

## Revolutionizing Grazing Animal Care Precision Livestock Farming Applications (PLF)

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### ABSTRACT

The developing economies of Asia and South America have driven up the consumption of animal products over the last 40 years, which has led to an increase in the world's dietary requirements. This has led to massive changes in the way livestock are managed inside livestock production systems. Due to workforce and resource limitations, producers often need help to evaluate each grazing animal in a herd individually. Precision livestock farming is all about utilizing sensors and computer algorithms to keep an eye on animals in real-time. This helps catch problems early and also makes producers more aware of what each animal requires. Some examples of these technologies include virtual fencing for herd and grazing management, automated weighing systems, geographic information systems (GIS) for evaluating and optimizing pastures, radio frequency identification (RFID) sensors for detecting and monitoring individual animals' behavior, and body temperature monitoring. Economic and cultural barriers, as well as a lack of technical infrastructure, limit the adoption of existing commercial goods, which are primarily designed for cattle. This review delves into the various PLF systems and applications for grazing animals, offering insights into their current state and future directions for research and tactics aimed at enhancing their uptake and utilization in modern large livestock systems.

**Keywords:** Precision livestock farming; grazing animals; technology; sensors; livestock applications

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### Introduction

Animal herd sizes have increased in response to rising demand for both more and better animal products, particularly in developing nations, but farmer numbers have fallen<sup>1,3</sup> and grasslands have become scarcer as a result of cropping. Consequently, there is a decline in grazing animal welfare<sup>1</sup> and health-related and performance-related worries due to dwindling feed availability and less time for farmers to evaluate individual animals' needs. Precision Livestock Farming (PLF) methods offer a once-in-a-lifetime chance to automate or semi-automate herd management, which might greatly reduce the occurrence of such issues. Improved farm waste management, reduced on-farm labor and veterinary expenses, enhanced health and wellbeing, and increased economic and environmental sustainability are all possible outcomes. Grazing land is utilized by around 360 million cattle and more than 600 million sheep and goats. It also constitutes 60% of the global agricultural land. Ten percent of the world's beef and thirty percent of the world's sheep and goat meat comes from grazing animals<sup>6</sup>.

In addition, more than 200 million people rely only on grazing animals for their livestock needs. The utilization of by-products by grazing animals is a significant benefit, as it. It would otherwise go to waste, increase grass diversity via hoof-borne seed dispersal, and promote soil health through manure. Furthermore, the animals' trampled soil breaks up the crust, which then stimulates grass growth and soil regeneration to a greater extent. But regulations are helping to turn pasture into farmland, which threatens a lot of the world's grazing lands. The land is considered deserted when it is used up and left to fallow since it does not regenerate into a healthy pasture.

In the event that a problem is identified, PLF systems are designed to send out a sequence of alarm signals and concentrate on controlling any variable that disrupts the manufacturing process<sup>2</sup>. The animals will let the system know when they're unhappy because of things like a shortage of food or bad weather by changing their behavior, which are called bio-responses. Therefore, a behavioral study using animal-based observations is the initial stage in developing a PLF model<sup>6</sup>. However, the bio-responses of the animals serve as system indicators and, to some extent, stand in for the feedback sensor in a closed-loop control system.

"Precision Livestock Farming" (PLF), "technology," "camera-based," "audio analysis," "RFID," "GPS," "GIS," "collars," "data loggers," "environmental conditions," "virtual fence" (VF), "robots," "electronic drinker or feeder," "IoT," "convolutional neural network" (CNN), "applications," "advancements," "grazing," "free ranging," "cattle or cow," "sheep or lamb or ewes," "goat," "ruminant," "poultry," "chicken or chic," "pigs," and "duck." First, we looked into the general area, and then we did further targeted investigation if we found a promising technical application or study. Since we aimed to incorporate as many papers as possible, our research period was 1991–2022. Consequently, our collection now includes 173 papers detailing PLF's uses and associated studies with grazing animals.

### PLF in Grazing Cattle

Over the last 40 years, milk and dairy consumption have been steadily on the rise, with predictions showing a further 50% increase from 2010 levels by 2050<sup>27</sup>. Over the last century, production yield increased due to higher animal numbers per herd and the introduction of high milk-yield cow breeds. Still, farmers' capacity to estimate the demands of individual animals diminished<sup>(28,29)</sup>. Consequently, production components such as the human-animal bond, animal wellbeing, and the sustainability of units have been impacted, as have consumers' demands for safe, high-quality food and goods<sup>(29)</sup>. When it comes to evaluating or resolving these issues, PLF technologies have shown tremendous promise. Regardless of the herd size, the farmer can evaluate agricultural techniques and keep tabs on the animals' daily activities without causing any harm<sup>(29,30)</sup>. Consequently, PLF systems can boost farmers' yearly revenue, improve animal performance (i.e., the quality and quantity of the end product), and improve soil health, pasture utilization, and management.

Cattle equipped with radio frequency identification (RFID) tags, boluses, collars, and noseband sensors can have their grazing behavior measured<sup>(31)</sup> and their respiratory and cardiovascular patterns monitored (i.e., their heart and breathing rates as well as their oxygen saturation) to evaluate their health and welfare<sup>(32)</sup>. For the purposes of identifying individuals<sup>(33–35)</sup>, documenting individual data (such as maternal pedigree), and monitoring disease trajectories<sup>(36)</sup>, ear tags and injectable glass tags are utilized. Additional PLF systems include electronic scales and walk-over platforms, thermal analysis systems for evaluating body temperature, camera analysis models for estimating methane emissions and detecting positions, sound analysis systems for classifying and analyzing ruminating sounds, video analysis for detecting early signs of disease, classifying behavioral patterns, and tracking mating behavior, and GPS, GIS, and accelerometers for tracking the location of individual animals, preventing theft, detecting feeding and ruminating behaviors, detecting of feed intake, and monitoring of reproduction.

### RFID Technologies

Grazing cattle are a common target for Radio Frequency Identification (RFID) systems due to the reliability and low cost of this technology's remote, non-contact, continuous identification and monitoring capabilities<sup>(38,39)</sup>. Numerous important pieces of data, including gender, breed, weight, and health status, can be stored in RFID tags<sup>(33)</sup>. Based on their operating frequency, RFID technologies can be categorized into two types: low-frequency, which is mostly used for animal identification, and high-frequency, which is mainly used to track populations rather than individuals<sup>(34)</sup>. There are two subtypes of radio frequency identification tags: active tags, which generate radio waves, and passive tags, which do not. The reading range of active tags is 20-100 m at high frequencies ranging from 455 MHz to 5.8 GHz, while the range of passive tags is no more than 3 m<sup>(33)</sup>. Ear tag data has been used to build management software that automatically records and stores individual attributes such as medical treatments, growth performance, pedigree, and reproductive factors<sup>(18,40)</sup>.

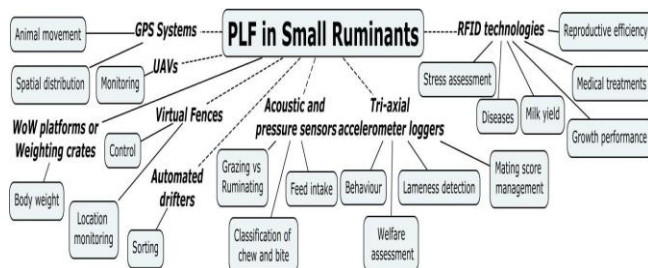
### GPS and GIS Systems

Economically oriented pasture systems have been the primary focus of most research on grazing animal behavior and farmer grazing tactics <sup>14</sup>. The difficulty in collecting and storing data is the reason why there is a lack of knowledge on more holistic techniques in grazing systems <sup>15</sup>. Traditional methods of animal tracking are laborious and difficult because animals feed in typically harsh rangeland environments <sup>13</sup>. Notably, a significant amount of foraging and grazing occurs during the night, which further complicates data collecting <sup>12, 14</sup>. Possible solutions to this issue could be provided by GPS and GIS technologies. For long-term, low-cost monitoring of grazing animals, this kind of technology is useful. In addition, these technologies could assist farmers in managing the herd's grazing activity in a way that is less harmful to the environment, which is important considering the increasing intensification of graze lands and the imminent threat to biodiversity <sup>5, 8</sup>.

**PLF in Small Ruminants**

Due to their low input costs and enhanced resilience against market fluctuations, extensive grazing-based systems are especially appealing to small ruminants. As a rule, PLF isn't regularly used in sheep and goat production because the farms are small, and the owners are conservative and wary of new technology <sup>9</sup>. However, there are exceptions to this rule all over the globe, such as Mediterranean dairy farms and Australian and New Zealand meat production systems. Financial constraints and inadequate technical infrastructure (such as power, telephone, and internet networks) further restrict PLF's widespread adoption <sup>9</sup>.

Figure 1 shows the results of the development of various PLF technologies for use in small ruminant pasture-based farming systems during the past few decades. Ear tags, ruminal boluses, and subcutaneous transponders are some of the most common forms of electronic identification (EID) systems, which are mandated in the EU. The use of innovative technologies like social activity loggers, global positioning systems (GPS), accelerometers, gyroscopes, and a host of other on-animal sensors can greatly simplify flock management. These devices collect data on a variety of behavioral parameters, as well as health and welfare status. In addition, there are robots in development that can detect animals and determine if they pose a threat (such as predators) or not, which can help herds be safer. Virtual fencing,



automated weight monitoring with walk-over-weighing or other technologies connected to milking parlors, flock monitoring with drones and image analysis methods, and other commercially available management systems that aid farmers are also available <sup>14</sup>.

**Conclusion**

Good livestock management is essential in view of the ever-increasing worldwide need for better food and enhanced animal welfare as a result of sustainable agricultural practices. This problem could be tackled in an animal-friendly way with the use of PLF technologies, which also give farmers information that helps them make better decisions. Simple process automation, reduced labor, and environmental impact, and enhanced animal welfare are the goals of applying such technologies. Due to the impracticality of automated decisions about crucial health and welfare issues and efficient management, PLF programs can only assist farmers in making decisions. In addition, while there are a number of commercially accessible PLF treatments for grazing animals, they are mostly used in cattle production and not in small ruminants or other different species. Producers' hesitation owing to budgetary restrictions, unsolved welfare problems, complexity in applying the technology, lack of specialized nearby services, and the worth of individual animals are likely to be blamed. Farmers do not want to use these technologies because there has been little testing and no cost-benefit analysis. Emphasizing the positive impact, future PLF research should center on increasing the assessment parameters of the systems and be grounded in realistic and comprehensive economic analysis. At the same time, more farmers need to be convinced to use the technology by using "friendly" software and efficient marketing strategies.

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