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Precision livestock farming for climate-resilient animal husbandry

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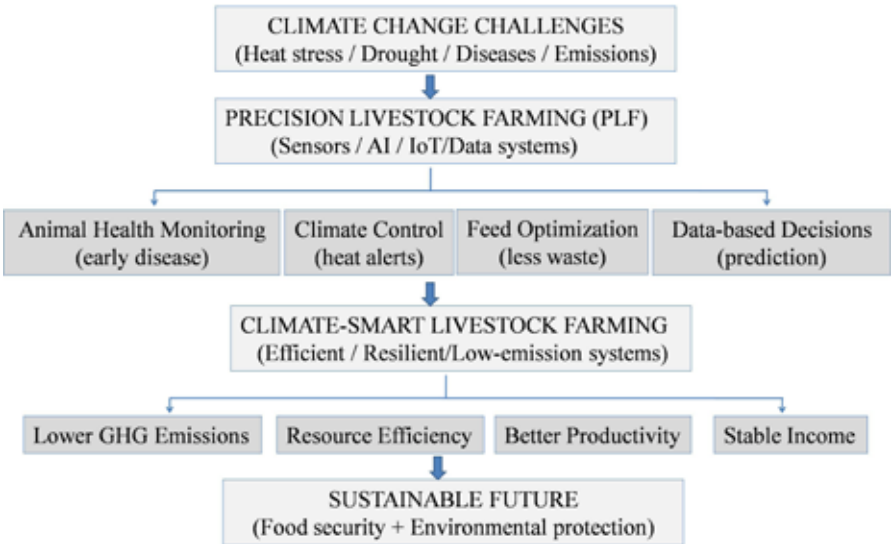
Precision Livestock Farming (PLF) refers to the application of sensor-based technologies, automated monitoring systems, and data-driven analysis to manage livestock production efficiently. By enabling continuous monitoring of animal health, behaviour, and environmental conditions, PLF supports informed decision-making and enhances the resilience of livestock systems against the increasing challenges posed by climate change. PLF is intended to optimise livestock health, production, and welfare while addressing environmental challenges. Several PLF platforms have been developed, about estrus detection systems, calving detection, seasonal prediction of milk production, and seasonal health-related issues, as well as feeding regimens. The impacts of climate change, including rising temperatures, erratic precipitation patterns, and increased extreme weather events, demand adaptive strategies to ensure animal welfare.

Keywords: Climate change, Estrus detection systems, Health monitoring, Smart livestock management

RAPID population growth, shrinking natural resources (growing demand for groundwater, arable land, etc.), and nutritional transition have increased the demand for livestock products such as milk and meat. These pressures, along with climate change, pose significant challenges for animal husbandry. Rising temperatures, erratic rainfall patterns, and extreme weather conditions are threatening animal productivity and adversely affecting animal health and welfare; furthermore, they require demonstrable technological solutions to ensure sustainability and resilience.

These climatic shifts directly impact physiological processes in livestock, reducing productive and reproductive performance while indirectly affecting the availability of quality feed and fodder and the recurrence of deadly disease outbreaks. Addressing these challenges involves innovative strategies to enhance the adaptability and sustainability of livestock systems. A holistic approach, including proper management of resources, precision farming, development of stress/disease-resistant breeds/animals, and adoption of newer efficient technologies, is required to tackle this crucial situation.

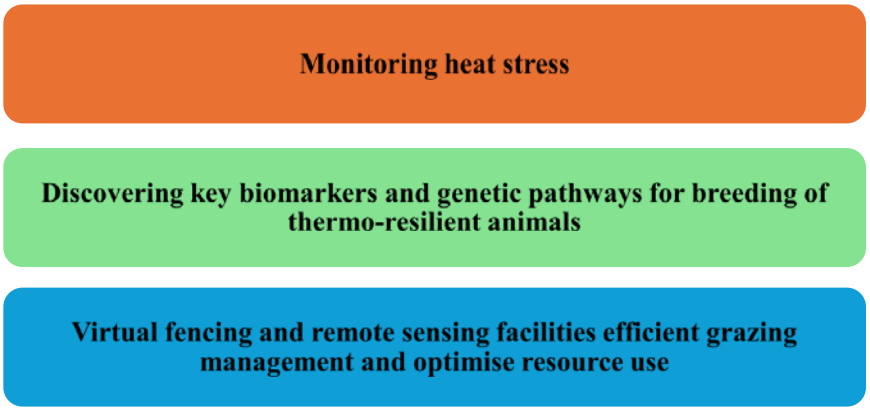
Precision farming, a transformative approach that leverages advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and Big Data analytics, offers a pathway to climate-resilient livestock farming. By integrating real-time monitoring tools, such as wearable sensors and automated feeding systems, precision farming enables proactive decision-making to optimise animal welfare, health, and productivity. Moreover, these cutting-edge technologies provide efficiency and sustainability to livestock farming by reducing greenhouse



Role of precision livestock farming in addressing climate change

gas emissions and minimising the carbon footprint.

It is crucial that digitalisation has become more relevant in modern dairy husbandry. Exploring the potential of precision farming in building climate-resilient animal husbandry systems is an important initiative. Data-driven innovations can mitigate the adverse effects of climate change, improve production efficiency, and contribute to sustainable livestock management.



Applications of precision livestock farming

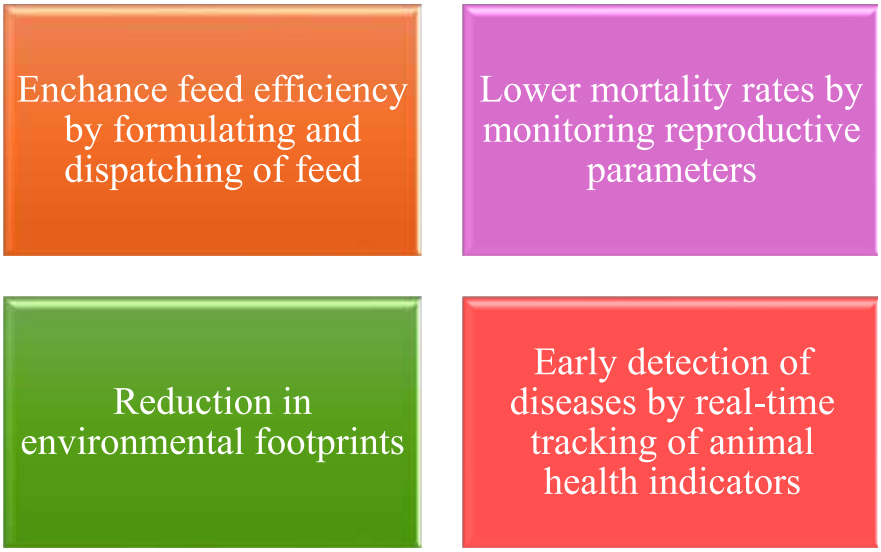
Applications and benefits of precision livestock farming

These advanced technologies enable precise tracking of livestock health, behaviour, and environmental interactions, ensuring optimal welfare and productivity in the face of climate challenges.

Precision livestock farming (PLF) enhances resilience by allowing farmers to dynamically adapt to climate variability, maintaining productivity under stress conditions. However, implementation challenges persist, including high costs and limited technological accessibility for small-scale farmers. Feed management systems optimise nutrient delivery and minimise waste, lowering emissions linked to livestock feeding and feed production. Additionally, environmental monitoring helps to reduce heat stress, a significant factor in productivity loss, by tailoring microclimates to animal needs.

PLF also contributes to disease prevention through early detection systems that reduce recovery times and minimise antibiotic use, thereby addressing environmental contamination. These technologies generate data-driven insights for breeding thermo-resilient livestock, offering long-term adaptation strategies to combat climate fluctuations. Moreover, PLF supports circular economies by integrating waste management systems that reduce methane emissions and repurpose by-products into valuable resources.

Economic efficiency is improved by adopting PLF techniques, as farmers can significantly reduce the resource intensity of livestock farming, leading to financial savings and increased profitability. Overall, implementing PLF can lead to healthier livestock, increased productivity, and more sustainable farming practices.



Benefits of precision livestock farming to farmers

Different PLF technologies

***Sensors*:** These are small electronic devices placed on animals or inside barns. They measure body temperature, rumination (chewing), heart rate, movement, milk yield, etc. and record real-time data to a computer or mobile app. They can help in early disease detection (before visible symptoms), reduce animal mortality, treatment costs and improve productivity.

***Wearable devices (Smart collars, ear tags, pedometers, RFID)*:** These are attached to individual animals for identification and tracking location, activity level, grazing time, heat detection (for breeding) and can also track free-grazing livestock.

***Computer vision (AI + cameras)*:** Cameras installed on farms analyse animal behaviour using AI that can detect lameness, posture changes, aggression, feeding behaviour, etc. It can provide continuous monitoring of animals without human labour, and improve animal welfare.

***Automated milking systems (AMS)*:** It can also be called as robotic milking systems. In this system, cows voluntarily walk into a machine that cleans and milks them. It also records milk quantity, quality, milking frequency, and saves labour. This can also help in detection of mastitis (udder infection) at an early stage.

***Environmental monitoring systems*:** Sensors installed in sheds and barns measure temperature, humidity, ammonia gas, ventilation, and give automatic alerts if conditions go beyond safe limits; thus prevent heat or cold stress

Popular precision livestock farming tools (AI generated)

and improve animal comfort and productivity.

***Genetic and breeding technologies*:** Use of data and biotechnology to improve livestock quality using DNA testing, genomic selection, breeding records. It helps in improving disease resistance, higher milk/meat yield, and climate tolerance.

***Robotics and automation*:** Machines like robotic feeders, manure cleaners, and herding robots can perform routine farm tasks and reduce labour dependency, ensure consistency in tasks, and improve hygiene and efficiency.

Role of PLF in climate resilience

PLF can help farmers make smarter decisions every day which can play an important role in climate resilience.

***Less wastage of resources*:** PLF tools can quickly detect if an animal is sick or stressed. Farmers can manage resources (feed, water) and reduce the wastage of resources.

***Efficient use of feed and water*:** Sensors can help farmers to provide animals exactly what they need and avoid overfeeding or underfeeding and this also saves water, which is especially important during droughts.

***Reduces greenhouse gas emissions*:** Methane, a major greenhouse gas can be reduced by improved feeding practices by monitoring digestion and productivity using PLF tools.

***Better response to extreme weather*:** PLF systems can monitor temperature, humidity, and animal comfort and alert farmers during heat waves or cold stress, so that farmers can manage cooling, shelter, water, etc. to protect animals from climate extremes.

***Data for smarter decisions*:** Farmers get real-time data and predictions. Thus, they can plan for droughts, disease outbreaks, or feed shortages and adjust farming practices in advance for better resilience.

Mobile apps developed in India for livestock farming

***e-Gopala app*:** The e-Gopala app is a mobile application developed by the National Dairy Development Board (NDDB) to support livestock owners and dairy farmers across India. It serves as a comprehensive platform for managing cattle breeding, health, and productivity, promoting technology-driven livestock development under India's National Digital Livestock Mission. It helps to improve productivity and herd management like breeding services (AI, vaccination, treatment), nutrition guidance, and ethno-veterinary practices; alerts for vaccination, calving, pregnancy diagnosis, a marketplace for buying/selling germplasm (semen, embryos), etc.

***Bharat Pashudhan*:** It is the official android mobile app of India's National Digital Livestock Mission (NDLM), led by the Department of Animal Husbandry and Dairying (DAHD), Government of India. It is used mainly by field workers and department staff to capture and manage livestock data across the country. It is used for animal identification and registration and provides access to government schemes and maintaining digital livestock database. It mainly acts as a national-level livestock data platform.

***Pashudhan e-app*:** Pashudhan e-app generally refers to the government-backed 'Bharat Pashudhan', a livestock management mobile application under NDLM. It helps livestock owners and field workers to manage animal identification, health, breeding, and access to government schemes through a unified digital platform. It works offline with a simple interface.

***GrowAgro Pashu Palan app*:** This mobile app is focused on AI-assisted livestock healthcare and farm management for dairy and cattle farmers. It combines disease-detection tools, health records, diet planning, and access to the veterinarians to support day-to-day 'pashu palan' (animal husbandry) activities. GrowAgro connects users to qualified veterinarians for live or scheduled tele-consultations directly from the app. This hybrid of AI guidance plus human experts aims to shorten response time for serious conditions in villages where vets are hard to reach.

***Amul Pashudhan app*:** This app is a mobile application developed by the Gujarat Cooperative Milk Marketing Federation, India's largest dairy cooperative, to support dairy farmers in managing livestock and improving productivity. It provides digital access to veterinary services, breeding information, and nutrition guidance, strengthening the supply chain that sustains the Amul network.

Challenges of PLF in livestock production

- High investment and high complexity of technology adoption.
- Lack of widespread digital infrastructure and digital skills among farmers.
- Unequal access to these innovations.
- Poor internet connectivity.

Some mobile apps developed in India (AI generated)

- Regulatory uncertainties and an absence of standardised frameworks.
- Data breaches and technical glitches.
- Use of invasive devices, such as sensor implants or wearables, leading to animal welfare concerns.
- Reduced human-animal interactions and a decline in traditional husbandry skills.

Way forward for Indian livestock farming

PLF is closely related to climate-smart livestock farming. Both aim to improve productivity while reducing environmental impact and increasing resilience to climate change. PLF is expected to shape climate-smart livestock farming in the coming years, briefly by:

- Highly efficient livestock systems by using precise data.
- Reduction in greenhouse gas emissions through improved feed formulations.
- Better adaptation to climate stress (automated systems will adjust housing conditions).
- Farmers will be able to predict problems before they occur through the integration of AI, IoT, and big data.
- Climate-resilient breeding will ensure heat-tolerant animals and disease-resistant breeds.
- Ensure economic resilience for farmers through stable income despite climate variability and lower input costs (feed, medicine, labour).
- PLF can provide accurate data for carbon footprint measurement and may allow farmers to earn incentives through carbon credits.

SUMMARY

Precision livestock farming (PLF), which consists of leveraging tools such as IoT sensors, machine learning, and real-time analytics, enables proactive decision-making to mitigate climate stressors. It enhances resource efficiency as well as foster climate-resilient livestock husbandry by integrating advanced technologies to monitor, analyse, and optimise animal welfare as well as animal health and its environmental impact. This approach minimises greenhouse gas emissions, optimises feed utilisation, and ensures the well-being of animals, contributing significantly to sustainable livestock systems. However, PLF comes with many challenges and limitations, such as high initial implementation costs and the digital divide among urban and rural regions. The risks of adopting PLF can also involve dependency on technology, changing human-animal relationships, and a change in human perception of dairy farming. PLF is a transformative tool which can bridge the gap between productivity and sustainability in animal husbandry, making it indispensable for climate-resilient animal husbandry.

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