

# The Smart Farm Revolution: How Precision Livestock Farming Is Transforming Animal Health

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## ABSTRACT

Precision livestock farming and smart farming represent revolutionary advancements in modern livestock farming, utilising advanced technologies to enhance productivity and viability. It utilises information technology tools to monitor and manage animals in real time, which can improve animal health, welfare, and productivity, contributing to the social, economic, and environmental sustainability of the farm. Wearable collar technologies have become integral to the advancement of precision livestock farming, and these technologies help to monitor the health and behaviour of animals. These devices include accelerometers, GPS receivers, microphones, gyroscopes, and magnetometers to provide non-invasive, real-time insights that improve animal health and welfare. To bring PLF technology further into field application, increased development and testing of PLF technologies is required in real farms to implement reliable solutions. Risks of increasing PLF usage include dependency on the technology, and there is an alteration in the human-animal relationship and changes in the public's perception of dairy farming.

**Keywords:** Precision livestock farming, biosensors, veterinary applications, sensor technology, early diagnosis, virtual fencing system.

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## Introduction

The livestock industry is a foundation of the agricultural economy. Traditional management practices do not meet the needs of modern livestock farming [1]. There will be a 20% increase in the world population over the next 30 years; a significant increase in demand for animal products is foreseen. Dairy farmers are facing this issue to meet this conflict; on one hand, they must increase productivity to meet demand, and on the other hand, consumers' interest in animal welfare and environmental aspect increasing, due to which farmers must increase awareness of animal welfare and environmental protection on their farms [2]. In the old traditional method, humans can do it with direct-contact tools or in situ observation, but human observation is limited; there is a chance of error in detecting animal behaviours. For example, the presence of humans often affects the cow's natural behaviour because the cow is suffering from stress during manual handling; people may face the risk of suffering from injury. Secondly, the results are affected by the traditional method, and humans are manually operating cattle management, and they cannot detect small, subtle changes due to limited observation capacity.

Precision livestock farming (PLF), with the help of information technology, has become an inevitable trend in advancing modern livestock farming. It refers to continuous, direct, non-invasive monitoring of animal health and welfare, providing them with better results and meaningful information [3]. The term precision livestock farming was first introduced by Daniel Berckmans, who asserted that continuous direct real-time monitoring of animals allows the farmer to quickly identify and address health-related issues in animals [4]. PLF systems usually consist of sensors that may be attached to or implanted inside the animals. Such sensors provide a wide variety of information about the animals or the environment in which the animal is living [5]. This technology enables the farmer to monitor the health and welfare of extensive animal populations, promptly detect issues with individual animals, and potentially predict problems, comprising a wide variety of applications. Examples of common applications include the surveillance of bovine behaviours, the identification of vocalisations, the monitoring of coughs in several animal species to diagnose respiratory ailments, and the detection of bovine pregnancy [6]. In this article, we will discuss the fundamentals of Precision livestock farming, emerging technologies, veterinary applications, and implementation challenges of Precision livestock farming.

## Precision Livestock Farming Fundamentals

The main objective of PLF is continuous real-time monitoring of animal health, welfare, reproduction, and environmental influence. The word continuous means PLF Technology measures animal performance every second, 24 hours, and 7 days a week. Farmers get a warning when there is something wrong with the animal; in this way, the PLF system brings them to the animal(s) that need their attention at that moment [7]. Precision livestock farming and smart livestock farming use the principles and

technologies of process engineering, where smart sensors, big data analysis, and conventional mathematical and artificial intelligence models bring innovation in livestock farms [8].

PLF is a technological system for real-time monitoring of farm animals, aimed at managing the temporal variability of the smallest manageable production unit, known as the 'per-animal approach'. The individual electronic milk meter for cattle was the first significant implementation of PLF. To obtain such a functional control and monitoring system, three conditions must be fulfilled. The first condition is to constantly monitor the animal variables and for this information to be constantly analysed. The second condition is the development of a prognosis based on how animal variables will differ and how animals will respond to the environmental changes. The third condition is that these predictions, together with digital measurements, are incorporated in an analytical algorithm for the online monitoring of animal health and welfare. Continuous technological developments contribute to the creation of PLF diagnostic tools that can detect farm problems without manipulation of animals (non-invasive data gathering) or inducing stress and help to recognise any disease outbreak before any farmer would [9].

## Emerging Technologies

The original objective of PLF was to monitor individual animals in the herd. Initially, it emerged in the context of intensive livestock farming, but recently it has also been applied to extensive farming systems (Precision Livestock Extensive Farming, PLEF). PLEF shifts transition livestock farming from manual to automated or semi-automated, improving herd management, pasture management, environmental control, health monitoring, and feeding optimisation. These technologies use cameras, sensors, and acoustic devices integrated with AI, enabling data collection and analysis.

The management of pasture with the help of PLF technologies helps to prevent overgrazing and under-grazing. Overgrazing can cause soil erosion, increase biodiversity, and decrease water quality. Conversely under grazing can lead to the accumulation of unpalatable, low forage quality, and an increased risk of wildfires. In large farms, it is difficult to make physical fences and to monitor animals. Therefore, advanced technologies help farmers to cope with these challenges. A virtual fencing system helps the farmer to create more dynamic boundaries using GPS, sensors, and communication devices. This system involves wearable devices or collars equipped with GPS and sensors that monitor the location and behaviour of animals. When an animal approaches or crosses a virtual boundary, it receives stimuli such as auditory signals, vibration, or mild electric pulses to redirect its movement and guide it back to its area or prevent it from entering restricted zones [10].

SENSORS play a vital role in PLF technology by collecting real-time data across various aspects of livestock production, including animal behaviour, health status, and environmental conditions. These sensors provide valuable

information about the health status of the animals, as they record vital signs such as body temperature, heart rate, respiratory rate. Animals' bodies may show changes indicating signs of illness or stress. In terms of environmental conditions, they can measure changes in the animal's environment in terms of temperature, humidity, air quality, and light conditions. These sensors are attached to animals' bodies as portable devices in barns and pastures, and they collect and analyse data using advanced techniques of artificial intelligence and machine monitoring system which detect patterns and anomalies in animals' bodies. Farmers detect these changes and improve management practices on the farm [11].

Most common sensors used in PLF systems, particularly in dairy farm management, are activity sensors (e.g., accelerometers to monitor movement and lying behaviour), sensors with a Global Positioning System (GPS) antenna, sensors with a Radio frequency identification (RFID) tag, pressure sensors, intra-ruminal sensors, intra-vaginal devices, environmental sensors (e.g., temperature and humidity sensors to monitor barn conditions), microphones, magnetometers, gyroscopes, cameras and thermal cameras, thermometers, and heart rate monitors [12].

#### Veterinary applications

Information technologies collect a wide range of data that helps in decision-making on dairy farms. With the help of emerging technologies like Internet of Things (IoT), Artificial Intelligence (AI), and Computer Vision (CV), it is possible for farm managers and veterinarians to detect disease as early as possible and to manage it properly [13]. Animal health management with the help of biosensors is gaining momentum worldwide. Farm managers, veterinarians, and farmers themselves can use sensors to monitor animal movements, food intake, sleep cycles, and even shelter air quality.

Oestrus detection on dairy farms is a major challenge, especially in those farms that use artificial insemination. As the cattle move from late gestation to early lactation there are many changes occur in the body of the animal, and the likelihood of diseases increase like metritis, mastitis, displaced abomasum, and ketosis [14]. Lameness is a deviation of gait due to discomfort or pain caused by any injury. Due to lameness, animal reproduction, production, and welfare are compromised. On farms veterinarian usually detect lameness by visual observations, assigning a lameness score according to gait or posture characteristics. But these are subjective, time-intensive methods and vary from person to person. Automated measurements have been used that surpass human observations. Walking behaviour, feeding behaviour, rumination, activity, and lying time have been used to detect lameness [15].

Mastitis is one of the significant diseases of the dairy industry; it affects milk production, quality, and farm economics. Somatic cell count is the most widely used indicator for assessing udder health. The Somatic cell count (SCC) in milk above 200,000 cell/mL is generally considered abnormal and indicates inflammation in the udder. It has been reported that 70-80 percent of mastitis is reported as subclinical, and it is the major challenge in the dairy industry due to the absence of any visible sign. (INFRARED THERMOGRAPHY) IRT is a non-invasive technology that is used to detect subclinical mastitis, but it is not suitable for automated disease detection on commercial farms because it is biased towards warmer temperatures. (FLIR) Quick software analyses the ocular surface temperature (OST) and udder skin surface temperature (USST) of thermographic images for the early detection of subclinical mastitis in indigenous cows, and it is found that the USST temperature of subclinical mastitis affected quarter by subclinical mastitis is significantly higher than body temperature, and it has a positive correlation with SCC. An Internet of Things (IoT)- based animal social behaviour sensing framework helps to estimate the probability of disease transmission in animals and forecast mastitis infection probabilities. This framework is demonstrated by theoretical and simulation- based analytics. The correctness of this model is validated by SCC in real-world scenarios [16].

#### Implementation Challenges and Future Directions

Although PLF is a fundamental technology, there are still many challenges that must be tackled so that PLF technology can be widely used for livestock species. First, PLF tools should be designed according to the global region of each country, not only in terms of the specific climate conditions but also farm sizes and technological level, labour availability and labour training, market requirements, etc. For example, while electricity, Internet, and cell phone signal may be more broadly available in rural areas of developed countries, these facilities may not be available in developing countries [17]. The primary goal of precision livestock farming is to generate reliable data using biosensors and run it through intelligent software systems to create value for the farmer, the environment, and the animals in the form of improved animal health and welfare, increased productivity, and yield. By forecasting future disease outbreaks, early detection of disease helps to reduce stress on animals, increase animal welfare, and to decrease performance losses [14].

#### Conclusion

Precision livestock farming (PLF) represents an appealing approach for the future of sustainable agriculture. It presents data-driven technologies and strategies that provide a systematic approach to management and decision-making through understanding, processing, and application of information. This approach can facilitate the cost-effective, efficient, and safe expansion of corporate farming and achieve the modernisation of livestock production. The main objective of PLF is to create a management system based on automatic, continuous, real-time monitoring and control of all aspects of livestock management. Farmers and veterinarians can also cull sick animals before they spread disease to the entire herd of cattle. An early warning system for effective livestock health management can be created if infectious disease biomarkers are detected in real time.

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