



Prioritization of Zoonotic Disease Agents in Malawian Cow's Milk: A Multi-Criteria Decision Analysis

REPORT 16/2026

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Suggested citation

Kachepa Upile, Krosness Marie Myklatun, Ngunguni Shareef, Njunga Gilson, Høgåsen Helga Rachel, Wolff Cecilia, Nkhoma Joseph, Chulu Julius and Jørgensen Hannah Joan. Prioritization of Zoonotic Disease Agents in Malawian Cow's Milk: A Multi-Criteria Decision Analysis. Norwegian Veterinary Institute 2026.
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Quality controlled by

Edgar Brun and Shima E. Ali, Norwegian Veterinary Institute

Commissioned by

Central Veterinary Laboratory (CVL)- Malawi and Trustees of Agricultural Promotion Programme (TAPP)



Published

2026 on www.vetinst.no

ISSN 1890-3290 (electronic edition)

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Colophon

Cover photo: Comfort Jiya

www.vetinst.no

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Summary

A Multi Criteria Decision Analysis (MCDA) was conducted to prioritise zoonotic diseases that could be transmitted through cow's milk in Malawi. Seven animal health experts in Malawi participated in the study, with no participants from the public health sector.

The zoonotic agents ranked as the five most important in Malawi cow's milk were *Mycobacterium bovis*, *Staphylococcus aureus*, *Salmonella* spp., *Brucella* spp., and *Escherichia coli* (pathogenic strains). In addition to the MCDA, experts were asked to list what they regarded as the three most important zoonotic diseases in dairy cattle, as well as the three most important diseases in dairy cattle in general. Zoonotic diseases mentioned were those caused by *M. bovis*, *Brucella* spp., *S. aureus*, *E. coli* and Rift Valley fever. The important diseases identified in dairy cattle were East Coast Fever, tick-borne diseases, mastitis, intestinal worm infections, and Lumpy Skin Disease.

The study revealed challenges in obtaining reliable data on disease incidence and prevalence in Malawi. This scarcity of data underscores the need for improved surveillance and diagnostic capabilities. Furthermore, in this MCDA study respondents were asked to score their level of certainty (certainty levels), allowing them to quantify their confidence in their own assessments. This is an innovative approach that addresses one aspect of the inherent uncertainty in MCDA.

1 Introduction

Milk and dairy products contribute to food security, enhance health outcomes, and support global nutrition¹. Global milk production for human consumption exceeds 800 million tons annually and continues to grow, with at least 80% sourced from cow's milk¹⁻³. The per capita consumption of milk and milk products is higher in developed countries, however, the gap with many developing countries is gradually narrowing driven by factors such as increased urbanization and changing lifestyles⁴. In developing countries, smallholder dairy farmers remain the primary producers⁵, playing a crucial role in household livelihoods, food security, and nutrition. In response to the growing demand for milk and dairy products in Malawi's major cities⁶, the government has supported the dairy sector through initiatives such as crossbreeding programs, the establishment of organized markets, the provision of extension services to farmers, and research on improved forage production and feeding technologies targeted at smallholder farmers^{7,8}. Furthermore, many international development donors have supported the expansion of the dairy industry in Malawi, as well as the development of more efficient dairy processing and marketing systems^{9,10}. Notably, the Norwegian Investment Fund (Norfund), funded by the Norwegian government, has financed Lilongwe Dairy (the largest dairy processor in Malawi) to invest in larger warehouses, expand pasteurization capacity, and acquire new packaging machines¹¹. These investments will contribute to increased incomes for small-scale farmers and improved access to locally produced dairy products for the Malawian population.

Despite the significant role and existing opportunities within Malawi's dairy industry, its growth remains constrained by numerous challenges, notably, the frequent occurrence of animal diseases often linked to poor management practices¹⁰. The common health challenges include subclinical mastitis and clinical mastitis, foot-and-mouth disease and vector-borne illnesses such as East Coast fever, babesiosis, anaplasmosis, heartwater, and lumpy skin disease^{10,12,13}. These diseases threaten the animal health, leading to milk losses, high treatment costs, reduced milk quality, and livestock mortality¹⁰. Some of the livestock diseases also pose public health risks due to their zoonotic nature. In Malawi, reported human zoonotic infections include rabies and cryptosporidiosis, while bovine tuberculosis, brucellosis, rabies, and cryptosporidiosis have also been documented in animals¹⁴. The exact burden of these diseases remains unknown due to limited studies and diagnostic capacity. However, zoonotic diseases pose a significant public health threat, accounting for approximately 26% of the infectious disease burden in humans globally¹⁵.

Dairy cattle can harbour a range of zoonotic pathogens, including bacteria, viruses, and parasites, which are primarily transmitted to humans through the consumption of unpasteurized milk or direct contact with infected animals⁶. Malawi's animal health sector has independently prioritized five zoonotic diseases for control: rabies, bovine tuberculosis, brucellosis, cysticercosis, and human African trypanosomiasis¹⁶. Among these, *Mycobacterium bovis* and *Brucella* spp. are particularly relevant to the dairy value chain. However, this prioritization excludes other important zoonotic diseases relevant to dairy production, emphasizing the need for further assessment to identify and address additional zoonotic threats within the dairy sector. Therefore, a Multi Criteria Decision Analysis (MCDA) was used to assess the relative importance of zoonotic diseases transmitted through cow's milk with respect to their potential impact on human and animal health in Malawi. The MCDA was carried out as part of the master thesis "An investigation of Milk Production in Malawi in the Perspective of Food Security and Food Safety" and this report is based on the thesis¹⁷

2 Methodology

2.1 Step 1: Selection of Zoonotic Diseases

A list of potential zoonotic diseases was developed based on findings from an extensive systematic literature review and outcomes of previous disease prioritization workshops conducted across Africa. Inclusion criteria included diseases with known zoonotic potential originating from cattle and that are prevalent within the African context. Emphasis was placed on diseases listed by the World Organization for Animal Health (WOAH) and those identified as research priorities by the World Health Organization (WHO).

The selected zoonotic pathogens were:

1. *Coxiella burnetii*
2. *Brucella abortus*
3. *Mycobacterium bovis*
4. *Salmonella* spp.
5. *Staphylococcus aureus*
6. *Escherichia coli*
7. *Listeria monocytogenes*
8. *Campylobacter jejuni*
9. *Leptospira* spp.
10. Rift Valley Fever Virus
11. Crimean Congo Hemorrhagic Fever Virus (CCHF- virus)

2.2 Step 2: Design of Multi Criteria Decision Analysis (MCDA) Form and Criteria

To establish a structured MCDA framework, criteria were defined based on existing research¹⁸. Two main categories were identified: impact of the disease on human health and the impact on animal health. Within each category, specific criteria were delineated, encompassing aspects such as disease prevalence, disease severity, the associated reduction in farmers income linked to the diseases and estimated burden of disease caused by milk consumption in human. The rules for scoring the criteria were defined. The full set of categories, criteria, and scoring rules is presented in Table 1. For each score, the respondents could report their level of certainty, with a minimum level of 0 implying that the answer is a pure guess, and maximum level of 5 meaning that they felt completely confident.

Table 1. Full set of categories and criteria used for the Multi-Criteria Decision Analysis

Animal/human health	Criteria	Measurement	Score
Animal health	Disease frequency in cattle	Prevalence of infection in Malawi (sub-clinical and clinical infection)	<ol style="list-style-type: none"> 0. The infection is absent in cattle (herd prevalence 0%) 1. The infection is very rare (herd prevalence is <1%) 2. The infection is rare (herd prevalence is between 1-15%) 3. The infection is common (herd prevalence 16-50%) 4. The infection is very common (herd prevalence 51-100%)
	Disease severity in cattle	Most observed severity of disease in infected individuals	<ol style="list-style-type: none"> 0. None (no health consequences or production loss) 1. Mild (For example sub clinical/mild mastitis, reduced milk production for a day or two) 2. Moderate (For example reduced feed intake, permanently reduced milk production, fertility issues) 3. Severe (For example early abortion, chronic illness resulting in dry udder and no milk production) 4. Very severe (For example abortion of full developed calf or death or culling of cow)
	Financial burden associated with cattle health (for farmers)	Economic consequences in terms of reduced income for farmers	<ol style="list-style-type: none"> 1. Low cost 2. Medium cost 3. High cost
Human health	Expected disease frequency in humans in Malawi	How often do people in Malawi get sick from the different pathogens?	<ol style="list-style-type: none"> 0. The disease is absent in humans 1. The disease is very rare in humans 2. The disease is rare in humans 3. The disease is common in humans 4. The disease is very common in humans
	Disease severity in humans	Most common severity of symptoms/disease in infected individuals	<ol style="list-style-type: none"> 0. No symptoms 1. Mild: Medical intervention is not required, symptoms are transient, and health effects are short lasting 2. Moderate: Medical intervention may be required; persisting (>1 month) health effects are rare 3. Severe: Medical intervention is usually required; persisting (>1 month) health effects occur. 4. Very severe: Medical intervention required, permanent health effects are common, including death and long-lasting disability.
		Mean proportion of severe or very severe cases in humans	<ol style="list-style-type: none"> 0. Neither severe nor very severe cases among symptomatic cases 1. Mean proportion of severe or very severe cases among symptomatic cases is very low: <1% 2. Mean proportion of severe or very severe cases among symptomatic cases is low: 1-15% 3. Mean proportion of severe or very severe cases among symptomatic cases is moderate: 16-50% 4. Mean proportion of severe or very severe cases among symptomatic cases is high: >50%
Estimated burden of disease in humans caused by milk consumption in Malawi	Share of the total number of human cases in Malawi, for each disease, that can be attributed to consumption of milk or milk products	<ol style="list-style-type: none"> 0. No (0%) 1. Low (1-20%) 2. Moderate (20-50%) 3. High (50-80%) 4. Very high (80-100%) 	

2.3 Step 3: Piloting and Adjustment

A pilot test was undertaken with a veterinarian at Central Veterinary Laboratory (CVL) in Malawi to refine the MCDA form. Feedback from the pilot study prompted the removal of one criterion, specifically "*occurrence of outbreaks in humans in the last five years*" due to constraints in data availability. The revised form was then disseminated to experts for independent completion, with plans to meet later for discussion.

2.4 Step 4: Selection of Participants

Fifteen experts with diverse backgrounds in animal health and public health were identified and invited to participate in the study via email, with assistance from personnel at CVL. These experts represented various esteemed institutions in Malawi, including Lilongwe University of Agriculture and Natural Resources (n=4), CVL (n=3), Shire Highlands Milk Producers Association (n=1), the Public Health Institute of Malawi (n=2), Lilongwe Dairy (n=2), the Department of Animal Health and Livestock Development (n=1), Blantyre Agricultural Development Division (n=1), and Blantyre Regional Veterinary Laboratory (n=1). Those willing to participate were sent the MCDA form, information sheet, and consent form via email.

In total, 7 experts agreed to participate in the study: 2 from Lilongwe University of Agriculture and Natural Resources (LUANAR), 2 from the Central Veterinary Laboratory, 1 from the Shire Highlands Milk Producers Association (SHMPA), 1 from the Department of Animal Health and Livestock Development (DAHLD), and 1 from Blantyre Agricultural Development Division (BLADD). All participants had an animal health background, and none of the public health experts participated in the study.

2.5 Step 5: Data collection

Respondents completed the MCDA form and submitted their responses via email. After the initial data submission, individual meetings were scheduled with each participant to facilitate discussions on their evaluations and gather additional insights into the epidemiological landscape and the milk value chain in Malawi. Each meeting lasted between 30 and 45 minutes.

2.6 Step 6: Data Analysis

Collected data were processed using Microsoft Excel. Weights were calculated by multiplying the scores of the main categories by the scores of the criteria within each respective category. Raw scores were aggregated and subjected to an averaging process. Additionally, consideration was given to the levels of certainty expressed by the experts, which informed the generation of certainty-corrected scores for each expert. These scores were then subjected to a normalization and averaging process, followed by weighting, culminating in the determination of a certainty-corrected ranking for the zoonotic diseases under evaluation.

3 Results

Seven experts completed the MCDA form, and five of them participated in follow-up interviews. Most experts were based in Lilongwe, from academic institutions (*LUANAR*, n=2), the veterinary referral laboratory (*CVL*, n=2), and the Department of Animal Health (*DAHLD*, n=1). In Blantyre, experts were from the milk association (*SHMPA*, n=1) and the agricultural development division (*BLADD*, n=1). All participants had animal health background, with none representing the public health sector. Most respondents (69%) perceived zoonotic diseases as having a greater impact on animal health than on human health. Notably, the criterion "financial burden to farmer" received the highest weighting (35%). The results of the weighting of categories and criteria are presented in detail in Table 2.

Table 2. Mean weights given to categories and criteria in the Multi Criteria Decision Analysis

Criteria Main Category	Mean weight	SD	Min	Max
Animal Health (cattle)	69%	13%	55%	90%
Human health (public health)	31%	13%	10%	45%
Sum	100%			
Criteria				
Disease frequency in cattle	17%	10.6%	6%	33%
Disease severity in cattle	17%	5.2%	9%	25%
Financial burden of disease for farmer	35%	19.5%	7%	68%
Disease frequency in humans	7%	6.2%	2%	20%
Disease severity in humans 1	6%	6.4%	2%	20%
Disease severity in humans 2	6%	6.4%	2%	20%
Contribution of milk consumption to total disease burden	11%	8.5%	0%	24%
Sum	100%			

Disease scoring revealed that *M. bovis*, *S. aureus*, *Salmonella* spp., *Brucella* spp., and *E. coli* had the highest weighted raw and certainty-corrected scores, while Crimean-Congo hemorrhagic fever virus and *Coxiella burnetii* had the lowest scores (Figure 1). The top two pathogens with the highest weighted raw and certainty-corrected scores were *M. bovis* and *Staph. aureus*. These two pathogens also had the highest score when calculations were made without weighting. Moreover, the self-assessed certainty of the experts had little impact on the ranking.

In addition to the MCDA, the experts were asked to list what they regarded as the three most important zoonotic diseases in dairy cattle, as well as the three most important diseases in dairy cattle in general. The three most important zoonotic diseases/pathogens in cattle, as identified by the experts, were *M. bovis* (7/7), *Brucella* spp. (4/7), *Staph. aureus* (3/7), *E. coli* (2/7), and Rift Valley fever (2/7). Diseases identified as important in dairy cattle but not included in the MCDA were East Coast fever and other tick-borne diseases (4/7), mastitis (3/7), intestinal worm infections (2/7), and lumpy skin disease (2/7).

The invited experts were asked whether any other additional zoonotic diseases should have been included in the study; two out of the seven respondents said they would have included other pathogens. The pathogens mentioned were *Bacillus anthracis*, *Cryptosporidium* spp., and *Mycobacterium avium* subsp. *paratuberculosis*.

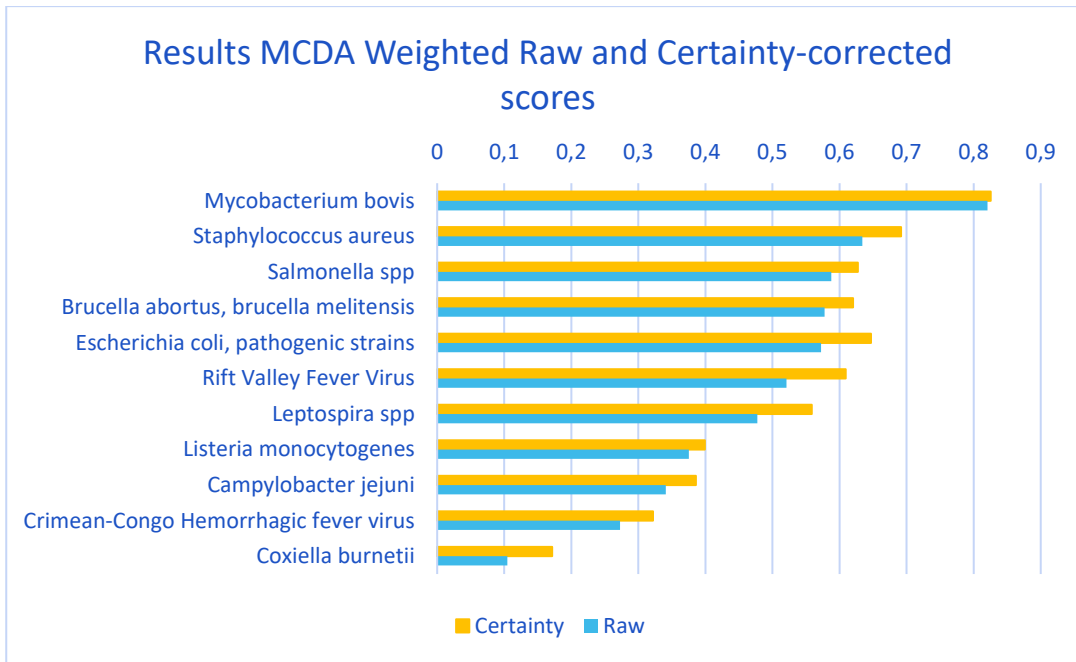


Figure 1. Disease scores and ranking of importance from a Multi Criteria Decision Analysis with animal health experts (n=7) in Malawi, 2023. The ranking follows the weighted raw scores.

4 Discussion

This study used Multi Criteria Decision Analysis (MCDA) to prioritise important zoonotic diseases transmitted through cow's milk or other routes, focusing on their potential impact on human and animal health in Malawi. The study highlights *M. bovis* and *Staph. aureus* as the most important zoonotic pathogens in the dairy value chain, while Crimean-Congo hemorrhagic fever virus and *Coxiella burnetii* were considered the least important, according to the animal health experts.

Mycobacterium bovis was ranked as the top disease in the MCDA. However, it remains difficult to determine whether this high ranking accurately reflects the true burden of the disease in Malawi or is partly influenced by the public's high awareness of the disease. The disease is recognized by the Malawi government as one of the top zoonotic threats¹³ with control measures in place including routine testing and culling of reactors in dairy and beef farms¹⁹, as well as regular meat inspections at abattoirs, where affected carcasses are condemned and discarded²⁰. The ranking of *M. bovis* as number one in this study also aligns with a prioritization exercise in neighboring Mozambique, where *M. bovis* was ranked number 2 out of 48 diseases²¹. *S. aureus*, ranked number 2 by the experts, is a common cause of bovine mastitis²², which affects both animal health and milk productivity. Mastitis has also been reported as a prevalent disease in dairy cattle in Malawi²³, which may have influenced its high ranking by the animal experts. Additionally, *S. aureus* can cause food poisoning in humans, though most symptoms are self-limiting.

Within the MCDA, respondents attributed greater weight to animal health considerations (69%) compared to human health (31%). Notably, the criterion "financial burden to farmer" received the highest weighting (35%). Given that all respondents hailed from the animal health sector, this bias likely influenced the MCDA results. Some of the lower scores in the MCDA may additionally stem from a lack of familiarity with specific pathogens and the lack of diagnostic and surveillance data. Stakeholder analysis revealed that while Malawi possesses functioning laboratories, their activity levels are notably low. A limited diagnostic capacity may contribute to a deficit in knowledge regarding the prevalence and impact of different zoonotic diseases. Therefore, it is crucial to strengthen animal health surveillance and diagnostic capabilities in Malawi to address this gap.

In resource-limited countries like Malawi, inadequate diagnostic capacity and data limitations make it challenging to use MCDA effectively for disease prioritization, as the method relies on reliable and comprehensive data for scoring of each criterion²⁴. Nevertheless, the MCDA does serve as a valuable tool for identifying critical knowledge gaps. In this study, we introduced certainty levels, allowing each respondent to quantify their subjective confidence in their assessments. To the best of our knowledge, this represents an innovative approach to addressing one aspect of the inherent uncertainty in MCDA. In contrast, previous MCDAs for zoonotic disease prioritisation have utilized alternative methods for managing uncertainty, often depending on the use of literature-based scoring or the number of experts involved in scoring each disease²⁵. Moreover, MCDAs are frequently conducted as collaborative workshops spanning several days, involving participants in joint literature review and deliberation on criteria weighting and alternative scoring^{25,26}, this study adopted an individual respondent approach. It is plausible that conducting the MCDA as a group discussion among experts may have yielded distinct results, particularly if involving both animal and public health professionals. Previous MCDAs have encompassed a broader spectrum of experts with diverse backgrounds and a larger participant pool than the current study²⁵.

Despite several limitations, this study provides baseline information on the important zoonotic diseases in the dairy value chain, which can aid in decision-making when prioritising zoonotic diseases of animal health importance in Malawi. The findings will also assist other researchers in expanding the scope of similar studies in the future.

5 Conclusion

The Multi Criteria Decision Analysis (MCDA) conducted in this study provides crucial insights into the prioritisation of zoonotic diseases transmitted through cow's milk in Malawi. It is worth noting that the study primarily engaged only experts from the animal health sector, potentially introducing a bias towards animal health considerations. Despite this, the top-ranking diseases remained consistent even when criteria were equally weighted. While this study employed an individual respondent approach, collaborative workshops involving experts from both animal and public health sectors could yield different results. It is also worth considering that a broader spectrum of experts with diverse backgrounds and a larger participant pool may provide additional perspectives in future studies. However, this MCDA study represents a critical step towards prioritising resources for the surveillance and control of zoonotic diseases within the milk value chain in Malawi. Moreover, it underscores the need for improved data collection and diagnostic capacities to further refine and validate these prioritisations.

Acknowledgement:

This work was carried out as part of the project One Health – Controlling Zoonotic Diseases and AMR in the Milk Value Chain in Ethiopia, Malawi and Tanzania, with financial support from Norway.

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