THE SCIENCE WORLD
A Monthly e Magazine
ISSN:2583-2212
Popular Article
December, 2025 Vol.5(12), 11187-11191

Smart Livestock Management in India: Integrating Artificial Intelligence for Precision Animal Farming

Pulkit Chugh#, Man Singh, Devender Singh Bidhan, Sandeep Dhillod, Narender Singh and Vishal Sharma
Department of Livestock Production Management, LUVAS, Hisar-125004 (Haryana), India
#Corresponding Author: pulkitchugh04@gmail.com
DOI:10.5281/ScienceWorld.18110651

Abstract

Modern animal agriculture has advanced significantly with the use of artificial intelligence (AI) and machine learning (ML) in smart livestock management. Precision livestock systems enable ongoing monitoring of animal health, behavior, productivity, and welfare through the integration of sensor technologies, Internet of Things (IoT) platforms, and intelligent data analytics. AI-driven precision methods present viable ways to improve productivity, lower financial losses, and advance sustainable animal husbandry in India, where livestock farming is primarily smallholder-based and extremely susceptible to climate variability. With a focus on the necessity of locally tailored innovations, policy support, and farmer capacity building, this article critically examines the technological framework, key applications, adoption obstacles, and future prospects of AI and ML in Indian livestock farming.

Keywords: Smart, livestock management, precision animal farming, artificial intelligence

1. Introduction

A major contributor to rural livelihoods, job creation, and nutritional security, livestock farming is a pillar of India's agricultural economy. Despite having the largest livestock population in the world, India's productivity per animal is still low because of issues like inadequate disease surveillance, ineffective reproduction, a lack of feed, and stress brought on by the climate (Norton & Berckmans, 2016). Traditional management techniques must give way to data-driven and technologically enabled systems due to the growing demand for milk, meat, and eggs as well as growing concerns about animal welfare and environmental sustainability.

By enabling real-time, individual-animal monitoring and well-informed decision-making, Smart Livestock Management, also known as Precision Livestock Farming (PLF), offers a scientific framework for resolving these issues (Berckmans, 2017). By combining AI and ML, PLF is transformed from simple sensor-based monitoring into intelligent systems that can anticipate health risks, recognize patterns in behavior, and assist with proactive farm management (Tullo et al., 2019). This paradigm change is especially pertinent to India, where sustainable livestock development depends on early disease detection, effective resource use, and climate resilience.

2. Conceptual Framework of AI-Enabled Precision Livestock Systems

The integration of sensing technologies, digital connectivity, data analytics, and decision-support mechanisms is the foundation of AI-enabled precision livestock systems. Animal-level data on activity, rumination, body temperature, feed intake, posture, and spatial movement are continuously recorded by wearable and non-wearable sensors (Halachmi et al., 2019). Real-time data transmission is made possible by IoT infrastructure, even in farm environments that are geographically remote.

Large and complex datasets are processed by machine learning algorithms, such as supervised, unsupervised, and deep learning models, to find behavioral patterns, spot anomalies, and produce predictive insights about productivity, health, and reproduction (Monteiro et al., 2021). As new data becomes available, AI models continuously increase their predictive accuracy, in contrast to traditional rule-based systems. These analytical results are transformed into useful suggestions for farmers, veterinarians, and farm managers by decision-support dashboards.

3. Applications

3.1 Health Surveillance and Disease Prediction

One of the most significant uses of AI in precision livestock systems is early disease detection. Mastitis, lameness, and metabolic disorders are examples of subclinical conditions that frequently show up as minor behavioral and physiological changes prior to the onset of overt symptoms. In order to detect possible health issues early on, ML-based models examine variations in body temperature, activity levels, milk composition, and rumination patterns (Van Steenkiste et al., 2023). Research has shown that AI-driven disease surveillance improves herd health and farm profitability by drastically lowering treatment costs, production losses, and overuse of antibiotics (Denholm et al., 2020).

3.2 Reproductive Efficiency and Calving Management

In Indian dairy farming, reproductive inefficiency continues to be a significant obstacle that results in long calving intervals and financial losses. It has been demonstrated that AI-enabled estrus detection systems that use accelerometers and rumination sensors increase the precision of heat detection and insemination timing (Mayo et al., 2019). Additionally, ML-based prediction models that use physiological and behavioral sensor data can identify dystocia risks and predict calving time, allowing for prompt intervention and better neonatal survival (Crociati et al., 2022).

3.3 Behavioural Analysis and Animal Welfare Assessment

Animal behavior is a sensitive indicator of stress and well-being. Continuous, non-invasive monitoring of posture, gait, lying behavior, and social interactions is now possible thanks to developments in computer vision and deep learning (Wang et al., 2023). These systems support welfare-oriented livestock management by making it easier to identify lameness, heat stress, and discomfort early on. These technologies are especially useful in large dairy and poultry operations because it is getting harder to observe individual animals (Guarnido-Lopez et al., 2024).

3.4 Precision Feeding, Grazing, and Climate Adaptation

AI-powered precision feeding systems analyze feed intake trends, growth performance, and production responses to optimize ration formulation. These systems aid in lowering methane emissions, increasing feed conversion efficiency, and decreasing feed waste (Monteiro et al., 2021). Sustainable pasture management is facilitated by the use of GPS and RFID technologies in conjunction with machine learning algorithms to monitor grazing behavior, pasture utilization, and animal movement in grazing-based systems. Furthermore, AI-based heat stress prediction models help farmers adjust their management strategies to climate variability, which is becoming a bigger issue in tropical India (Tullo et al., 2019).

3.5 Digital Transformation of Dairy Value Chains

Applications of AI in dairy processing and marketing go beyond the farm gate. Intelligent milking systems decrease reliance on labor while increasing animal comfort, efficiency, and hygiene (Halachmi et al., 2019). During the processing and storage of milk, AI-enabled quality control systems identify spoilage, microbial contamination, and adulteration. Throughout the dairy value chain, the integration of AI with IoT and blockchain technologies improves consumer confidence, traceability, and transparency (Khanna et al., 2022).

4. Adoption Challenges and Policy Implications

AI-enabled precision livestock systems are still not widely used in India, despite their potential. Major obstacles include high initial investment costs, dispersed landholdings, low digital literacy, uneven rural connectivity, and a lack of locally annotated datasets for AI model training (Aharwal et al., 2023). Furthermore, a lot of AI models may not function as well in Indian agroclimatic conditions or with native breeds because they were created using data from temperate regions.

Scaling adoption requires policy interventions like targeted subsidies, cooperative-based service models, public-private partnerships, and integrating digital livestock management into extension programs. Relevance and efficacy will be further increased through capacity building through farmer training and the creation of datasets and algorithms unique to India.

5. Conclusion

AI and ML-powered smart livestock management offers Indian livestock farmers a revolutionary way to increase sustainability, animal welfare, and productivity. AI-driven systems can solve a number of persistent issues in the industry by facilitating early disease detection, enhanced reproductive efficiency, precision feeding, and welfare monitoring. Adoption can be accelerated by inclusive implementation strategies, locally adapted innovations, and supportive policies, even though socioeconomic and infrastructure barriers still exist. Adopting intelligent precision techniques will be essential to bolstering India's livestock industry and guaranteeing robust and sustainable food systems.

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Published 18/12/2025

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Published 18/12/2025