementation of PPE

In general, the usage of the four PPE items was high across seven situations. Farm-dedicated clothing and gloves were the most frequently used items, while protective glasses were the least used. Notably, nearly one-fifth of participants always used face masks when making contact with healthy animals, but approximately 30% never used them in risky situations. Similarly, at least 40% of the participants never used protective glasses in any situation, including assisting parturition and disposing of aborted membranes, although 24.5% always used them during stable cleaning (Table 3).

Table 3: Level of implementation of personal protective equipment (PPE) by farmers across different situations (n = 433).

Situation	Frequency	Farm-dedicated clothing n (%)†	Gloves n (%)†	Face mask n (%)†	Protective glasses n (%)†
Contact with healthy animals	Always	279 (64.4)	163 (37.6)	86 (19.9)	77 (17.8)
	Sometimes	112 (25.9)	154 (35.6)	116 (26.8)	79 (18.2)
	Never	42 (9.7)	116 (26.8)	231 (53.3)	277 (64.0)
Contact with clinically sick animals	Always	339 (78.3)	291 (67.2)	191 (44.1)	121 (27.9)
	Sometimes	63 (14.5)	105 (24.2)	116 (26.8)	108 (24.9)
	Never	31 (7.2)	37 (8.5)	126 (29.1)	204 (47.1)
Contact with animals suspected of having a disease	Always	352 (81.3)	324 (74.8)	213 (49.2)	141 (32.6)
	Sometimes	55 (12.7)	77 (17.8)	112 (25.9)	110 (25.5)
	Never	26 (6.0)	32 (7.4)	108 (24.9)	181 (41.9)
Contact with dead animals / disposal of carcasses	Always	347 (80.1)	338 (78.1)	229 (52.9)	138 (31.9)
	Sometimes	50 (11.5)	60 (13.9)	91 (21.0)	105 (24.3)
	Never	36 (8.3)	35 (8.1)	113 (26.1)	190 (43.9)
Assisting parturition	Always	354 (82.1)	319 (74.0)	154 (36.4)	94 (22.6)
	Sometimes	56 (13.0)	84 (19.5)	119 (28.1)	101 (24.3)
	Never	21 (4.9)	28 (6.5)	150 (35.5)	220 (53.0)
Disposal of placentas and stillbirths	Always	334 (77.1)	306 (70.7)	186 (43.0)	125 (28.9)
	Sometimes	59 (13.6)	80 (18.5)	113 (26.1)	102 (23.6)
	Never	40 (9.2)	47 (10.9)	134 (30.9)	206 (47.6)
Cleaning surfaces/stables	Always	316 (73.3)	254 (58.7)	132 (30.5)	106 (24.5)
	Sometimes	90 (20.9)	130 (30.0)	139 (32.1)	102 (23.6)
	Never	25 (5.8)	49 (11.3)	162 (37.4)	225 (52.0)

† Percentages are calculated column-wise.

The PPE use scores generally had a high median value of approximately 6 (i.e., three out of four PPEs were always applied) (Figure 5).

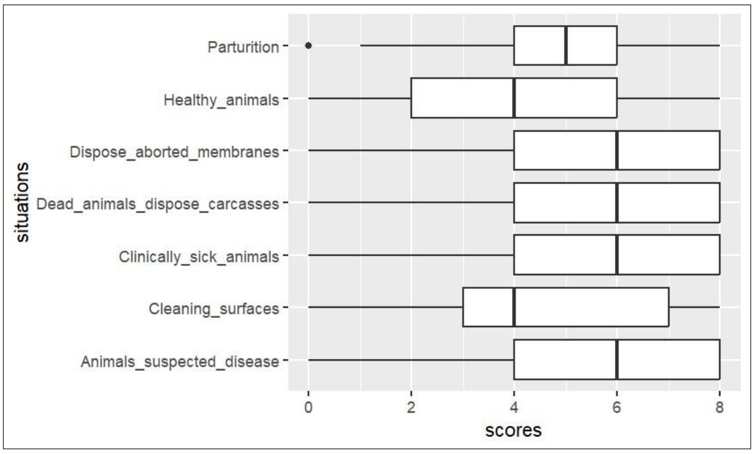

Figure 5: Personal protective equipment (PPE) usage scores among farmers across different livestock-related situations. Boxplots display the distribution of composite PPE scores (range 0–8) derived from the reported use of farm-dedicated clothing, gloves, face masks, and protective glasses across seven scenarios. Higher scores indicate greater adherence to PPE use, with a median score of approximately six.

Perceived risk of contracting zoonoses

Among the situations presented, being in contact with healthy animals, assisting parturition, and cleaning surfaces/stables were perceived as the least likely to cause zoonosis transmission (Figure 6).

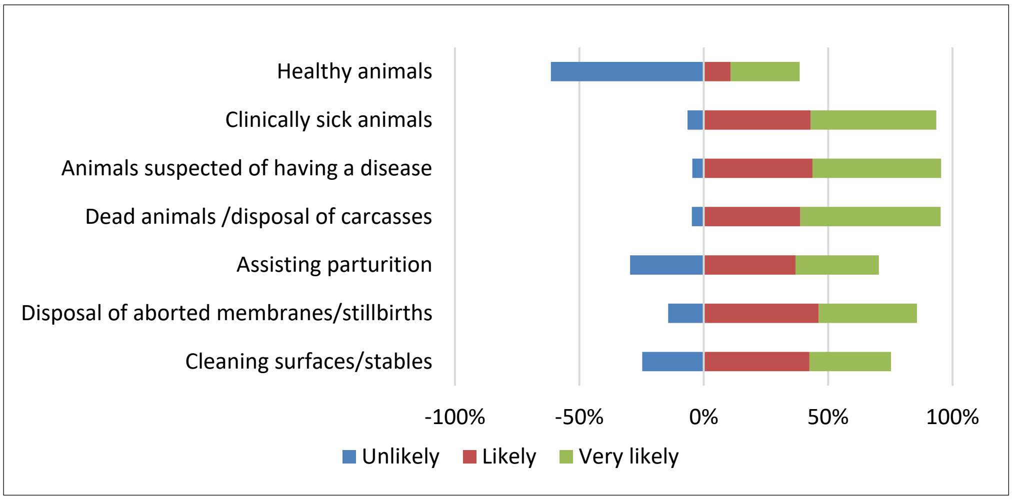

Figure 6: Farmers' perceived risk of contracting zoonotic diseases during contact with healthy animals, assisting parturition, and cleaning stables or facilities were considered as lower-risk activities.

Motivators and obstacles to the use of PPE

Almost all the proposed motivators for using PPE were agreed to some extent to be effective. However, over 20% of the respondents disagreed that vulnerability and knowing of others with a history of zoonosis encouraged them to take this biosecurity measure (Figure 7).

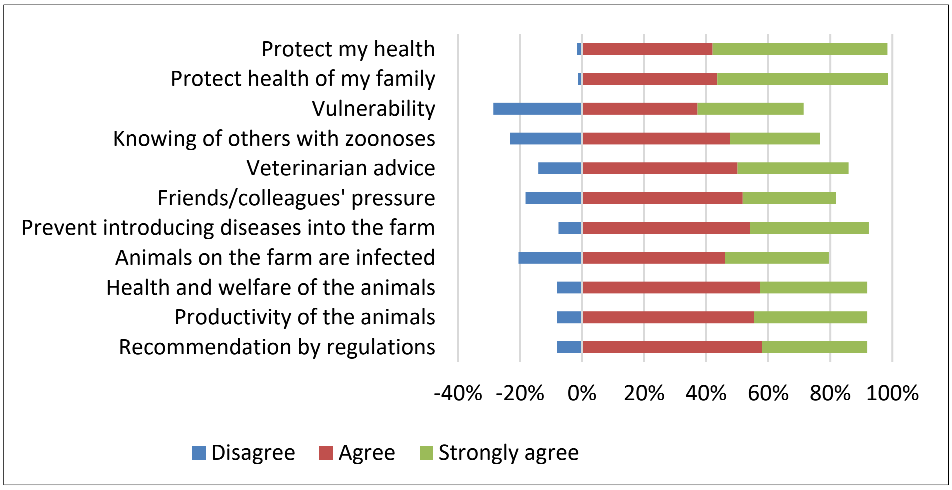

Figure 7: Motivators influencing personal protective equipment (PPE) use among farmers. The figure illustrates farmers' agreement with potential motivators for PPE use, including self-protection, legal requirements, animal health protection, and advice from veterinarians. Perceived vulnerability and knowing others with zoonotic disease history were less frequently identified as motivating factors.

The primary obstacles in using PPE were discomfort and hot or humid conditions, whereas approximately half of the respondents disagreed that PPE was expensive or difficult to use. Approximately 70% reported knowing how and when to use PPE (Figure 8).

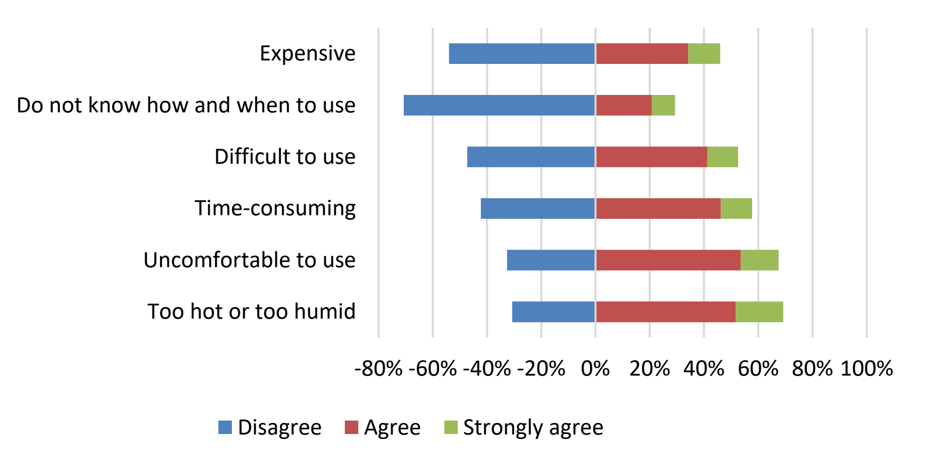

Figure 8: Perceived obstacles to personal protective equipment (PPE) use among farmers. Reported barriers include discomfort and hot or humid conditions, while cost and complexity were less frequently perceived as limiting factors. Responses reflect farmers' self-reported constraints under field conditions.

Education and training

Among the farmers, 52.2% reported having discussions on PPE and zoonotic disease prevention. Participants who had not had such discussions suggested that veterinarians might assume that farmers already possess this knowledge. The majority of farmers and their employees (90.8%) did not receive any training on the subject (Supplementary File 3).

Comparative analyses (farmers)

None of the scores for any of the response variables followed a normal distribution (Supplementary File 3).

Significance tests revealed that female sex, high educational level, and engaging in discussions on PPE and zoonosis prevention positively influence adherence to PBMs, whereas increased experience in livestock management is associated with less compliance.

Surprisingly, farmers who did not believe they could contract a disease from their animals tended to score higher in implementing all PBMs (Supplementary File 3).

A strong belief that PPE was uncomfortable or too hot and humid to wear was associated with lower compliance across many situations (Supplementary File 3).

Veterinarian survey results

Socio-demographic features

Although the targeted sample size was 200 veterinarians (100 field and 100 official veterinarians), a total of 117 veterinarians were surveyed, including 69 field veterinarians (face-to-face survey) and 48 official veterinarians (online recruitment; 9.6% response rate).

Three surveys from the online questionnaire were excluded due to incomplete data, leaving 114 for analysis. Most respondents were male, over 40 years of age, and married, with half having more than 20 years of experience in livestock care. The majority worked 1–2 days/week. Only a small number (n = 11) of participants reported having a chronic disease. Most veterinarians cared for beef or dairy cattle, and almost half worked with SRs (Table 4).

Knowledge of zoonoses

Seventy-two percent rated their knowledge of zoonoses as high, yet only four correctly identified zoonoses from the list given. The most recognized zoonotic diseases were brucellosis, anthrax, hemorrhagic fever, animal tuberculosis, and ringworm. Seven participants reported contracting zoonosis in the past decade (Supplementary File 3).

Hygiene and good general practices for zoonosis prevention

Seventy-four point six percent of veterinarians washed farm-dedicated clothing daily, and 83.3% separately (Supplementary File 3). Most practiced proper hand washing, covered wounds, and used sharps containers.

However, risky behaviors, such as removing needles by hand and removing needle caps with the mouth, were avoided by only 24.6% and 49.1% of participants, respectively (Table 5).

Table 4: Socio-demographic characteristics of ruminant veterinarians participating in the nationwide cross-sectional survey in Georgia.

Variables	n	%†
Age (years)		
31–40	18	15.8
41–50	31	27.2
≥51	65	57.0
Gender		
Female	35	30.7
Male	79	69.3
Marital status		
Married	99	86.8
Not married	14	12.3
I do not want to answer	1	0.9
Years of experience		
≤10	17	14.9
11–20	40	35.1
21–30	26	22.8
31–40	23	20.2
≥41	8	7.0
Weekly working days		
1–2 days	55	48.2
3–4 days	31	27.2
Daily	28	24.6
Medical history of chronic diseases or immune disorders		
Yes	11	9.6
No	101	88.6
I do not want to answer	2	1.7
Type(s) of livestock worked with	n‡	
Beef cattle	97	–
Dairy cattle	100	–
Sheep	50	–
Goat	40	–

† Percentages are calculated column-wise. ‡ Multiple responses were allowed; values indicate the number of times each livestock type was selected.

Table 5: Good general practices for preventing zoonoses applied by ruminant veterinarians.

Practices	Always n (%)†	Sometimes n (%)†	Never n (%)†
Wash hands before contact with animals	109 (95.6)	5 (4.4)	–
Wash hands after contact with animals and their body fluids (e.g., blood, abortion materials, fetuses)	114 (100)	–	–
Wash hands after contact with animals when gloves are used	112 (98.2)	2 (1.7)	–
Wash hands after touching equipment contaminated with animal body fluids	114 (100)	–	–
Wash hands after removal of personal protective equipment	112 (98.2)	2 (1.7)	–
Wash hands with bar soap	101 (88.6)	11 (9.6)	2 (1.7)
Wash hands with liquid or foam soap	105 (92.1)	9 (7.9)	–
Wash hands before eating, drinking, or smoking	111 (97.4)	3 (2.6)	–
Use alcohol-based disinfectants after hand washing	88 (77.2)	24 (21.0)	2 (1.7)
Use disposable towels to dry hands	88 (77.2)	23 (20.2)	3 (2.6)
Wash wound site after a cut or abrasion at the farm	111 (97.4)	3 (2.6)	–
Cover cuts or abrasions with waterproof bandages	106 (93.0)	8 (7.0)	–
Dispose of sharps (e.g., needles) in sharps containers	108 (96.4)	3 (2.7)	1 (0.9)
Remove needle from syringe by hand	28 (24.6)	17 (14.9)	69 (60.5)
Remove needle cap with the mouth	56 (49.1)	12 (10.5)	46 (40.3)

†Percentages are calculated row-wise.

Implementation of PPE

Overall, PPE use was high, with farm-dedicated clothing and gloves most frequently used. Protective glasses were the least used: nearly 25% never used them during surgery, vaccination, treatment, or sampling, and 1 in 3 during parturition.

In addition, 27.2% of women never used face masks during parturition (Table 6). Scores on PPE use had a high median value of approximately 8 (i.e., all four PPE items were always applied) (Figure 9).

Table 6: Level of implementation of personal protective equipment (PPE) by veterinarians across different professional activities (n = 114).

Situation	Frequency	Farm-dedicated clothing n (%)†	Gloves n (%)†	Face mask n (%)†	Protective glasses n (%)†
Physical examination of healthy animals	Always	88 (77.2)	94 (82.5)	59 (51.8)	46 (40.3)
	Sometimes	8 (7.0)	10 (8.8)	23 (20.2)	26 (22.8)
	Never	18 (15.8)	10 (8.8)	32 (28.1)	42 (36.8)
Physical examination of clinically ill animals	Always	102 (89.5)	102 (89.5)	76 (66.7)	63 (55.3)
	Sometimes	10 (8.8)	6 (5.3)	21 (18.4)	24 (21.0)
	Never	2 (1.7)	6 (5.3)	17 (14.9)	27 (23.7)
Physical examination of animals with suspected infectious disease	Always	107 (93.9)	106 (93.0)	85 (74.6)	73 (64.0)
	Sometimes	2 (1.7)	2 (1.7)	18 (15.8)	20 (17.5)
	Never	5 (4.4)	6 (5.3)	11 (9.6)	21 (18.4)
Post-mortem examination	Always	102 (89.5)	102 (89.5)	91 (79.8)	76 (66.7)
	Sometimes	2 (1.7)	6 (5.3)	16 (14.0)	21 (18.4)
	Never	10 (8.8)	6 (5.3)	7 (6.1)	17 (14.9)
Contact with blood, body substances, membranes, feces, or animal fluids	Always	102 (89.5)	108 (94.7)	92 (80.7)	81 (71.0)
	Sometimes	4 (3.5)	3 (2.6)	13 (11.4)	17 (14.9)
	Never	8 (7.0)	3 (2.6)	9 (7.9)	16 (14.0)
Surgery	Always	94 (82.5)	93 (81.6)	84 (73.7)	70 (61.4)
	Sometimes	2 (1.7)	4 (3.5)	11 (9.6)	15 (13.2)
	Never	18 (15.8)	17 (14.9)	19 (16.7)	29 (25.4)
Vaccination, treatment, and sampling	Always	99 (86.8)	106 (93.0)	81 (71.0)	64 (56.1)
	Sometimes	4 (3.5)	3 (2.6)	11 (9.6)	21 (18.4)
	Never	11 (9.6)	5 (4.4)	22 (19.3)	29 (25.4)
Parturition	Always	93 (81.6)	94 (82.5)	74 (64.9)	63 (55.3)
	Sometimes	3 (2.6)	3 (2.6)	9 (7.9)	12 (10.5)
	Never	18 (15.8)	17 (14.9)	31 (27.2)	39 (34.2)
Examination and disposal of aborted fetuses and stillbirths	Always	99 (86.8)	101 (88.6)	87 (76.3)	74 (64.9)
	Sometimes	3 (2.6)	3 (2.6)	11 (9.6)	17 (14.9)
	Never	12 (10.5)	10 (8.8)	16 (14.0)	23 (20.2)
Disposal of carcasses	Always	104 (91.2)	103 (90.3)	93 (81.6)	81 (71.0)
	Sometimes	2 (1.7)	3 (2.6)	8 (7.0)	11 (9.6)
	Never	8 (7.0)	8 (7.0)	13 (11.4)	22 (19.3)

†Percentages are calculated column-wise.

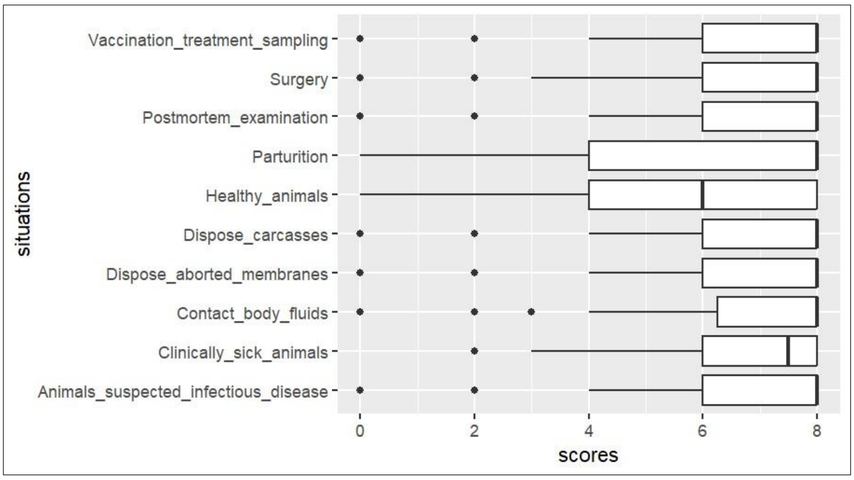

Figure 9: Personal protective equipment (PPE) usage scores among veterinarians across different professional activities. Boxplots show composite PPE scores (range 0–8) based on the reported use of four PPE items across veterinary procedures. The median score of approximately eight indicates high overall adherence.

Perceived risk of contracting zoonoses

Contact with healthy animals and parturition were considered the least likely to result in zoonoses (Figure 10).

Motivators and obstacles to the use of PPE

More than 30% of the respondents disagreed that vulnerability and experience with zoonoses were motivating factors in using PPE (Figure 11).

Regarding the obstacles, 64% agreed or strongly agreed that PPE use is a requirement for farmers. The majority disagreed that PPE use was expensive, difficult, time-consuming, uncomfortable, or too hot and humid. Many (83.3%) participants reported that they knew how and when to use PPE (Figure 12).

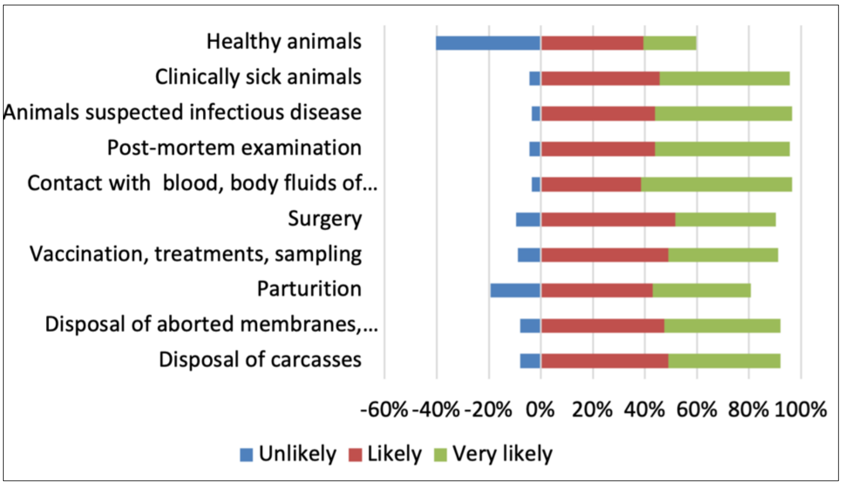

Figure 10: Veterinarians' perceived risk of contracting zoonotic diseases during contact with healthy animals and parturition was considered as a lower-risk activity.

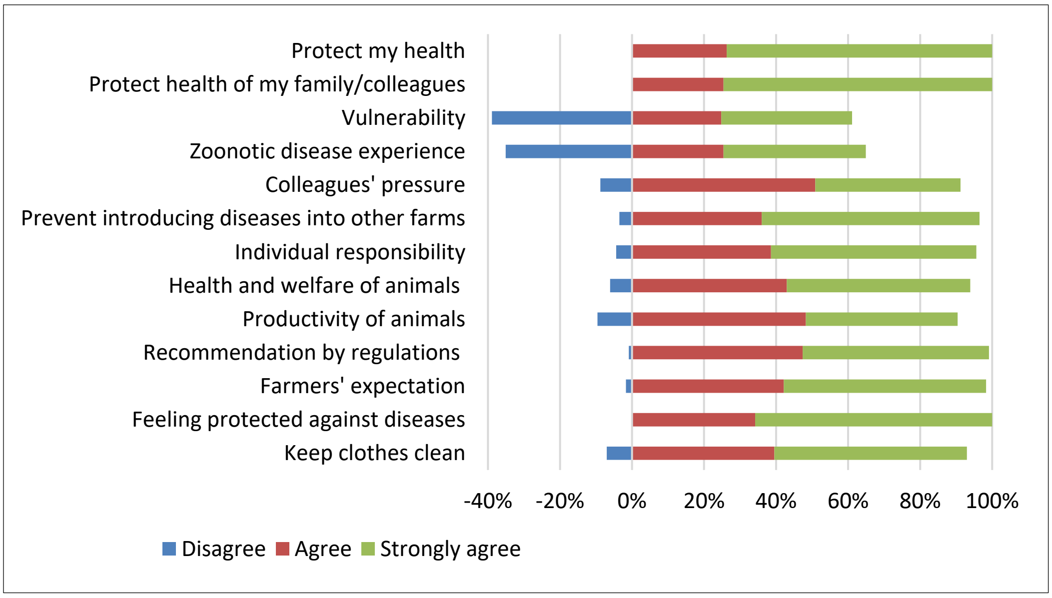

Figure 11: Motivators influencing personal protective equipment (PPE) use among veterinarians. The distribution of responses highlights professional responsibility, standard practice, and regulatory expectations as key motivators, whereas personal vulnerability and prior zoonotic disease experience were less influential.

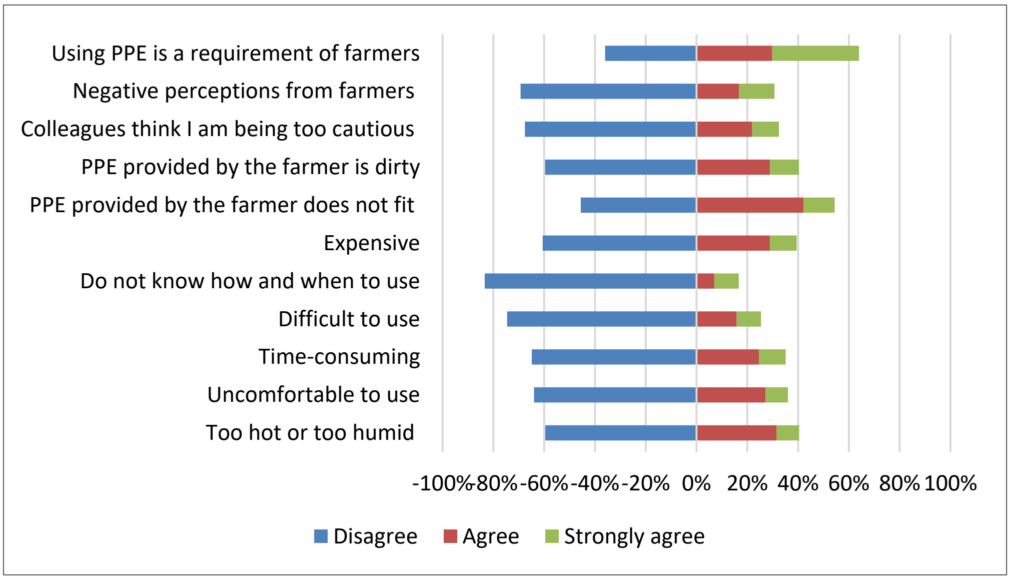

Figure 12: Perceived obstacles to personal protective equipment (PPE) use among veterinarians. The figure summarizes veterinarians' views on barriers to PPE use, indicating strong confidence in their own ability to use PPE correctly and a tendency to view PPE use as primarily the responsibility of farmers.

Education and training

All veterinarians advised farmers on personal biosecurity and zoonosis prevention. Eighty-six percent received training on the subject (Supplementary File 3).

Comparative analyses (veterinarians)

None of the scores for any of the response variables followed a normal distribution (Supplementary File 3).

Field veterinarians reported a higher level of perceived knowledge of zoonoses (Table 7) and consistently outperformed their official counterparts in PPE use for several procedures (Supplementary File 3).

Table 7: Association between veterinary profession and perceived level of knowledge on zoonoses (n = 114).

Veterinary profession	Good level n (%)†	High level n (%)†	Statistical analysis
Field veterinarians	13 (18.8)	56 (81.2)	χ^2 = 10.08, p = 0.0015
Official veterinarians	21 (46.7)	24 (53.3)	OR = 0.27 (95% CI: 0.10–0.67), Cramér's V = 0.30

†Percentages are calculated row-wise. OR = Odds ratio, CI = Confidence interval.

Working fewer than 3 days/week was associated with lower PPE use scores, whereas a high level of perceived knowledge about zoonoses was associated with higher PPE use across various scenarios.

DISCUSSION

Study significance and regional context

This study represents a pioneering effort to explore the adoption of personal biosecurity practices in Georgia, a country in the South Caucasus that is significantly affected by transboundary animal diseases that impose substantial economic and public health burdens on both humans and animals. This is one of the first comprehensive surveys in the region to simultaneously assess KAP among farmers and veterinarians, addressing a critical gap in the literature, as most existing studies have focused on Europe, Africa, and Asia, while data from this region, where the burden of zoonotic diseases is high, remain scarce. Our findings highlight region-specific challenges and opportunities by providing a comparative perspective with patterns reported from these areas.

Hand hygiene and cultural determinants of biosecurity behavior

Hand washing habits among agricultural workers vary worldwide [34–39]. Farmers and veterinarians in this study commonly practiced this measure, which is comparable to neighboring Türkiye, where 92% of ruminant farmers reported hand washing [40]. In Finland, 62% of veterinarians always washed their hands with soap after examining cattle [36], whereas in three European countries, 66% washed their hands after farm visits, though only 25% used soap [37]. In Sweden, a lack of hand washing facilities was a barrier to hygiene [38], and in Belgium, some farmers deemed hand washing unimportant [34]. These findings suggest that hygiene practices may depend more on cultural norms and ethical factors than a country's economic status.

Milk consumption and awareness of brucellosis transmission

Most Georgian ruminant farmers boiled milk before consumption, similar to 77% of cattle farmers surveyed in eastern Anatolia, Türkiye [40]. However, studies found that many farmers and veterinarians in South Africa [41] and Cameroon [42] did not worry about consuming unpasteurized dairy products. Given that brucellosis was the most frequently identified zoonosis by farmers in this study, participants must be aware of its transmission routes and preventive measures.

Echinococcosis awareness and preventive behaviors

To prevent endemic echinococcosis in the Caucasus, washing produce, avoiding raw or undercooked meat, and not feeding pets viscera are crucial. Most farmers in this study, such as 87% in Türkiye [40], avoided consuming raw meat. However, despite high adherence to its preventive practices, awareness of echinococcosis as a zoonosis was surprisingly low. Given the scarcity of data on this neglected disease [11], additional research is needed to determine its current prevalence and associated health impacts, while efforts to raise community awareness should be intensified to mitigate risks.

Carcass and waste disposal practices

Proper carcass and waste disposal are vital for preventing zoonoses such as anthrax. Most farmers in this study reported implementing such measures, similar to 91% of cattle farmers in Türkiye [40], who buried carcasses. However, a European study found only 60% adherence to proper methods [43]. The endemicity of anthrax in the Caucasus and its recognition by participants may explain why farmers in affected regions are more likely to adopt preventive practices.

PPE use: Global comparisons

Overall, PPE use was consistently high among the study participants. At least 55% of veterinarians used all four PPE items, and 70% of farmers used farm-dedicated clothing and gloves, with 22% wearing masks and protective glasses during parturition or when managing aborted materials. Similarly, 91% of cattle veterinarians in Finland reported the consistent use of protective coats [35, 36].

However, contrasting findings were evident in other regions. In the UK [18] and Australia [44], over two-thirds of veterinarians reported not using PPE when handling healthy animals, whereas in Nigeria [45] and the USA (Arizona) [39], only 4% and 17% of veterinarians reported using appropriate PPE, respectively. During parturition, <5% of US veterinarians used respiratory or eye protection [46], compared with 20% in Nigeria [45]. Similarly, only 6% of cattle farmers and 41% of veterinarians in Cameroon used gloves and masks when handling aborted materials [42].

While at least 56% of the veterinarians in this study used four PPE items for sample collection, 95% of the Finnish veterinarians never used a mask when collecting fecal samples [36]. In the United States, 83% of large animal veterinarians did not use respiratory protection during surgery, and 96% omitted respiratory or eye protection during necropsies [46].

These differences highlight the variability in PPE safety practices, which are often influenced by the perceived zoonotic risk. For example, in Belgium, farmers infrequently used PPE despite its availability [47], and in Australia [44], veterinarians implemented stringent infection control only when deemed necessary. Therefore, establishing a standardized PPE protocol for specific situations or veterinary procedures may be challenging, as preventive measures must be adjusted for each case [23].

Global research gaps and underrepresentation of LMICs

It is crucial to highlight the paucity of biosecurity research in low- and middle-income countries, with personal biosecurity remaining largely unexplored. Existing research addressing farm-level biosecurity has revealed low levels of implementation among comparable small-scale dairy farms in Ethiopia and Bangladesh [48, 49]. This highlights a significant research gap, as limited evidence is available from regions that are disproportionately affected by zoonotic diseases and their associated human health, animal health, and economic impacts.

Risk perception paradox and behavioral complexity

Surprisingly, despite widespread PPE use, 41.8% of the farmers surveyed in this study did not believe they could contract diseases from animals. Moreover, paradoxically, those who denied the possibility of zoonotic transmission scored higher in PBMs than those who acknowledged such risks. This inconsistency may reflect social desirability bias, where participants overreport protective behaviors to align with perceived expectations. Alternatively, it may suggest differences in farmers' interpretation of "disease risk" – some may equate it with severe or clinically clear infections rather than everyday exposure to pathogens. Another possibility is that routine or externally driven practices (e.g., veterinary advice, training, or regulations) encourage the use of PPE even among individuals who do not personally perceive high-risk. A similar pattern has been reported among U. S. veterinarians, who were paradoxically less likely to wear PPE when dealing with suspected zoonotic transmission [50].

Comparable unexpected findings were also reported from Ethiopia, where farmers with additional income sources and those who had experienced zoonotic diseases within the previous 2 years were less likely to implement farm biosecurity measures [48]. The same study found that trust in government interventions was associated with lower compliance, whereas trust in farmers' information was linked to higher compliance. Similarly, a study from Kenya demonstrated that cultural beliefs and social norms strongly influenced adherence to biosecurity and zoonosis prevention practices [51].

Together, these findings illustrate the complexity of risk perception and self-reported behavior, underscoring the need for targeted, culturally sensitive risk communication strategies in zoonosis prevention.

Knowledge of zoonoses among veterinarians

Most veterinarians in this study perceived their knowledge of zoonoses as high. However, many were unable to correctly identify all zoonoses listed, with 80% failing to recognize echinococcosis, an endemic disease in the country. Knowledge was self-assessed using broad categorical levels, which are inherently subjective and lack clear definitions for what constitutes high, good, or poor knowledge levels. Nevertheless, these findings highlight that echinococcosis remains an endemic yet under-recognized disease among both farmers and veterinarians in the region.

Cleaning, disinfection, and hygiene practices

Proper cleaning and disinfection are vital for preventing the transmission of infectious diseases. Farmers and veterinarians in this study showed strong hygiene awareness, similar to 95% of British dairy farmers who maintained farm cleanliness [52]. In addition, 84% of Australian and all UK veterinarians recognized equipment hygiene as critical for reducing zoonotic risks [18, 44, 53]. Supporting this, studies conducted in Greece (goat farms) and Bangladesh (small-scale dairy farms) showed that cleaning and disinfection were among the most widely adopted practices, although overall biosecurity measure implementation was poor [33, 49]. The high adoption of cleaning and disinfection practices in the present study may stem from past disease outbreak experiences in the region (such as Q-fever and foot-and-mouth disease outbreaks), which have highlighted the importance of hygiene measures.

Disease prevention and livestock health management

This study also underscored the practices used to prevent disease transmission in livestock. More than 90% of the surveyed farmers sought veterinary help for sick animals, similar to 91% of Turkish farmers [40]. While fewer than 40% of farmers isolated sick animals in a European pilot study [43], approximately three-quarters did so in the study population, a rate comparable to the 82% reported among Greek goat farms [33]. Farmers in the United Kingdom, Belgium, and Uganda noted the need for additional land, labor, and time to isolate animals [54–57]. Furthermore, high vaccination rates were observed in the current study, consistent with findings from Greece, Bangladesh, South Africa, and Ethiopia [33, 48, 49, 58]. This is likely attributable to state-led vaccination campaigns that began in 2013, following lessons learned from unsuccessful delegation of vaccination to livestock owners in 2007 (Mikheil Sokhadze, personal communication, 2024).

Motivators and barriers to PPE adoption

There was a notable rate of disagreement with the statement that PPE use is motivated by vulnerability or previous experience with zoonoses. This finding is consistent with the small proportion of participants reporting a history of chronic diseases or zoonotic infections. However, this low reporting may not reflect the true situation. Farmers may underreport zoonotic diseases due to limited access to diagnostic services, lack of awareness, or fear of economic repercussions such as animal culling or trade restrictions. In some cases, social stigma may also discourage open reporting.

Discomfort, heat, and humidity were common barriers to PPE use, consistent with previous studies [25, 44, 54, 56, 57, 59, 60–62]. However, over 60% of veterinarians and 45% of farmers did not perceive PPE as expensive or difficult to use, with 70% reporting knowledge of proper PPE application. This may reflect the influence of international livestock biosecurity projects and government/donor-supplied PPE in Georgia (Mikheil Sokhadze, personal communication, 2024).

Communication and training gaps

Regarding biosecurity communication, 47.8% of the farmers stated that no one had discussed it with them, although all veterinarians claimed to have provided advice. This gap may stem from farmers not recalling the advice or veterinarians assuming that their guidance was understood without reinforcement. In Canada, fewer than one-quarter of dairy farmers reported discussing biosecurity with a veterinarian [63], whereas in the UK, 92% of veterinarians advised cattle producers on the topic [64]. In this study, farmers who engaged in informal discussions about PPE and zoonosis prevention scored higher in PPE usage, whereas those who underwent formal training showed no similar effect. This dual farmer–veterinarian analysis offers unique insight into communication and perception gaps between both groups within the same cultural context.

Socio-demographic and professional determinants of biosecurity practices

The unique demographic, professional, and cultural characteristics of farmers and veterinarians shape their decision-making regarding animal health and biosecurity [65]. Consistent with previous studies [33, 40, 43, 46, 48, 51, 63], this study found that female farmers and those with higher education scored higher in implementing PBMs, although some research found no such demographic effects [49]. This gender difference may reflect behavioral factors such as greater attention to hygiene often reported among women. Educational background may also contribute through better access to information and understanding of zoonotic prevention. Conversely, farmers with more livestock care experience scored lower on such measures, aligning with findings from Cameroon [42] and Ireland [50].

Veterinarians working fewer days per week scored lower in PPE use, likely due to perceived lower risk. Field veterinarians reported higher self-assessed knowledge and PPE use than official counterparts, indicating that hands-on animal contact enhances both awareness and compliance.

Study limitations and future directions

This study has several limitations. Due to the lack of a complete livestock household dataset and challenging geography, convenience sampling was used, introducing potential selection bias and limiting representativeness. This may have overrepresented participants who were more aware or engaged in biosecurity practices.

Differences in biosecurity practices between livestock types (e.g., LRs vs. SRs) or production systems (dairy vs. beef) could not be analyzed due to overlapping farm structures.

Self-reported behaviors may be subject to social desirability bias, potentially overestimating compliance, while zoonotic disease occurrences may be underreported due to limited diagnostics or stigma.

As a descriptive cross-sectional survey, causal relationships between knowledge, attitudes, and behavior could not be established, and seasonal variations were not assessed. Future studies should use analytical or longitudinal designs and consider qualitative or mixed-method approaches to better understand behavioral drivers.

Despite these limitations, this study provides baseline evidence from an under-researched region, enhancing understanding of local zoonotic risk behaviors and informing One Health–based interventions. Moreover, through its participatory approach and educational outreach, the study likely raised awareness of zoonosis prevention among participants, contributing to the broader goals of public health improvement and One Health integration [66].

CONCLUSION

This study provides the first comprehensive evidence on personal biosecurity practices among ruminant farmers and veterinarians in Georgia, revealing encouraging adherence to hygiene and PPE use, but also notable behavioral and perceptual inconsistencies. Overall, most participants demonstrated good hygiene awareness, frequent hand washing, safe carcass disposal, and consistent use of farm-dedicated clothing and gloves. However, protective glasses and face masks were less commonly used, and over 40% of farmers did not believe zoonotic transmission from animals was possible. Veterinarians reported higher perceived level of knowledge on zoonoses while exhibiting limited awareness of echinococcosis, an endemic but under-recognized disease.

The study’s strength lies in its dual assessment of farmers and veterinarians, which provides parallel insights into the behavioral, cultural, and professional determinants of biosecurity. Findings indicate that gender, education, and regular discussions about PPE use were positively associated with adherence, whereas greater farming experience and limited risk perception were negatively associated with compliance.

These results underscore the need for tailored communication strategies that integrate behavioral insights into One Health education programs. Practical interventions should focus on enhancing perceptions of zoonotic risk, reinforcing consistent PPE use, and improving dialogue between farmers and veterinarians through participatory extension and refresher training. Despite its cross-sectional nature, this study establishes a valuable baseline for Georgia’s livestock sector and demonstrates the potential of integrated behavioral surveillance to strengthen biosecurity and zoonotic disease prevention within a regional One Health framework.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

AUTHORS’ CONTRIBUTIONS

SŞ, DBA, FIKFG, and AOAP: Study design and conceptualization. DA and MS: Data collection and data entry. SŞ and AOAP: Data analysis and visualization. SŞ, AOAP, DBA, and FIKFG: Drafted the manuscript. SŞ, DBA, FIKFG, AOAP, DA, and MS: Supervised and reviewed the manuscript. DBA, DA, and MS: Project administrative work. All authors have read and approved the final version of the manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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