

**Indian Farmer**

Volume 12, Issue 08, 2025, Pp. 457-464

Available online at: www.indianfarmer.net

ISSN: 2394-1227 (Online)

Original article**Sustainable dairy farming: Challenges and Opportunities in the 21st century****¹Madhu Meena, and ²Amanish Kumar**¹PhD Scholar, Animal Reproduction Gynaecology and Obstetrics²PhD Scholar, Dairy Extension Section

ICAR -National Dairy Research Institute, ERS, Kalyani, 741235

*Corresponding author: meenamadhu385@gmail.com

Received: 08/08/2025

Published: 12/08/2025

ABSTRACT

India, while holding the distinction of being the world's largest milk producer, continues to face significant challenges that threaten long-term sustainability in the dairy sector. The predominance of low-yielding cattle, recurrent disease outbreaks such as Lumpy Skin Disease (LSD), and resource constraints demand urgent strategic interventions. Sustainable growth can be achieved by reducing the population of low producers and promoting high-yielding animals through advanced breeding technologies, including the adoption of sex-sorted semen. Engaging and empowering youth in dairying, coupled with increased automation and precision dairy farming practices, are crucial for improving productivity, profitability, and resilience. A forward-looking approach integrating genetic improvement, technology adoption, and youth participation will be key to securing India's dairy future.

INTRODUCTION

India is the world largest milk producer contributing 25% of the global milk production (BAHS,2024). Out of 239.30 million tonnes of milk produced in India during 2023-24, 31.11 was contributed by crossbred. the bovine species, commonly known as Indian milking machines has attracted global attention due to its multifunctional utilization for production of milk, milk products, draught power, meat and leather products. India possesses a 109.85 million buffalo and 193,46 million cattle population (livestock census 2019). Dairy farming has long been a cornerstone of rural economies and human nutrition. However, as the 21st century advances, the sector stands at a crossroads due to shortage of grazing lands, increases in cost of feed ingredients, lack of interest among youth on dairy farming, outbreaks of newer diseases. How can we balance increasing demands for dairy products with the urgent need to preserve our environment, ensure animal welfare, and support farmer livelihoods?

Rising Milk Production and Cattle Population in India: Yet Sustainable Dairy Farming Remains Elusive

In recent years, India has witnessed a steady increase in milk production along with a continuous rise in the cattle and bovine population. This trend is clearly reflected in official data and agricultural reports as shown in Table 1. However, despite these positive indicators, the country has not yet been able to achieve truly sustainable dairy farming.

The growth in milk output and livestock numbers suggests progress in terms of quantity, but the qualitative aspects of dairy farming remain a concern.

Table 1. Bovine Population in India

Year	Cattle (million)	Buffalo (million)	Total Bovines (million)
1951	155.3	43.4	198.7
1972	178.3	57.4	235.7
1992	204.6	84.2	288.8
2012	190.9	108.7	299.6
2019	192.5	109.9	302.3

Source: Basic Animal Husbandry Statistics, MoFAHD, DAHD, GOI

Table 2. Milk Production and Per Capita Availability in India

Year	Production (Million Tonnes)	Per Capita Availability (g/day)
1991-92	55.6	178
2000-01	80.6	217
2010-11	121.8	281
2020-21	210.0	427
2023-24	239.3	471

Source: Basic Animal Husbandry Statistics, MoFAHD, DAHD, GOI

But now question arise India’s milk production and cattle population are increasing. So why haven’t we achieved sustainable dairy farming yet? But first understand what is it.

What is Sustainable Dairy Farming?

Sustainable dairy farming refers to practices that meet current dairy demands without compromising the environment, public health, animal welfare, or the ability of future generations to meet their own needs. It encompasses responsible management of land, water, animals, and economic resources

now that we have examined the various aspects of dairy farming, it becomes clear what the key challenges are in achieving sustainable dairy farming. These challenges span environmental, economic, ethical, and technological dimensions, and understanding them is essential to designing effective and practical solutions.

Key Challenges in Sustainable Dairy Farming

1. Environmental Impact

Dairy farming contributes significantly to greenhouse gas emissions, particularly methane. Manure management, overgrazing, and inefficient water use also impact soil and water quality.

Methane is produced during enteric fermentation in cows and from anaerobic decomposition of manure. It's a potent greenhouse gas, with a global warming potential approximately 28 times greater than carbon dioxide over a 100-year period. Nitrous oxide is emitted during nitrogen cycling in soils and manure storage units. It has a global warming potential about 298 times that of carbon dioxide over a 100-year period. Manure is the second-largest source of greenhouse gas emissions on a dairy farm after enteric methane. It accounts for approximately 7% of both agricultural methane and nitrous oxide emissions.

Can dairy production be intensified without increasing its environmental footprint?

2. Animal Welfare

High milk yields can strain animal health. Confinement systems may also limit natural behaviours, raising ethical concerns. Tie-stall and other confinement housing systems limit cows' ability to move freely, hindering natural behaviours such as walking, lying down comfortably, and social interactions. This restriction can lead to physical discomfort and stress.

Behavioural Limitations: Confinement can prevent cows from expressing natural behaviour's, which are essential for their well-being. The inability to engage in activities like grazing, socializing, and exploring can lead to frustration and behavioural issues.

Studies indicate that when given a choice, cows prefer pasture access over confinement. Pasture-based systems allow for greater freedom of movement and expression of natural behaviors, contributing to improved welfare

How can farmers ensure that productivity does not come at the cost of animal welfare?

3. Economic Pressures on Farmers

Dairy farmers often face fluctuating milk prices, high input costs, and debt. Smallholders especially struggle to remain competitive.

Milk prices in India are subject to seasonal and market fluctuations. During periods of surplus production, prices can drop significantly, reducing farmers' incomes. For instance, during the COVID-19 pandemic, the closure of hotels and restaurants led to a decrease in milk demand, causing prices to fall by ₹10–13 per litre

Additionally, the absence of a Minimum Support Price (MSP) for milk leaves farmers vulnerable to market volatility. Unlike other agricultural commodities like wheat and rice, milk lacks a government-backed price guarantee, making it difficult for farmers to plan and invest confidently.

The cost of inputs such as cattle feed, fodder, and veterinary care has been on the rise. For example, the price of a 50 kg bag of wheat straw increased from ₹850 before the pandemic to ₹1,200, and oil cakes cost ₹1,600 for 45 kg. These rising costs erode profit margins, especially when milk procurement prices remain stagnant.

What policy and market innovations can support economic sustainability for small and marginal dairy farmers?

4. Climate Change and Disease outbreaks

Climate change is reshaping the epidemiology of livestock diseases and threatening feed and fodder security. Among 65 major animal diseases of economic and social importance to smallholder farmers, nearly 58% are considered climate-sensitive, with transmission dynamics influenced by changing temperature and rainfall patterns. Shifts in climate manifesting as increased temperature variability, altered precipitation, and more frequent extreme weather events directly impact rangelands and pasturelands, deteriorating soil health, altering plant composition, and reducing both the quantity and nutritional quality of forage. This leads to nutritional stress, lower immunity, and increased vulnerability of livestock to disease.

Global evidence underscores this threat: in Bolivia's Andean highlands, decreased rainfall and rising temperatures have led to the drying of feed crops and severe livestock mortality. In India, recent experiences with the Lumpy Skin Disease (LSD) outbreak in 2022 illustrate the magnitude of climate-linked disease risks. LSD, a vector-borne viral disease of cattle, caused widespread morbidity and mortality, with over 3 million cases and more than 100,000 cattle deaths reported across multiple states, leading to substantial economic losses for dairy farmers. Warmer temperatures and prolonged wet conditions are believed to have enhanced vector survival and transmission rates, exacerbating the outbreak's scale.

These impacts highlight the urgent need for integrated adaptation strategies combining climate-resilient fodder production, improved animal nutrition, disease surveillance, and preventive vaccination—to safeguard India's livestock sector against the compounded threats of climate change and emerging diseases

How can farmers adapt to climate variability while maintaining productivity?

5. Consumer Expectations

Increasing consumer awareness about ethical and sustainable food production demands transparency and certification. Recent surveys indicate that a significant portion of consumers prioritize sustainability in their purchasing decisions. For instance, a study by the Harvard Business Review found that three factors are driving a major shift in consumption patterns where consumers consider sustainability as a baseline requirement for purchase: trust drives behaviour, sustainability promotes trust, particularly among younger generations, and younger generations will soon have most of the purchasing power in the U.S. Similarly, a survey conducted by Eurofins revealed that

six in ten global consumers are interested in knowing where their food comes from, emphasizing the importance of supply chain transparency and sustainably sourced ingredients.

Are dairy consumers willing to pay more for sustainably produced milk?

While the challenges are significant, there are also promising avenues that can transform dairy farming into a more environmentally friendly, economically viable, and socially responsible sector.

Opportunities for a Sustainable Future

1. Adoption of Climate-Smart Practices

In India's dairy sector, climate-smart practices are increasingly recognised as essential for reducing greenhouse gas emissions, improving soil health, and sustaining productivity under changing climatic conditions. Rotational grazing, though more common in countries like the USA and Australia, has significant potential in India, particularly in semi-arid and rainfed regions. By periodically shifting livestock between grazing plots, this practice prevents overgrazing, encourages pasture regeneration, and enhances soil organic carbon and nitrogen content. Pilot projects in states such as Rajasthan and Karnataka have shown that rotational or community-managed grazing improves forage biomass and reduces land degradation, while supporting fodder security during dry spells.

Adaptive Multi-Paddock (AMP) grazing, a more structured form of rotational grazing, could be adapted for Indian conditions by integrating native fodder species, silvopastoral systems, and water conservation measures. Such approaches can help restore degraded rangelands, maintain year-round forage availability, and improve resilience against droughts critical for sustaining livestock in climate-vulnerable districts.

Efficient manure management is another priority. In India, where dairy farms range from smallholder households to large cooperatives, manure is often stored in open pits, leading to methane and nitrous oxide emissions. Introducing anaerobic digesters (biogas plants) offers a dual benefit: capturing methane to produce renewable energy for cooking or electricity, and producing nutrient-rich slurry as an organic fertiliser. Studies from Indian dairy cooperatives, such as those in Gujarat and Punjab, indicate that biogas units can reduce methane emissions from manure storage by more than 50% while lowering household dependence on firewood and chemical fertilisers.

The large-scale adoption of these climate-smart interventions, supported by government schemes such as the National Dairy Plan and the Gobardhan Scheme, could significantly reduce the dairy sector's climate footprint while enhancing rural incomes and resource efficiency.

2. Technological Innovations

Precision dairy technologies (like sensors for health and estrus detection), mobile apps for record-keeping, and AI-driven nutrition plans are transforming farm efficiency. Wearable sensors, including collars, pedometers, and rumen boluses, are employed to monitor various physiological and behavioural parameters of dairy cows. These devices track activity levels, temperature, and rumination patterns, facilitating early detection of health issues and oestrus cycles. For instance, studies have demonstrated that multi-sensor data fusion combined with machine learning techniques can accurately identify estrus-specific behaviours, such as increased movement and restlessness, thereby improving breeding efficiency. Artificial Intelligence (AI) is increasingly being utilized to

develop precision feeding strategies tailored to the specific needs of individual cows. By analysing data on milk production, body condition, and health status, AI algorithms can formulate optimal diets that improve feed efficiency and reduce waste. Implementing AI-driven nutrition plans has been associated with increased milk yields and a significant reduction in methane emissions, contributing to both economic and environmental sustainability.

Breeding and Genetic Improvement

Sustainable dairy development in India depends on genetic strategies that enhance productivity while ensuring adaptability to local environmental stresses. The selection and promotion of **heat-tolerant, disease-resistant, and high-yielding indigenous breeds** such as Gir, Sahiwal, Tharparkar, and Murrah buffalo offer a dual advantage: sustaining production under climate stress and reducing vulnerability to endemic diseases. Advances in breeding technology now enable the selection of traits that directly improve sustainability, including higher feed conversion efficiency, improved reproductive performance, and enhanced immunity. These genetic gains lower resource inputs and greenhouse gas emissions per unit of milk produced, thereby reducing the sector's carbon footprint.

A key technological revolution is the **adoption of sex-sorted semen**. By allowing over 90% probability of producing female calves, this technology addresses multiple challenges:

- **Population optimisation** – Reduces the need for maintaining large herds of low-yielding animals, enabling more milk production from fewer, more efficient animals.
- **Reduction in unwanted male calves** – Minimises economic losses and welfare concerns associated with surplus male calves, particularly in dairy breeds where male offspring have limited commercial value.
- **Greenhouse gas emission control** – Smaller, more productive herds emit less methane and require less feed, lowering the environmental footprint.
- **Improved animal welfare** – Reduces culling pressure and improves resource allocation per animal, resulting in better care and living conditions.

In the Indian context, integrating **sex-sorted semen** with **progeny testing and genomic selection programmes** can accelerate the dissemination of superior germplasm from elite bulls and high-performing indigenous cows. This targeted approach is aligned with national breeding initiatives such as the *Rashtriya Gokul Mission* and *National Dairy Plan*.

Future Scope involves scaling up sex-sorted semen production within India to reduce dependence on imports, integrating it with artificial insemination networks in remote rural areas, and combining it with genomic tools to select animals resilient to climate change. Over the next decade, widespread adoption could trigger a "Genetic Efficiency Revolution" in Indian dairying producing more milk with fewer animals, lower emissions, and improved profitability for farmers.

4. Integrated Crop-Livestock Systems

Recycling nutrients through manure application, intercropping, and fodder cultivation enhances resource use efficiency.

5. Policy and Institutional Support

Government schemes promoting sustainable inputs, veterinary services, and fair pricing are crucial. Cooperatives can empower smallholders.

6. Capacity Building and Education

Farmer training, especially for women and youth, can lead to better adoption of sustainable practices. By integrating these technologies, dairy farmers can meet current demands and align with future sustainability goals and regulatory standards. As these examples illuminate, the path to sustainability is a journey toward better farming and a thriving, thriving future for the dairy industry.

Conclusion: Is Sustainable Dairy Farming Achievable?

Yes, but only through a coordinated, multi-stakeholder approach involving farmers, scientists, policymakers, industry leaders, and consumers. Achieving sustainability in India's dairy sector will require the integration of innovative technologies with robust institutional support, capacity building, and strong public awareness. Climate-smart practices, efficient resource use, and genetic improvement programmes must be implemented at scale, while preserving the adaptability and resilience of indigenous breeds.

Sex-sorted semen technology will play a pivotal role in shaping the future of sustainable dairying by enabling herd optimisation, reducing the number of low-yielding and surplus male calves, improving resource efficiency, lowering greenhouse gas emissions, and enhancing animal welfare. When combined with genomic selection, improved feeding systems, disease control, and automation, it has the potential to usher in a new era of "precision dairying" in India.

The path forward demands urgency. The real question is not whether sustainable dairy farming is technically possible. It is whether stakeholders will act decisively and in time to secure a future where India's dairy sector remains both highly productive and environmentally responsible, ensuring livelihoods, food security, and ecological balance for generations to come.

REFERENCE'S

Aguirre-Villegas, H. A., & Larson, R. A. (2017). Evaluating greenhouse gas emissions from dairy manure management practices using survey data and lifecycle tools. *Journal of cleaner production*, 143, 169-179.

Abagandura, G. O., Mamo, M., Schacht, W. H., Shropshire, A., & Volesky, J. D. (2024). Soil carbon and nitrogen after eight years of rotational grazing in the Nebraska Sandhills meadows. *Geoderma*, 442, 116776.

Ashley Reichheld, John Peto & Cory Ritthaler. (2023). Consumers' Sustainability Demands Are Rising.

Basic Animal Husbandry Statistics, Dept. Of Animal Husbandry, Dairying and Fisheries, Govt. of India. (2010).

Beaver A, Ritter C, Von Keyserlingk MAG. The Dairy Cattle Housing Dilemma: Natural Behaviour Versus Animal Care. *Vet Clin North Am Food Animal Practice*. 2019 Mar;35(1):11-27

Challenges & Solutions of Dairy Sector. India Pashudhan. (2022)

EFSA Panel on Animal Health and Animal Welfare (AHAW); Nielsen SS, Alvarez J, Bicout DJ, Calistri P, Canali E, Drewe JA, Garin-Bastuji B, Gonzales Rojas JL, Gortázar Schmidt C, Herskin M, Michel V, Miranda Chueca MÁ, Padalino B, Roberts HC, Spoolder H, Stahl K, Velarde A, Viltrop A, De Boyer des Roches A, Jensen MB, Mee J, Green M, Thulke HH, Bailly-Caumette E, Candiani D, Lima E, Van der Stede Y, Winckler C.(2023). Welfare of dairy cows. *EFSA J*;21(5)

Grace, D., Bett, B., Lindahl, J., & Robinson, T. (2015). Climate and livestock disease: assessing the vulnerability of agricultural systems to livestock pests under climate change scenarios. *Consultative Group on International Agricultural Research Research Program on Climate Change, Agriculture and Food Security, Copenhagen), Climate Change Agricultural and Food Security Working Paper, (116).*

Keleman Saxena, A., Cadima Fuentes, X., Gonzales Herbas, R., & Humphries, D. L. (2016). Indigenous food systems and climate change: impacts of climatic shifts on the production and processing of native and traditional crops in the Bolivian Andes. *Frontiers in public health, 4, 20.*

Muzzo, B. I., Ramsey, R. D., & Villalba, J. J. (2024). Changes in Climate and Their Implications for Cattle Nutrition and Management. *Climate, 13(1).1*

Teague, R., & Kreuter, U. (2020). Managing grazing to restore soil health, ecosystem function, and ecosystem services. *Frontiers in Sustainable Food Systems, 4, 534187.*

Wang, R., Li, Y., Tian, F., Liu, Y., Wang, Z., Yuan, C., & Lu, X. (2025). Estrus detection in dairy cows using advanced object tracking and behavioural analysis technologies. *Computers and Electronics in Agriculture, 235, 110331.*