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Application of Artificial Intelligence in Cattle Farming: A Scope Review

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Abstract

Cattle farming started in this country with the arrival of cattle brought in the colonial period and since then it has grown and become highly importante both economically and socially. Currently, it is noticeable evident that the advancement of technology and its application in cattle raising has the potential to make livestock even more promising. Therefore, the purpose of this article is to analyze various applications of the technology in cattle raising through a scope review. Database searches were performed and 20 studies that met the inclusion criteria were analyzed and used in the review. These studies are divided into 8 main themes, and in general a very diversified number of variables, technologies and algorithms were used. It was possible to conclude that machine learning approaches are increasingly being studied, tested and considered as a viable and promising approach for cattle raising in several aspects.

Keywords *Bos indicus; Bos taurus;* cattle; livestock; technology

Introduction

Cattle farming is the activity focused on raising cattle and its techniques, being divided into beef cattle, to produce meat and leather and dairy cattle (Teixeira & Hespanhol, 2014).
This type of breeding began in the country with the arrival of cattle brought in during the colonial period, to carry out traction on the sugar mills. It is an activity that has a very large social and economic impact, since it generates many jobs directly and indirectly (Teixeira & Hespanhol, 2014).
According to data from the Brazilian Institute of Geography and Statistics (IBGE), in 1975 there were 102.5 million cattle in the country. The number of animals has increased considerably, with Brazil being a great player in the world bovine culture, having the largest bovine herd in the world, with 222 million animals according to data from the Ministry of Agriculture, Livestock and Supply (MAPA).
Since the beginning of animal domestication, many protocols and standards for animal husbandry activities have relied on empiricism, experience and sensory signals for decision making. Currently, it is increasingly evident that the advancement of technology and its application in animal production have the potential to make livestock better manageable, with efficient production on a large scale (Neethirajan, 2020).
Today, technologies such as computers, sensors, cloud computing, machine learning (ML) and artificial intelligence (AI) are already transforming many industries. They provide bigger and more efficient gains. We need to explore how these advanced technologies can help us in animal husbandry, especially cattle farming (Wolfert et al, 2017).

Therefore, the objective of this article is to analyse various applications of the technology in cattle breeding through a scoping review (which provides an overview of available research evidence, without producing a summarized answer to a distinct research question) to understand its importance in helping farmers improve animal health, increase profits and mitigate environmental damage (Sucharew; Macaluso, 2019).

Metodology

This article is a scope review, whose central theme is: What are the applications of artificial intelligence in cattle farming? The elaboration of the study had the following phases: 1) formulation of the research question; 2) search for relevant studies; 3) selection of studies; 4) data categorization; 5) collection, summary and mapping of results.

The electronic search was performed in Pubmed, Scopus, Scielo and CAB databases. The terms used to carry out the research were (artificial intelligence OR machine learning) AND (precision cattle farming). These studies were analyzed according to the following inclusion criteria: 1) primary studies; 2) any language; 3) availability of the full text; and exclusion: 1) review studies; 2) studies in other species (figure 1).

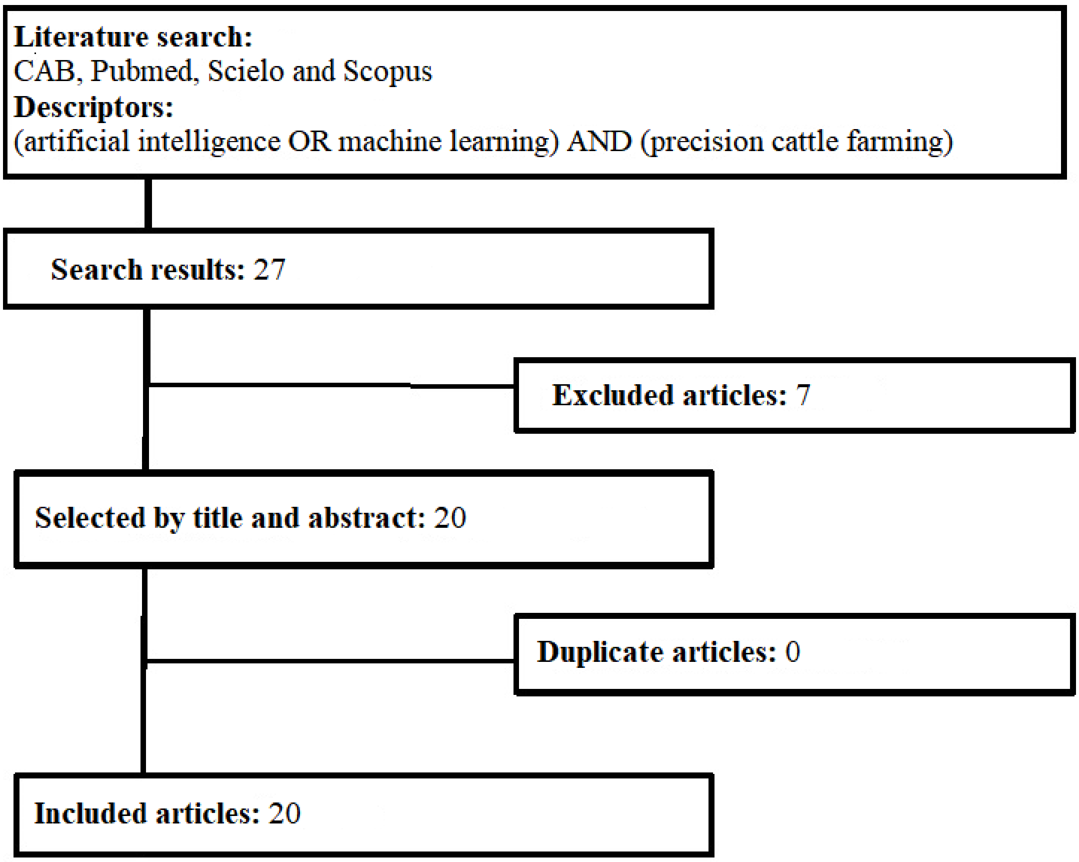

Figure 1. Flowchart of search and selection of the articles used.

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A total of 27 articles were found by searching the databases. Of the 27 studies, seven were excluded because they were literature reviews. Twenty studies (table 1) were selected for full-text analysis, met the criteria, and were included in the review.

Table 1 – Studies used.

Author	Method	Application
Becker et al, 2021	Logistic regression, Gaussian Naive Bayes and Random Forest	Predict the accuracy of the heat stress scoring system in dairy cattle
Bovo et al, 2021	Random Forest	Assess the trend of a cow's daily milk production in relation to environmental conditions
Carslake et al, 2021	AdaBoost	Classify and quantify multiple behaviors in dairy calves
Cairo et al, 2020	Logistic regression, Gaussian Naive Bayes and Random Forest	Early detection of estrus in dairy heifers.
Higaki et al, 2020	Support Vector Machine (SVM)	Predict calving in cows
Hintze et al, 2020	Cspade	Explore inactive behavior in cattle
Keceli et al, 2020	Recurrent Neural Networks	Predict calving in cows
Miller et al, 2020	Random Forest	Predict calving in cows
Pacheco et al, 2020	Artificial Neural Networks	Predict the individual heat stress state of animals.
Xu et al, 2020	Mask R-CNN	Sort and count livestock.
Xu et al, 2020	Mask R-CNN	Automated livestock count.
Dallago et al, 2019	Multivariate linear regression (MLR), random forest (RF) and artificial neural network (ANN)	Predict milk production on the first day of testing of dairy heifers.
Higaki et al, 2019	Decision Tree, SVM and ANN	Evaluate the effectiveness of estrus detection based on continuous measurements of temperature and vaginal conductivity
Miller et al, 2019	Artificial Neural Networks	Predict live weight and carcass characteristics of live beef cattle

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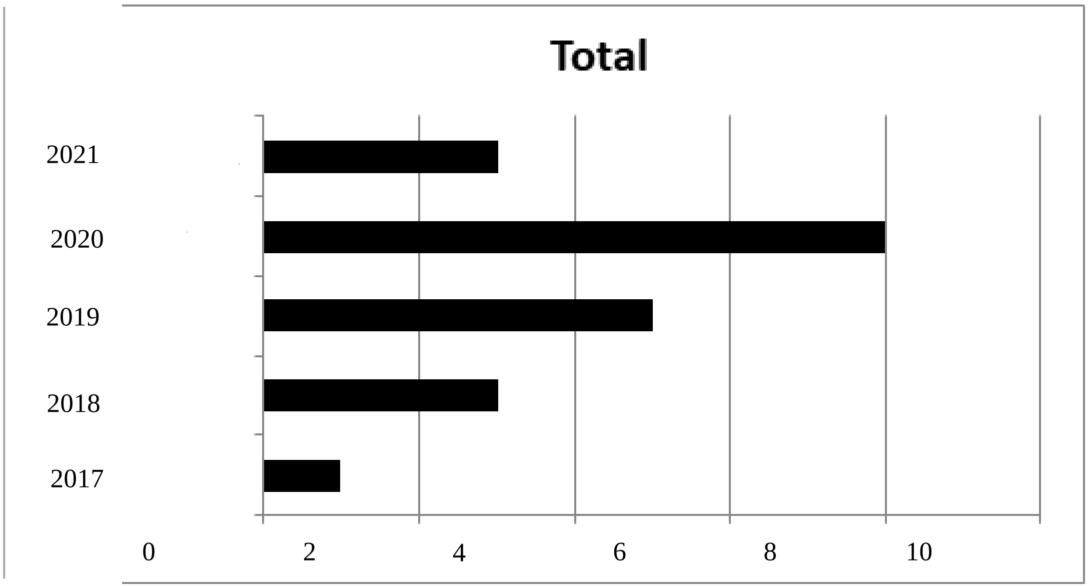
Schweinzer et al, 2019	Wearable software algorithms	Detect estrus in cows
Tamura et al, 2019	Decision Tree	Classifications of dairy cattle behavior
Alvarez et al, 2018	Convolutional Neural Networks (CNN)	Estimate body condition of cows
Chelotti et al, 2018	Chew-Bite Intelligent Algorithm (CBIA)	Detect and classify jaw movements in grazing cattle
Sousa et al, 2018	Artificial Neural Networks	Estimate the live weight of cattle.
Liakos et al, 2017	ANN, RF and SVM	Predict lameness in cattle.

Studies included by year of publication

The graph 1 shows a chronological growth in the number of publications related to artificial intelligence applied to cattle farming, and it is important to note that by the end of 2021 the number of studies will likely increase, in line with the trend of recent years.

Graph 1 – Studies included according to year of publication.



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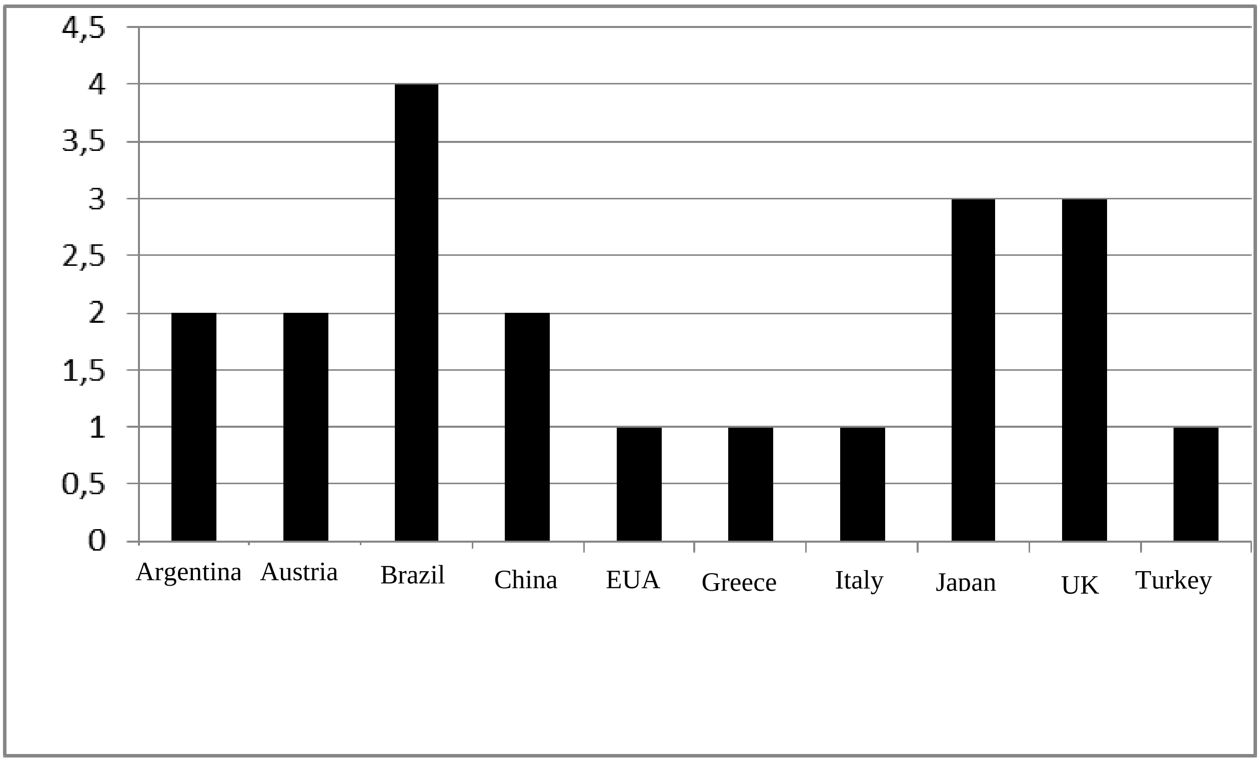
Geography of included studies

Studies originating from 10 countries were found. The graph 2 shows the number of studies included by country. Most (4/20) of the studies included are from Brazil, a reference country in beef production, and almost half (7/20) of the studies were carried out in America. The countries with the fewest published studies on the topic are the United States, Greece and Italy.

Graph 2 - Number of studies included by country.



Study topics

The main focus of the included studies fit into some themes (Table 2); they are:

Table 2 – Number of studies included according to the theme.

Study topic	Number of articles
Estrus detection	3
Calving prediction	3
Heat stress	2
Body weight/condition	3
Behavior	4
Production	2
Animal count	2
Claudication prediction	1

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Main concepts and evidence available

Estrus detection

Estrus can be detected through variables found in behavior habits, which can be both eating habits (feed consumption and water intake) and movement patterns, or measurements of physical parameters such as temperature (Cairo et al, 2020; Higaki et al., 2020; Higaki et al. al, 2019; Schweinzer et al, 2019).

Artificial neural networks, decision trees and random forests were used in 2/3 of the studies, the latter two being supervised learning methods, which differ in some respects (Cairo et al, 2020; Higaki et al, 2019; Schweinzer et al, 2019).

Random forest creates an ensemble of decision trees, which are usually trained with bagging, which combines learning models and increases the overall result, providing a more stable and more accurate prediction (Cairo et al, 2020; Higaki et al., 2020; Higaki et al. al, 2019; Schweinzer et al, 2019).

An interesting method that was also used is called SMARTBOW (Smartbow GmbH, Weibern, Austria), in which the movement patterns of each cow's ear are analysed to obtain various information that will be used for predictions. There is no information about its algorithm, as it is a commercial product (Cairo et al, 2020; Higaki et al, 2019; Schweinzer et al, 2019).

The techniques used showed potential for efficient and accurate estrus detection in cattle.

Calving prediction

Precise prediction of calving time in cattle is very important to reduce problems such as dystocia and pain, and it can be done with different measurements as variables and different algorithms, achieving efficient results (Keceli et al, 2020).

Skin temperature measurements at the base of the tail can be used to train a supervised learning model, as there is a gradual temperature-independent decrease around 36 to 16 h before parturition, and a sharp ambient temperature-dependent decrease around 6 hours before delivery (Higaki et al, 2020).

The training of the SVM algorithm obtained sensitivities and accuracies for calving in the next 24h of 85.3% and 71.9% in one farm (n = 75), and 81.8% and 67.5% in another (n = 33) (Higaki et al, 2020).

Behavioral traits of cattle and behavioral monitoring sensors can also be coupled with machine learning models for calving prediction. This application can be performed with the Bi-directional Long Short-Term Memory (Bi-LSTM) method to predict the day of delivery, and the RusBoosted Tree to predict the 8 hours remaining before delivery, in addition to these methods, the Recurrent Neural Networks also provide high performance for calving day prediction (Keceli et al, 2020). In addition, random forest algorithms also show promising results using this type of variable (Miller et al, 2020).

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Heat stress

Heat stress has an important influence on milk production, and dairy breeds, Holstein and Jersey, were used in the studies (Pacheco et al, 2020; Becker et al, 2021).

To verify the influence of heat stress, one study used a scoring system based on measurements performed on each animal and environmental measurements, and evaluated its accuracy, while another used infrared thermography and measurements performed on each animal and in the environment.

Becker et al (2021) used three machine learning techniques (logistic regression, Naive Bayes Gaussian and Random Forest). All showed consistent results, varying only according to the variables used for a given group.

Pacheco et al (2020) used models based on artificial neural networks that were established with perceptron, feedforward and multilayer architectures. The model responses were used as classifiers of heat stress levels (comfort, alert, danger and emergency).

Both researches delivered good results, which can help dairy producers detect heat stress before it becomes severe and significantly affects production (Pacheco et al, 2020; Becker et al, 2021).

Body weight/condition

The measurement of the live weight of animals and body condition is an important parameter for management activities. It has a significant economic impact on animal production and artificial intelligence helps a lot in this process. (Sousa et al, 2018).

Weight or body condition can also be estimated using artificial intelligence techniques, working with different algorithms and input data. Acoustic monitoring, for example, can be used to estimate the amount of forage ingested and is something practical to be measured, but the interpretation of these data by algorithms is something that encounters some obstacles for a better success in use. Because of this, a new algorithm called Chew-Bite Intelligent Algorithm (CBIA) was used in a study and obtained a recognition rate of 90% (Chelotti et al, 2018).

It is also possible to use the Body Composition Score (BCS), which is a method for estimating the body fat reserves and accumulated energy balance of cattle, placing the estimates on a scale from 1 to 5 (Alvarez et al, 2018).

Periodic classification of BCS of dairy cows is very important as BCS values are associated with milk production, reproduction and cow health. But in practice, obtaining ECC values is a time-consuming and subjective task performed visually by evaluators (Alvarez et al, 2018).

An automatic system for estimating ECC values was created, based on Convolutional Neural Networks with transfer of learning and ensemble modelling techniques to improve accuracy, obtaining an overall accuracy of up to 97% (Alvarez et al, 2018).

Knowing the body condition is also important to select finishing beef cattle for slaughter, and currently, just like the ECC estimation, it is done subjectively by evaluators or by weighing. Differences in these assessments often occur and the animals do not comply with the slaughterhouse requirements (Miller et al, 2019).

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Consequently, a large number of cattle are not meeting the slaughterhouse's specifications. Currently, we can count on the use of video image analysis (VIA), which allows classifying carcasses with high precision. In addition to the possibility of using three-dimensional images and artificial neural networks, including feed-forward and multilayer architecture, to collect images, variables can be extracted and applied to the model (Miller et al, 2019; Sousa et al, 2018).
This method presents an opportunity to reduce discrepancies in meat production through autonomous monitoring of cattle termination on the farm and the marketing of animals at the ideal time (Miller et al, 2019).

Behavior
Demand has recently increased for an automated animal behaviour monitoring system as a tool for farm animal management (TAMURA et al, 2019).
It is possible to associate the behaviour of cattle with acceleration data collected on mounted three-axis accelerometers and calculate variations according to the activity level. And use decision trees to calculate the level of activity and livestock variations (TAMURA et al, 2019).
Animals kept in confinement often show high levels of inactivity, which can make animals bored. But there are still gaps about precisely how activity levels in different species are scarce (Hintze et al, 2020).
Through observations and recordings, it is possible to collect input data and use the cSPADE machine learning algorithm as a valuable tool to provide information about inactivity postures (Hintze et al, 2020).
Artificial intelligence does not only apply to adults, but also to calves, indicating the possibility of diseases according to behavioural changes. Sensors placed on calf collars and camera footage can have their data combined and applied in the AdaBoost algorithm to efficiently classify behaviours. This type of application has the potential to contribute with new insights to assess health and well-being in calves through the use of wearable sensors (Carslake et al, 2021).

Production
The study by Dallago et al (2019) determined which dairy herd improvement metrics have the greatest impact on milk production, as well as building and comparing predictive models. Three types of models were evaluated: multivariate linear regression, random forest and artificial neural network.
In the study by Bovo et al (2021) to assess the tendency of a cow's daily milk production in relation to environmental conditions, only the random forest model was used.
Both studies then used an ensemble method, which makes predictions by averaging the predictions provided by various random models. They show that the random forest model can represent a reliable and viable tool for evaluating future productive scenarios. However, in the study by Dallago et al (2019) the artificial neural networks were more accurate than the

random forest (which even showed overfitting - when the statistical model exactly fits its training data).
These results can help to develop and improve decision support for livestock keepers to increase milk production and animal welfare, as well as reduce resource utilization (Dallago et al, 2019; Bovo et al, 2021).

Others
A significant problem that precision ranching tries to mitigate is the identification of lameness in cattle. Through the number of steps per day, general walking per day, time lying down per day and time eating per day. This data can be applied to Artificial Neural Networks, Random Forest, and GPU-associated Support Vector Machine Library (GPU-LIBSVM) algorithms, allowing more resource-intensive computational models to be created and tested 30 times faster, can be used to predict this serious problem in the bovine clinic (Liakos et al, 2017).
In addition, artificial intelligence can also be used to count the animals in a herd, something that needs to be accurate and reliable and that can be done this way with quadcopters equipped with machine learning vision systems such as Mask R-CNN. , which is a deep neural network that aims to solve instance segmentation problems in machine learning or computer vision with promising results (Xu et al, 2020a; Xu et al, 2020b).

Conclusions
Machine learning approaches are increasingly being studied, tested and considered as a viable and promising approach to cattle farming in several aspects, providing better decision making. This scoping review identified 20 studies that investigate the applications of artificial intelligence in cattle farming.
The scope review cannot demonstrate causal effects, but reports evidence that is plausible and statistically consistent, as well as diversified, given the amount of possibility of input variables and algorithms used.
Existing evidence supports the need to promote applications of artificial intelligence in livestock, especially cattle.
Further studies will be important to support the development of these applications, especially in relation to the diseases involved in the livestock farming.

Declaration Conflict of Interest
The authors declare that they have no conflict of interest.

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