

Precision Goat Farming in the Digital Era: Transforming Traditional Herding into Smart Livestock Systems

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Abstract

Goat farming plays a vital role in ensuring food security, nutritional security, and livelihood support for millions of smallholder farmers worldwide. Traditionally, goat production has relied on manual observation, conventional record-keeping and generalized management practices, which often result in inefficient resource utilization, delayed disease diagnosis, poor reproductive performance, and reduced productivity. Recent advances in Precision Livestock Farming (PLF) have transformed goat husbandry by integrating digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Radio Frequency Identification (RFID), wearable sensors, Global Positioning System (GPS), machine vision, cloud computing, and automated decision-support systems. These technologies facilitate continuous monitoring of individual animals, enabling precision feeding, health surveillance, reproductive management, welfare assessment, and environmental monitoring. Precision technologies improve productivity, reduce labor costs, optimize feed efficiency, enhance animal welfare, and support sustainable livestock production under changing climatic conditions. Despite remarkable technological progress, widespread adoption among smallholder farmers remains constrained by high investment costs, inadequate digital infrastructure, limited technical expertise, and poor internet connectivity. Future developments in affordable sensors, edge computing, blockchain, robotics, and genomic technologies are expected to accelerate the digital transformation of goat farming. This review summarizes the recent advances in precision technologies in goat farming, their applications, benefits, challenges, and future prospects for developing climate-resilient and economically sustainable goat production systems.

Keywords: Precision livestock farming, Goat farming, Artificial intelligence, Internet of Things, RFID, Smart sensors, Digital agriculture, Animal welfare

1. Introduction

Goats are among the earliest domesticated livestock species and are reared across diverse agro-climatic regions because of their remarkable adaptability, prolific reproductive performance, and ability to thrive under resource-limited conditions. Goat

farming contributes substantially to rural livelihoods through the production of meat, milk, fiber, skin, and manure while requiring relatively low capital investment compared with other livestock enterprises. Nevertheless, conventional goat farming continues to face challenges such as poor record-keeping,



inefficient disease detection, labor-intensive management, fluctuating feed resources, and climate-related stressors.

The rapid advancement of digital agriculture has introduced Precision Livestock Farming (PLF), an innovative management approach that combines engineering, sensor technology, artificial intelligence, and data analytics to monitor individual animals in real time. Rather than treating the herd as a homogeneous unit, PLF enables farmers to manage each goat based on its physiological status, productivity, health, and behavioural characteristics. Such precision management improves production efficiency while simultaneously enhancing animal welfare and environmental sustainability. Recent developments in IoT, cloud computing, machine learning, and smart sensors have accelerated the adoption of precision technologies in small ruminant production systems, creating opportunities for intelligent and data-driven goat farming.

2. Precision Technologies in Goat Farming

Precision goat farming integrates advanced sensing devices with communication networks and automated analytical tools to provide continuous information on individual animals. Information generated by these systems assists farmers in making timely management decisions, reducing uncertainty, and improving production efficiency.

2.1. Internet of Things (IoT)

IoT forms the technological backbone of modern precision goat farming. Smart devices such as RFID ear tags, wearable collars, rumen boluses, environmental sensors, and automated weighing platforms continuously collect physiological and environmental data. These devices communicate through wireless networks to centralized databases or cloud platforms where information is analysed in real time. Farmers receive instant alerts regarding abnormal

behaviour, elevated body temperature, feed intake abnormalities, or animal movement, enabling rapid intervention before clinical symptoms become apparent.

2.2. Radio Frequency Identification (RFID)

Electronic identification has replaced conventional ear tags in many commercial goat farms. RFID tags store each animal's unique identity and are linked to comprehensive digital records, including pedigree, reproductive history, vaccination schedules, disease treatments, and production performance. Automatic identification reduces recording errors, improves traceability, facilitates breeding decisions, and simplifies flock management. RFID technology also integrates seamlessly with automated feeders, weighing systems, and milking equipment.

2.3. Wearable Sensors

Wearable sensors attached to the neck, leg, or ear continuously monitor physiological and behavioural parameters such as activity level, rumination, heart rate, respiration rate, body temperature, and grazing behaviour. Accelerometers detect subtle behavioural changes associated with illness, lameness, estrus, or kidding. Continuous monitoring enables farmers to identify health disorders several days before visible clinical signs appear, thereby reducing mortality and treatment costs.

2.4. Artificial Intelligence and Machine Learning

Artificial Intelligence has become an indispensable component of precision livestock farming. Machine learning algorithms analyze massive datasets collected from sensors to identify complex patterns associated with animal health, reproduction, nutrition, and productivity. AI-based decision-support systems predict disease outbreaks, optimize feeding strategies, estimate body condition scores, detect estrus, forecast kidding dates, and evaluate genetic merit. These predictive models

significantly improve farm management by transforming raw data into actionable recommendations.

2.5. Machine Vision

Computer vision systems employ digital cameras combined with deep learning algorithms to assess goats without physical handling. These systems estimate body weight, body condition score, locomotion, growth rate, and injury status by analyzing digital images. Facial recognition technologies can even identify individual animals, enabling automated monitoring throughout the production cycle. Machine vision minimizes animal stress while improving monitoring accuracy.

3. Applications of Precision Technologies

3.1. Precision Health Monitoring

Disease detection is among the most valuable applications of precision livestock farming. Smart sensors continuously record physiological indicators including temperature, movement, feed intake, and rumination activity. Deviations from normal patterns generate automatic alerts that allow farmers to isolate affected animals promptly. Early diagnosis reduces disease transmission, lowers treatment costs, minimizes antibiotic usage, and improves survival rates.

Wireless rumen boluses further monitor rumen temperature and pH, enabling early detection of metabolic disorders and digestive disturbances. Combined with AI-based predictive models, these technologies support preventive veterinary healthcare rather than reactive treatment.

3.2. Precision Feeding

Feed constitutes the largest operational expense in goat farming. Automated feeding systems distribute precise quantities of feed according to each animal's age, body weight, physiological stage, and production status. Precision feeding reduces feed wastage, improves feed conversion efficiency, and

minimizes environmental pollution through reduced nutrient excretion.

Automated weighing platforms installed near feeding stations continuously monitor body weight, allowing nutrition plans to be adjusted dynamically according to growth performance.

3.3. Precision Reproduction

Reproductive efficiency directly influences farm profitability. Precision technologies assist in estrus detection, pregnancy diagnosis, kidding prediction, and reproductive record management. Activity sensors identify behavioural changes associated with estrus, while AI algorithms analyze historical reproductive records to determine optimal breeding schedules.

Accurate prediction of kidding dates facilitates improved nutritional management during late pregnancy, reduces neonatal mortality, and enhances kid survival.

3.4. Welfare Monitoring

Animal welfare has become a critical component of sustainable livestock production. Precision technologies continuously evaluate welfare indicators including body condition, locomotion, environmental comfort, behavioural patterns, and physiological stress responses.

Environmental sensors installed within goat houses monitor temperature, humidity, ammonia concentration, and ventilation. Automated climate control systems regulate fans and ventilation equipment to maintain optimal housing conditions, reducing heat stress and improving productivity.

4. Benefits of Precision Goat Farming

The adoption of precision technologies offers numerous economic, environmental, and social advantages.

Continuous monitoring significantly reduces labor requirements by automating routine observations and record maintenance. Accurate data collection enhances breeding

decisions, improves genetic progress, and increases productivity. Feed efficiency improves through individualized nutritional management, resulting in lower production costs and reduced environmental impact.

Early disease detection decreases mortality, veterinary expenditure, and production losses while improving animal welfare. Automated record systems simplify farm management, facilitate traceability, and support certification programs for quality assurance.

Precision technologies also contribute to climate-smart livestock production by optimizing resource utilization, reducing greenhouse gas emissions, conserving water, and minimizing nutrient losses. Overall, precision livestock farming enhances profitability while promoting sustainable agricultural development.

5. Challenges and Future Prospects

Despite considerable progress, several constraints hinder widespread adoption of precision technologies in goat farming. High installation costs, limited rural internet connectivity, inadequate technical expertise, poor digital literacy, and lack of affordable technologies restrict implementation, particularly among smallholder farmers.

Future research should focus on developing low-cost sensors, solar-powered IoT devices, edge-computing platforms, and farmer-friendly mobile applications suitable for extensive production systems. Integration of blockchain technology will enhance product traceability and consumer confidence, while advances in robotics, drones, genomic selection, and digital twins will further revolutionize goat farming.

Government support, public-private partnerships, capacity-building programs, and targeted extension services are essential for facilitating technology adoption among resource-poor farmers. Development of locally adapted precision livestock farming systems

will play a crucial role in improving productivity, resilience, and sustainability of goat production in developing countries.

6. Conclusion

Precision livestock farming represents a paradigm shift from conventional herd management to intelligent, data-driven individual animal management. The integration of IoT, AI, RFID, wearable sensors, machine vision, cloud computing, and automated decision-support systems enables continuous monitoring of health, nutrition, reproduction, welfare, and environmental conditions. These technologies improve productivity, reduce labor costs, optimize feed utilization, enhance animal welfare, and support sustainable livestock production. Although challenges related to infrastructure, affordability, and technical capacity remain, ongoing technological innovations and supportive policy initiatives are expected to make precision goat farming increasingly accessible. The digital transformation of goat husbandry will play a pivotal role in ensuring resilient, profitable, and climate-smart goat production systems capable of meeting the growing global demand for animal-source foods.

