Precision Livestock Farming in Cattle and Buffalo: Role of AI, IOT, and Data Analytics

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ABSTRACT

This article explores the implementation of Precision Livestock Farming (PLF) in Indian cattle and buffalo production through Artificial Intelligence (AI), the Internet of Things (IoT), and Data Analytics. Faced with challenges like rising feed costs, disease outbreaks, silent estrus, labor shortages, and climate-induced heat stress, PLF shifts traditional, reactive dairy management toward continuous, predictive, and real-time monitoring. Using IoT sensors—such as smart collars, automated milking systems, and environmental monitors—farmers continuously collect data on rumination, temperature, milk conductivity, and barn conditions. AI algorithms and computer vision transform these inputs into actionable insights, enabling early disease detection, precise heat stress management, and improved reproductive efficiency. Supported by Indian initiatives like Amul's "Sarlaben" AI assistant,

PLF enhances milk yield, animal welfare, and operational profitability. Despite barriers like high initial costs, digital literacy gaps, and infrastructure constraints, PLF is driving the transformation toward sustainable, autonomous smart dairy farming in India.

INTRODUCTION:

India is the world's largest milk producer, with dairy farming serving as a vital source of income, nutrition, and employment for millions of rural households. Cattle and buffalo production significantly contribute to the country's agricultural economy; however, farmers face several challenges, including rising feed costs, labor shortages, disease outbreaks, reproductive inefficiencies, and increasing heat stress due to climate change (Rathod & Dixit, 2020). To address these challenges, Precision Livestock Farming (PLF) has emerged as a modern approach that utilizes Artificial Intelligence (AI), Internet of Things (IoT), and Data Analytics to monitor and manage animals more efficiently. Through smart sensors, wearable devices, automated milking systems, and environmental monitoring tools, real-time data on animal health, behavior, production, and welfare can be continuously collected and analyzed (Rutten *et al.,* 2013; Gehlot *et al.,* 2022).

AI-powered systems can detect diseases, predict estrus, monitor feeding behavior, and provide timely alerts to farmers, enabling proactive management and reducing production losses (Berckmans, 2017). These technologies are particularly valuable in buffalo farming, where challenges such as silent estrus and heat stress often limit productivity (Prasanna *et al.,* 2024). By integrating advanced digital technologies with livestock management, Precision Livestock Farming is transforming traditional dairy farming into a smart, data-driven, and sustainable enterprise. It offers significant opportunities to improve animal health, productivity, profitability, and welfare while ensuring the long-term sustainability of cattle and buffalo production systems (Halachmi & Guarino, 2016; Zaninelli *et al.,* 2021).

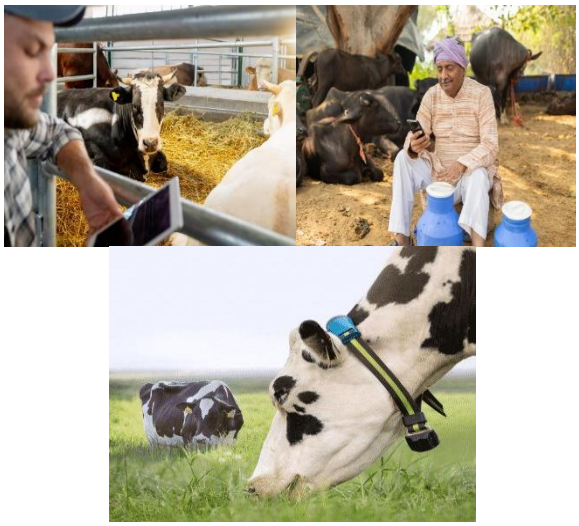


Figure 1. Emerging smart dairy technologies in Indian cattle and buffalo farming.

Why Traditional Dairy Management Needs an Upgrade

For generations, dairy farmers have relied on visual observation to identify illness, estrus, and production problems. While effective for small herds, this approach becomes increasingly difficult as herd sizes grow. Research indicates that farmers may miss up to 50% of heat events and often detect diseases only after clinical symptoms appear, resulting in production losses and increased treatment costs (Rutten *et al.,* 2013). Precision Livestock Farming addresses this challenge by continuously monitoring animals 24 hours a day, 365 days a year.

The Three Pillars of Smart Dairy Farming: Think of a smart dairy farm as a living digital ecosystem.

Sensors = Eyes and Ears

AI = Brain

Data Analytics = Decision-Maker

SENSORS → DATA COLLECTION → AI ANALYSIS → FARMER ALERT → ACTION

1. Internet of Things (IoT): Connecting Animals to Information

The Internet of Things refers to interconnected devices capable of collecting and transmitting real-time information without human intervention.

Smart Collars and Ear Tags: Modern wearable sensors monitor:

✓ Animal activity

✓ Rumination time

✓ Body temperature

✓ Feeding behavior

✓ Walking patterns

✓ GPS location

A sudden reduction in rumination often indicates digestive disorders or fever several days before visible symptoms emerge (Abeni & Galli, 2017).

Smart Milking Systems: Automated milking equipment records:

✓ Milk yield

✓ Milk temperature

✓ Milking duration

✓ Electrical conductivity

Changes in milk conductivity help identify subclinical mastitis at an early stage, reducing economic losses and improving milk quality (Rutten *et al.,* 2013).

Environmental Monitoring: Barn sensors continuously measure:

✓ Temperature

✓ Relative humidity

✓ Air quality

✓ Ammonia concentration

✓ Ventilation efficiency

These systems help reduce heat stress and improve animal comfort.

Did You Know?

✓ A high-producing dairy cow can lose **10–25% milk yield** during severe heat stress.

✓ Heat stress costs the Indian dairy industry billions of rupees annually.

2. Artificial Intelligence: The Digital Veterinarian

AI transforms millions of data points into practical recommendations for farmers.

Early Disease Detection: Machine learning algorithms learn the normal behavior of each animal and identify abnormal patterns associated with:

✓ Mastitis

✓ Ketosis

✓ Lameness

✓ Respiratory diseases

✓ Lumpy Skin Disease

Researchers from Indian institutions including IIIT Allahabad have developed AI models capable of detecting several diseases using

computer vision and behavioral monitoring technologies (Maheshwari *et al.,* 2025).



Figure 2. AI-based computer vision systems for animal health monitoring.

Precision Reproductive Management: Reproductive inefficiency remains one of the largest economic constraints in dairy farming. Buffaloes often exhibit **silent estrus**, where behavioral signs of heat are weak or absent. AI systems analyze:

✓ Activity levels

✓ Rumination behavior

✓ Body temperature

✓ Feeding patterns

to accurately predict estrus and improve conception rates.

Benefits include:

✓ Reduced calving interval

✓ Increased lifetime milk production

✓ Improved reproductive efficiency

✓ Higher profitability

Computer Vision: Cameras That Understand Animals

Advanced camera systems can now:

✓ Identify individual animals

✓ Estimate body weight

✓ Monitor feed intake

✓ Detect lameness

✓ Assess Body Condition Score (BCS)

✓ Monitor welfare indicators

Importantly, these systems operate without physically touching the animal, reducing stress and labor requirements (Xu *et al.,* 2026).

3. Data Analytics: Converting Information into Profit

Data analytics transforms farm records into actionable management decisions.

Area	Application	Benefit
Feeding	Nutrient optimization	Reduced feed cost
Reproduction	Heat prediction	Higher conception rate
Health	Disease forecasting	Lower treatment expenses
Production	Yield monitoring	Increased milk output
Environment	Heat stress management	Better animal welfare

According to Halachmi and Guarino (2016), data-driven dairy farms are shifting management from reactive treatment to proactive prevention.

Precision Livestock Farming in Buffalo Production:

India possesses the world's largest buffalo population, exceeding **110 million animals**. Buffaloes contribute more than half of the nation's milk production but present unique management challenges:

- ✓ Silent heat
- ✓ Seasonal breeding
- ✓ High heat sensitivity
- ✓ Low sweat gland density
- ✓ Dark skin absorbing more solar radiation

These characteristics make buffaloes ideal candidates for precision technologies.

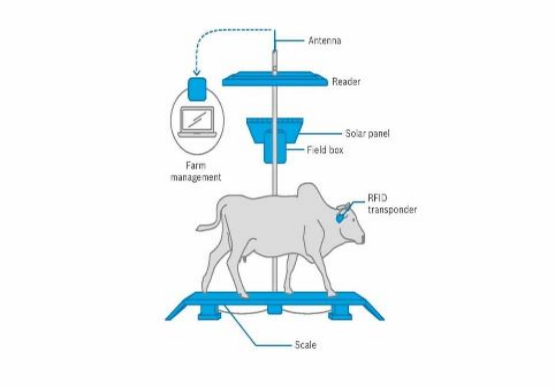


Figure 3. Precision technologies supporting buffalo production systems.

Smart Heat Stress Management:

One of the most promising applications in buffalo farming is automated climate control.

How It Works:

1. Sensors measure Temperature-Humidity Index (THI)
2. AI predicts heat stress risk
3. Automated fans and sprinklers activate
4. Animal comfort is restored

Studies show such systems significantly improve feed intake, milk yield, and welfare during summer months (Prasanna *et al.,* 2024).

Indian Innovations Leading the Way:

Amul's AI Assistant – "Sarlaben": In 2026, the Amul introduced **Sarlaben**, an AI-powered virtual assistant designed to support over 3.6 million dairy farmers.

The platform provides:

- ✓ Animal health guidance
- ✓ Feeding recommendations
- ✓ Vaccination reminders
- ✓ Breeding advice
- ✓ Government scheme information in regional languages.

ICAR and University Initiatives: The Indian Council of Agricultural Research and state agricultural universities are developing:

- ✓ Low-cost RFID systems
- ✓ Thermal imaging technologies
- ✓ AI disease detection models
- ✓ Smart reproductive monitoring tools tailored specifically for Indian farming conditions.

Benefits of Precision Livestock Farming:

Economic Benefits:

- ✓ Higher milk production
- ✓ Better feed efficiency
- ✓ Reduced veterinary costs
- ✓ Improved reproductive performance

Animal Welfare Benefits:

- ✓ Early disease detection

- ✓ Reduced stress
- ✓ Better housing conditions
- ✓ Improved comfort

Environmental Benefits:

- ✓ Lower methane emissions
- ✓ Reduced nutrient wastage
- ✓ Efficient resource utilization
- ✓ Sustainable dairy production

Challenges That Must Be Addressed: Despite its potential, several barriers remain:

- ➢ **High Initial Cost:** Smart collars, sensors, and automated systems require investment beyond the reach of many smallholders.
- ➢ **Digital Literacy:** Many farmers need training to effectively interpret digital reports and recommendations.
- ➢ **Connectivity Issues:** Internet and power infrastructure remain inconsistent in several rural regions.
- ➢ **Data Management:** Reliable storage, sharing, and security of farm data remain important concerns.

The Future: Towards Autonomous Dairy Farms

The next decade is expected to witness:

- ✓ Robotic milking systems
- ✓ AI-powered veterinary consultation
- ✓ Genomic selection using big data
- ✓ Digital twin models of animals
- ✓ Drone-assisted livestock monitoring
- ✓ Fully integrated smart dairy ecosystems

As technology costs decline and smartphone penetration increases, these innovations will become increasingly accessible to Indian farmers.

CONCLUSION:

Precision Livestock Farming is not merely a technological upgrade—it is a transformation in the way cattle and buffalo are managed. By integrating AI, IoT, and data analytics, dairy farmers can move from reactive management to predictive and preventive decision-making. For India, where dairy farming sustains millions of livelihoods, these technologies offer an opportunity to increase productivity, enhance animal welfare, improve profitability, and strengthen national food security. The future dairy farm will not only be more productive—it will be smarter, more sustainable, and more resilient.

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