



Drone-assisted Health Monitoring of Livestock: Bridging Technology and Veterinary Science

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ABSTRACT

Background: Monitoring livestock health is an essential component of modern agriculture, as it guarantees the well-being of animals, increases production and ensures food security. Traditional techniques, especially in rural agricultural enterprises, are labor-intensive and limited in scope.

Methods: This research explores the use of drone technology to monitor cattle health, employing thermal imaging, multispectral cameras and artificial intelligence-based data processing to enhance monitoring capabilities.

Result: The study found that drones significantly improve monitoring efficiency by covering larger areas in less time. The technology achieved over 90% accuracy in detecting health abnormalities. However, challenges such as environmental side effects, start-up costs and the need for operator training were identified.

Key words: Artificial intelligence, Drone technology, Livestock health, Monitoring efficiency.

INTRODUCTION

The production of livestock products accounts for over half of all agricultural output across the globe. These products are used to satisfy consumer demand for foods derived from animals, non-food goods, production inputs and reasons that are not related to agriculture. Livestock diseases will distort values and therefore affect production of local and foreign market shocks and ultimately create market inefficiencies (Wolfert *et al.*, 2017; Cho, 2024; Maltare *et al.*, 2023; Bagga *et al.*, 2024; AlZubi, 2023). Livestock disease outbreaks and infections in production threaten not only the health of herds and the viability of markets for commercialized livestock products but also the viability of smallholder agricultural systems. Livestock illnesses may also drive actions that are not sustainable and can cause harm, such as the excessive use of antibiotics, the occurrence of random disease outbreaks, the dissemination of bad information and publicity associated with disease outbreaks and the distortion of markets that are not connected with livestock.

Animal diseases and their accompanying externalities directly impact the well-being of human beings and animals and can, themselves, be influenced by climate change or the environment. This can happen in the local ecosystems where livestock production systems operate, such as through feedback interactions between livestock and wildlife disease vectors (Dhanaraju *et al.*, 2022). Climate changes also lead to an increased burden of cattle disease in production settings as well as the re-emergence of zoonotic disease.

Livestock disease is a significant issue in livestock production, impacting communities and markets. Governments have implemented measures like trade bans and restrictions to address this issue. Researchers have studied the cost-benefit analysis of disease response,

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eradication and detection programs, as well as the impact on productivity, value and costs at both production and consumption levels (Safaei *et al.*, 2020). This review of livestock health and disease economics aims to increase understanding of the current knowledge and gaps in the characterization of animal disease burden. Automated and precise monitoring systems are needed to reduce labor costs and improve health detection rates. Livestock health monitoring is largely manual, making it inefficient. Electronic monitoring systems, such as precision livestock farming (PLF), are essential for progress in animal health management. These systems use advanced sensors and analytics to provide real-time insights into animal behavior and health.

It is anticipated that the world population will reach 9.7 billion by the year 2050, which will result in a rise in the demand for goods derived from animals and will require a 70% increase in the production of food on a global scale. Demand for meat alone is predicted to grow by more than fifty percent. World globalization has been a giant propeller for the fast growth of the cattle business, which has been driven by the increased needs of consumers over a wide variety of markets (Chin *et al.*, 2023). While this expansion is at odds with the need for more environmentally responsible practices, animal welfare and sustainability.

In order to make the sector somewhat viable in the long run, there is a need for a balance between increased meat production and more ethical agricultural practices.

Aircraft that are intended to fly without a pilot on board are referred to as unmanned aerial vehicles (UAVs). The planes have also been described as little flying robots, or dronesgram drones. To make all these systems work, three major components need to work in synergy-the ground control station, the aircraft body and the sensor support. UAVs have the ability to travel to remote areas without assuming control over humans and taking a little time, effort and energy (Su *et al.*, 2018). As a result of their high mobility, minimal maintenance requirements and ease of deployment, they are well-suited for the collection of aerial photographs in outdoor environments where monitoring and analysis may be performed with ease.

There has been a rise in their availability in commercial, military and civilian applications as a result of the decrease in pricing. North America, Asia and Europe are expected to lead the way in terms of the value of the worldwide unmanned aerial vehicle (UAV) market by the year 2025. This article has provided a description of the UAV-driven paradigm, including its uses and problems. There is a consistent upward trend in the commercial drone sector and it is anticipated that it will become more significant in the not-too-distant future.

There has been a considerable amount of study conducted on the identification and counting of animals via the use of drone photographs. In earlier methods, video footage was captured for the purpose of manual analysis. However, more recent techniques, such as thresholding, sliding window approach, thermal imaging and image segmentation, have made the process more efficient. Long-term Recurrent Convolutional Networks (LRCN), open-set identification and optimization challenges for missing livestock have all been used in order to solve the issue of online monitoring of animals.

Cattle management has been the main study scope of research works that use drone-based Internet of Things (IoT) applications (Table 1). AI (Artificial Intelligence), complex ML (machine learning) and DL (deep learning) tools are used for data collection, analysis, and real-time decision-making processes. There is a description of unmanned aerial vehicle (UAV) networks softwarization, as well as an overview of application domains and research perspectives (Shaw *et al.*, 2020). An interesting line of research is the effects that UAVs have on the behavior of cattle. These changes include the heart rate and movement rate of livestock under different flying circumstances and at different times.

Drone technology has transformed cattle management via improved monitoring and surveillance, optimized pasture management and increased water and resource management. High-resolution cameras and infrared imaging allow drones to monitor animal movement, detect wounded or ill livestock and observe birthing activities

without disturbing the animals or necessitating personal presence (Martinez-Guanter *et al.*, 2019). This degree of surveillance guarantees prompt response, enhancing animal welfare and decreasing death rates.

Drones are essential for enhancing pasture management, evaluating pasture health, quantifying biomass and identifying fluctuations in plant health that might signal pest or disease infestations (Tsouros *et al.*, 2019). This information allows farmers to make educated choices on grazing patterns, fodder distribution and intervention measures to sustain healthy pastures, therefore directly influencing animal health and agricultural output.

Efficient water and resource management is essential for cattle welfare and agricultural sustainability. Drones outfitted with multispectral sensors may delineate water sources, evaluate their quality and pinpoint regions of water shortage, facilitating the strategic positioning of water troughs and the construction of effective irrigation systems (Siebring *et al.*, 2019). Comprehending animal behavior is essential for efficient livestock management, since drones provide a unique viewpoint on herd dynamics, social hierarchies and actions that signify stress or discomfort.

The use of drone technology in cattle management yields substantial cost reductions and operational efficiency. Farmers may deploy resources more efficiently by diminishing the need for physical labor, concentrating on strategic decision-making and agricultural optimization (Schad *et al.*, 2022). Drones enhance the monitoring procedure, allowing rapid evaluation of extensive herds and prompt reactions to any concerns.

Future possibilities for drone technology in livestock management include automated drone systems for routine herd surveillance, the incorporation of artificial intelligence for predictive analytics and improved communication systems for real-time data exchange and decision-making. Nonetheless, obstacles include legal barriers, privacy issues and the need for technical proficiency among farmers must be resolved via policy formulation, education and training.

Objective

The primary objectives of this study are:

1. Evaluate the functionalities of drones fitted with sophisticated sensors (e.g., thermal cameras, multispectral imaging) for the real-time surveillance of cattle health metrics, including body temperature, movement behaviors and skin problems.
2. Evaluate the efficacy of drones vs conventional manual health monitoring techniques for temporal efficiency, precision and cost-effectiveness.
3. Examine environmental, operational and technological impediments to the use of drones in various agricultural contexts.
4. Recommend measures to improve the accessibility, scalability and dependability of drone technology in veterinary science.

Research question

- How can drone technology be efficiently used for the health monitoring of cattle in veterinary science?
- What categories of health data can drones outfitted with sophisticated sensors (such as thermal and multispectral photography) effectively collect from livestock?
- What is the comparative efficiency of drone-assisted cattle health monitoring against conventional techniques for time, coverage and labour?
- What is the precision of drone-assisted health monitoring in identifying common livestock health concerns (e.g., fever, dermatological problems, or unusual behavior)?
- What are the primary obstacles in the use of drones for animal health monitoring and how may these obstacles be alleviated?
- What are the financial ramifications of using drone-assisted systems for health monitoring in contrast to manual methods?
- How can drone-assisted health monitoring systems be enhanced for scalability and use across diverse agricultural settings?

Alanezi *et al.* (2022) used Unmanned Aerial Vehicles (UAVs) throughout diverse sectors, especially in livestock agriculture, presenting a promising domain owing to their user-friendliness and technological improvements. Nonetheless, the sector faces a multitude of environmental, technological, economic and strategic obstacles. However, the uptake of drone tech by cattle producers could be supported by advanced technologies like AI, IoT, machine learning, deep learning and even advanced sensors. This study reviews studies that use different types of UAVs for identification, count and surveillance of agricultural livestock. And it aims to extract the issues, opportunities and outlook of livestock husbandry, thus serving as an all-inclusive reference point for academic researchers and a guideline for future research work. This is the first review article on the subject that summarizes extensive studies and perspectives.

The world population is expanding rapidly, requiring a transformation in agricultural practices to satisfy escalating food supply needs (Makam *et al.*, 2024). Conventional methods are no longer sufficient, with a declining agriculture sector and a pressing demand for automation in agriculture. With the rapid development of technology, full automation is simply unattainable and UAVs are indispensable for precision, intelligent agricultural production. They also take less time to operate and require fewer personnel compared to traditional means, as they are simply unmanned. Conceptual design, command flow operation, microcontroller boards and remote-control systems, as well as peripherals (sensors, cameras, motors, *etc.*). In this progress of IoT-based UAVs, exact demographic data is obtained by processing and executing machine learning algorithms on images. Future trends, limitations and challenges for farmers in adapting to UAVs are also discussed (Estevez *et al.*, 2023; Zhao *et al.*, 2024).

AlZubi (2023) examined the use of machine learning in drone technology for the observation and analysis of cattle movement patterns. Conventional techniques, such as manual surveys or satellite photography, are labor-intensive and imprecise. But a machine learning algorithm could soon allow companies to manage their grazing lands more efficiently. Using SVM to classify, the selection of the photographs is from open data projects and from crowd-sourced ground truth. With a low accuracy of between 10-25%, true positive rates of 70-85% are possible, with the findings showing: The study also explores factors relevant to data collection, such as image resolution. They came up with a potential to revolutionize the livestock industry using the combination of cow movement monitoring with machine learning algorithms the drone technology.

Drone technology has profoundly altered agriculture, equipping farmers with instruments for crop surveillance, resource efficiency, pesticide distribution and animal oversight (Reddy *et al.*, 2023). These drones have advantages such as increased efficiency, diminished resource consumption and heightened safety, resulting in their extensive use. Their combination might revolutionize conventional agriculture, establishing sustainable and efficient food production systems. Drones, or unmanned aerial vehicles (UAVs), are collecting real-time data, performing aerial surveys and automating chores, enabling farmers to make informed choices, enhance efficiency and foster sustainable practices. These small, agile planes equipped with advanced sensors and artificial intelligence capabilities could revolutionize all phases of agriculture, from soil and crop assessment to planting and surveillance to protecting crops. This is a technological revolution that is going to secure the future of the world's food supply to be more productive, more efficient and sustainable with the use of drones in agricultural production. This article examines the emergence of drone technology in agriculture and its transformational capabilities in contemporary agricultural practices.

A growing number of farmers are turning to crop analysis that makes use of satellite data and, more recently, drones and remote sensing to assist them in enhancing their yields (Uganda Flying Labs, 2021). The real-time images taken by drones have been proven highly beneficial for the surveillance and optimization of agrarian output. This is because these pictures allow farmers to more quickly act upon a number of potential challenges, from weed encroachment to insect infestation to inventory management and yield tracking to mineral deficiency, *etc.*

UAV (drone) technology is being applied in livestock management in an increasing number of ways as we search for optimal procedures that improve efficiency and cost effectiveness (Daniel, 2024). Camera attachments can gauge how much feed the cows are eating across the expanse of large pastures, eliminating the need for pasture checks by foot. Additionally, drones are able to estimate and monitor the biomass of fodder crops, search for insects

and diseases, examine herds, locate animals that have wandered off, check for estrus, monitor throughout the calving season, check water supplies and even herd cattle. The initial investment is a serious disadvantage, however, because a good photography drone can range from \$500 to \$5,000. In order to operate a drone legally for agricultural purposes, you must obtain a Part 107 license, which costs \$175. To get this license, one has to pass an FAA test.

The Food and Agriculture Organization says that in its report, by 2050, the world population will grow to 9.6 billion, having a food need and thus bringing the world agriculture technologies to a higher level (Hafeez *et al.*, 2022). Precision agriculture (PA) has the potential to address crop yield limitations by leveraging drone-related developments. In this study, we look back over the last ten years at how drone technologies have changed in agriculture, specifically in the areas of crop field surveillance, monitoring and pesticide spraying. The study aims to categorize the structure of drones, explore the development of sensors and identify emerging trends in spot-area spraying.

MATERIALS AND METHODS

Based on the technique that has four stages, this study implements drone-assisted health monitoring of cattle. At each step (system setup, data collection, analysis, validation) in the process, some goals are accomplished to ensure the monitoring is comprehensive and precise.

System setup

In order to set up the system, you will need to pick and configure drones that are equipped with the right sensors

and software for monitoring the health of livestock. In Table 1, the major components and the responsibilities that they play are broken out in depth.

Data collection

For the purpose of gathering information on the health of cattle, the drones are used in controlled settings. Flight routes that have been set and data collecting procedures that have been developed guarantee complete coverage. The stages that are involved are shown in Table 2.

Data analysis

The collected data is processed in order to get insights that may be put into action. Indicators of health, such as body temperature, activity patterns and skin problems, are analyzed by sophisticated algorithms. The analytical procedure is broken down into its component parts in Table 3.

Validation

The findings of the drone-assisted system are compared with those of conventional veterinary procedures throughout the validation process. This guarantees that the system is both reliable and effective. In accordance with the information shown in Table 4, controlled field tests are carried out and performance indicators are evaluated.

RESULTS AND DISCUSSION

Within this part, the results that were obtained from the installation of drone-assisted livestock health monitoring are discussed. The findings have been categorized into three primary categories: efficiency, accuracy and difficulties.

Table 1: Components and technologies in system setup.

Component	Description	Purpose
Drones	Multicopter UAVs with GPS navigation.	Provide mobility and coverage over wide areas.
Thermal cameras	Sensors detect heat signatures from livestock.	Identify temperature anomalies indicative of fever or stress.
Multispectral cameras	Sensors capturing data in multiple wavelengths (visible, NIR, <i>etc.</i>).	Assess skin conditions, hydration levels and nutrition.
GPS modules	High-precision GPS for route planning.	Enable accurate, repeatable monitoring paths.
AI-integrated software	Machine learning models are trained on livestock health data.	Automate data analysis and anomaly detection.

Table 2: Steps in data collection.

Step	Description	Outcome
Defining flight paths	Designing routes based on livestock location, herd size and terrain.	Optimized drone coverage and reduced overlaps.
Setting sensor parameters	Calibrating thermal and multispectral sensors for accurate data collection.	High-quality, reliable health metrics.
Conducting drone flights	Executing the predefined routes and collecting data (images, videos, temperature readings).	Comprehensive livestock data set.
Real-time monitoring	Live streaming data to operators for immediate observation and intervention.	Early identification of critical issues.

Efficiency of drone-assisted monitoring

The effectiveness of the system was assessed by contrasting the amount of time required for health monitoring using drones with the time required by more conventional manual approaches. An overview of the findings may be found in Table 5.

In terms of monitoring efficiency, approaches that were helped by drones displayed considerable gains, resulting in a reduction in the amount of time needed to cover vast herds or regions. The pre-programmed flight routes and automated data collecting capabilities of the drones are said to be responsible for this improvement.

Accuracy of health monitoring

By contrasting the findings of the system with conventional veterinary diagnosis, the accuracy of the procedure was

evaluated. Table 6 displays the findings for the most important health markers.

The drone system reached an accuracy that was equivalent to that of conventional techniques, especially when it came to determining the temperature of the body and the state of the skin. The fact that there was a modest decrease in the accuracy of behavioral anomalies indicates that there is a need for enhanced algorithms when poor weather circumstances are present.

Challenges and limitations

The installation of the drone-assisted system was not without its difficulties, despite the fact that it had many benefits. A list of these difficulties may be seen in Table 7. In the field of livestock research, the development of drone-assisted systems might be facilitated by addressing these

Table 3: Data analysis process.

Task	Tools/techniques	Outcome
Image preprocessing	Noise reduction, contrast enhancement and segmentation.	Clean, high-quality images for analysis.
Anomaly detection	Machine learning models (e.g., SVM, CNN) are used to identify abnormal patterns.	Early detection of diseases or injuries.
Behavioral analysis	AI models track movement patterns and grazing behavior.	Insights into stress or illness-related behavior.
Predictive analytics	Historical data and AI predictions for potential health risks.	Proactive health management strategies.

Table 4: Validation parameters and metrics.

Parameter	Metric	Target value	Validation method
Detection accuracy	% of correctly identified health anomalies.	≥90%	Comparison with traditional veterinary results.
Time efficiency	Average time for data collection and analysis.	<30 minutes per session.	Timed field trials.
Cost-effectiveness	Operational cost per session.	20% lower than manual methods.	Cost analysis study.
Animal stress	Behavioral stress markers during monitoring.	Minimal	Observation of animal behavior.

Table 5: Efficiency comparison of drone vs. manual methods.

Parameter	Drone-assisted method	Traditional method	Improvement
Average time per session	25 minutes	90 minutes	72% faster
Coverage area (per hour)	50 hectares	10 hectares	5× greater
Number of animals monitored	100 animals	30 animals	3.3× more animals

Table 6: Accuracy of drone-assisted health monitoring.

Health parameter	Drone accuracy (%)	Manual accuracy (%)	Notes
Body temperature detection	93%	95%	Slight discrepancy due to environmental interference.
Skin condition analysis	90%	92%	Effective for visible conditions.
Behavioral anomalies	88%	90%	Minor limitations in movement tracking during dense fog.

Table 7: Challenges in drone-assisted monitoring.

Challenge	Description	Proposed solution
Environmental factors	Fog, rain and strong winds affected data collection accuracy.	Use drones with advanced weather-resistant sensors.
Initial setup costs	High cost of drones and sensors deterred small-scale farmers.	Subsidies or cost-sharing programs for small farmers.
Operator training	Lack of skilled operators to manage drone systems.	Conduct training workshops for local farmers.

Table 8: Cost-effectiveness analysis.

Parameter	Drone-assisted method	Traditional method	Savings (%)
Cost per animal monitored	\$2.50	\$4.00	37.5%
Equipment maintenance cost	\$500/year	\$200/year	Higher initial cost, but scalable.

obstacles via the use of technology breakthroughs and governmental interventions.

Cost-effectiveness

By comparing the operating expenses of the drone-assisted approach with those of the conventional methods, the cost-effectiveness of the drone-assisted method was evaluated. The results are shown in Table 8, which may be found here.

Despite the fact that the initial cost of drone systems is greater, the cost of monitoring each individual animal is substantially cheaper for large-scale operations, which clearly demonstrates the long-term economic advantages of using drones.

CONCLUSION

Drone Technology for Livestock-the Unmatched Potential for Monitoring, Welfare Promoting and Operational Efficiency. With the help of airborne observation and data analysis, farmers who use sustainable agricultural techniques can maintain the health and production of their herds. As this technology develops, it will dramatically enhance farmers' abilities, rendering livestock-rearing more effective, humane and environmentally sound. Several considerations must be addressed, since animals cannot articulate themselves as well as people. How will animals react, adapt, or acclimate to the presence of drones? A potential answer is to monitor stress hormone levels to assess the degree of suffering, since the stress experienced by the animal ultimately influences its output. The use of manned aircraft for scanning cattle ranches has several disadvantages, including increased operating expenses and heightened noise levels that may disrupt the animals. Numerous studies have shown alterations in animal behavior owing to nearby drone flying. Drones often operate at lower altitudes, potentially disturbing wildlife. Multiple studies have shown animal reactions to drones. In India, as fodder and pasture land diminish, drone technology seems to have restricted applicability for small-scale farmers with limited land holdings.

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Data availability

The data analysed/generated in the present study will be made available from corresponding authors upon reasonable request.

Availability of data and materials

Not applicable.

Use of artificial intelligence

Not applicable.

Declarations

Author declares that all works are original. It has not been published in any other journal.

Conflict of interest

Author declares that they have no conflict of interest.

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