Protocol for a scoping review of precision technologies for cattle monitoring

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Abstract

Background: Livestock farming has increased in complexity considerably due to the increased demand for animal products combined with a decreasing number of farmers and ranchers. To meet this challenge, Precision Livestock Farming (PLF) aims to develop fully automated tools that continuously monitor animals, such as cattle. Ineffective cattle management can have significant animal welfare implications, as well as financial consequences for both farmers and the economy because of the size of this substantial industry globally. To our knowledge, no scoping review with explicit published search protocol has broadly examined PLF technologies for both beef and dairy cattle to identify gaps in current research.

Objectives: The objective of this scoping review is to provide an overview of precision livestock farming technologies used for cattle monitoring.

Eligibility criteria: Peer-reviewed journal literature and conference papers in the English language will be included in the study. The focus of the literature included will be on technology systems used for cattle monitoring or detection. Research on animals other than cattle; on a cellular or excised tissue level of scope; or on monitoring with the intent of exploring ecosystem or environmental impacts, will be excluded. As the focus is on established and emerging precision technologies, studies will be excluded if published before 2005.

Sources of evidence: Searches will be conducted in three databases: Scopus, CAB Abstracts, and IEEE Xplore. All search lines will be included and published in the study. Further studies fitting the inclusion criteria will be added from citation tracking (backwards and forwards) from the final set of included studies.

Synthesis of results: Data extracted will include publication year, geographical region, type of technology being used, type of monitoring, goal of the intervention, and level of validation.

1. Introduction

1.1. Rationale:

Without causing unnecessary stress in animals, Precision Livestock Farming (PLF) aims to develop fully automated on-line tools that continuously monitor animals throughout their lifespan (Berckmans, 2006). Real-time data on animals is continuously gathered through the monitoring of their production and reproduction, health, welfare, and impact on the surrounding environment (Berckmans, 2017). It is then analyzed by the PLF system to provide farmers with critical information about individual animals (Berckmans, 2017). This can include sensors on or around the animal, camera and image analyses, or microphone and sound analyses (Berckmans, 2017). Fundamentally, the PLF approach recognizes that the animal is the most crucial component of the livestock production chain (Berckmans, 2006). However, monitoring animals is challenging because they are Complex, Individual, and Time-variant (CIT) systems, meaning each individual animal will behave differently at any time point (Berckmans, 2006). Hence, the PLF sector has undergone rapid development in recent years as universal dietary needs transition to greater protein and dairy consumption (FAO, 2017).

The global demand for animal products is anticipated to increase 70% by 2050 (Berckmans, 2017). Although there is an increasing number of animals to meet this demand, there is a decreasing number of farmers and operators (Berckmans, 2017). Consequently, the difficulty in managing animal health and maintaining the sustainability of livestock farming has increased considerably. Ineffective animal management can have significant animal welfare implications, as well as financial consequences for both farmers and the economy. In Canada, 25.9% of farms are beef (20.9%) and dairy (5%) operations, making cattle farming the country's second largest agricultural industry (Statistics Canada, 2022). The average expense-to-revenue ratio for cattle farming is high: 0.8 for dairy cattle and 0.94 for beef cattle (Statistics Canada, 2022). These expenses include veterinary services, medicine, and death loss due to various health conditions. In Alberta, Canada, 22.1% of beef cattle from 28 feedlots were diagnosed with some severity of

lameness, resulting in an average loss of $700 CAD per cow (Davis-Unger et al., 2017). Lameness is just one of many ailments that affect cattle and result in monetary repercussions.

Cattle farming is a significant agricultural industry globally. It is substantial in other countries, such as Australia (WWF-Australia, 2018) and the United States (USDA Economic Research Service, 2022). Therefore, research in PLF technologies has relevant and far-reaching impact. Although PLF reviews have been conducted, they focused on specific environments in which the technology is applied (e.g., Aquilani et al., 2022), had no restriction on the targeted animal population (e.g., Schillings et al., 2021), or investigated technology for only dairy cattle (e.g., Silva et al., 2021). Thus, to our knowledge, no scoping review with explicit published search protocol has broadly examined PLF technologies for both beef and dairy cattle. Through this scoping review, the prevalence of various cattle monitoring technologies can be understood, and gaps in current research can be identified. Identifying these knowledge gaps can lead to better technologies for farmers and reduce expenses related to cattle health and welfare.

1.2. Objectives:

The objective of this scoping review is to provide an overview of precision livestock farming technologies used for cattle monitoring.

The specific PICO elements are:

1. **P**opulation: cattle
2. **I**ntervention: technology that monitors cattle
3. **C**omparator: not applicable
4. **O**utcomes: what is measured by the technology

2. Methods

2.1. Protocol and registration

This protocol was prepared using the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) reporting guidelines (Shamseer et al., 2015) and the final

review will be prepared using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis for Scoping Reviews (PRISMA-ScR) reporting guidelines (Tricco et al., 2018).

The protocol will be published on the University of Calgary PRISM repository (https://prism.ucalgary.ca/) and registered with the Systematic Reviews for Animals & Food (SYREAF) platform (https://syreaf.org).

2.2. Eligibility criteria:

To be eligible for inclusion, articles and conference papers must be:

1. Peer-reviewed journal articles or conference papers published in English
2. Research on technology systems being used for cattle monitoring or detection
3. Research at the animal or herd level of scope
4. Research focusing on live animals
5. Research published since 2005

Furthermore, sources will be excluded corresponding to these exclusion criteria:

1. Review papers or book chapters
2. Conference proceedings without a full paper
3. Research on human subjects or for human intervention
4. Research on any animals other than cattle
5. Research on a cellular or excised tissue level of scope
6. Research on monitoring with intention of understanding ecosystems or environment

2.3. Information sources:

The following databases will be searched for relevant studies: Scopus, CAB Abstracts, and IEEE Xplore. All search strategies will be captured and published. Articles will be loaded into Covidence for de-duplication and screening at both title/abstract and full-text stages.

Further studies fitting the inclusion criteria will be added from citation tracking (backwards and forwards) from the final set of included studies.

2.4. Search strategy:

Search strategies were drafted by a librarian on the research team (James Murphy) and reviewed by content experts also on the team (Dr. Jennifer Pearson, Dr. Elise Fear, Dr. Pedram Mojabi, and PhD student Brendon Besler) as well as by a second librarian with expertise in veterinary medicine (Heather Ganshorn). The search strategy used in Scopus is shown in Table 1.

Search strategies for CAB Abstracts and IEEE Xplore have been translated from the Scopus search and adapted to each database.

Table 1 Scoping review search protocol for Scopus database (conducted April 28, 2022)

#	PICO	Search terms in Scopus	# of Results
1	P: Livestock synonyms	TITLE-ABS-KEY (livestock OR cattle OR cow OR calf OR calves OR bovine OR feedlot* OR pasture* OR beef OR dairy) AND NOT "bovine serum"	811,633
2	I: What are the desired tech to look for? And what do they do?	TITLE-ABS-KEY (precision OR PLF OR continuous OR automatic OR remote OR unsupervised OR wireless OR IOT OR robot* OR imaging OR imagery OR video OR "machine learning" OR "deep learning" OR algorithm* OR computational OR "artificial intelligence" OR AI) W/10 TITLE-ABS-KEY (sensor OR biosensor OR biomarker OR “multi-sensor*” OR GPS OR triaxial OR wearable OR implant* OR attached OR drone OR quadcopter OR UAV OR accelerometer OR thermograph* OR RFID OR tag OR "real time locat*" OR RTLS OR recognition OR facial OR transmitter OR NFC OR "near field" OR "vision system*") W/10 TITLE-ABS-KEY (monitor* OR track* OR analy* OR count* OR detect* OR sensing OR recogni* OR measur* OR examin* OR diagnos* OR manag* OR non-invasive OR farm*)	279,113

	C:	n/a	
3	O: What is the tech measuring?	TITLE-ABS-KEY (disease OR physiolog* OR condition OR sickness OR behavio*r OR lame* OR infection OR bacteria OR virus OR estr*us OR oestrus OR mastitis OR lactat* OR temperature OR heat OR overheat* OR vision OR biometric OR respiration OR heart OR weight OR feed* OR forage OR water OR drink* OR intake OR ruminat* OR emotion* OR affect* OR biomarker OR activity OR movement OR walk* OR gait OR anomaly OR mobility OR location OR proximity OR stress OR fear OR pain OR health* OR well-being OR wellbeing OR expectancy OR social* OR interact* OR injur*)	49,001,421
4	**Total**	**#1 AND #2 AND #3**	**1,032**

2.5. Selection of sources of evidence:

Studies will go through two stages of screening: title/abstract and full-text. Inclusion and exclusion criteria will be used to decide on exclusion of studies at both stages. Studies will be screened in Covidence by two reviewers of the research team. Any disagreements will be resolved by discussion and screening by a third member of the research team.

The review process will be tested with a random sample of 60 articles to ensure interrater agreement is above 80% across reviewers.

2.6. Scoping review software used:

Covidence will be used to organize imported records from all searches. Duplicate studies will be removed during the importing process. Covidence will also be used to screen studies at both the title/abstract and full-text stages.

2.7. Data charting:

Each article will be data charted by two members of the study team using Covidence Extraction 2.0. Data charting will be tested using 10% of the articles to ensure consistency across the study team. Conflicts will be resolved between the two members, and if necessary, a third member.

2.8. Data items:

The data items that will be extracted from the final set of included literature include:

- Authors
- Year of publication
- Region of world
- Type of technology being used
- Type of monitoring being conducted
- Goal of the monitoring intervention
- Level of validation (i.e., internal vs. external)

2.9. Critical appraisal

As this is a scoping review, a critical appraisal of the literature will not be undertaken.

2.10. Synthesis of results

Descriptions of resulting set of literature and data items will be presented using tables, figures, graphs and other visual summaries and comparisons. Current strengths and gaps in the literature will be presented for future research.

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