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India's Dairy Future

Aligning Livelihoods, Growth and Climate Solutions

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List of Abbreviations

AI	Artificial Insemination
BAHS	Basic Animal Husbandry Statistics
BMC	Bulk Milk Coolers
CBG	Compressed Biogas
EF	Emission Factor
EPR	Extended Producer Responsibility
ESG	Environmental, Social and Governance
ETT	Embryo Transfer Technology
FAO	Food and Agriculture Organization
FPO	Farmer Producer Organization
GADVASU	Guru Angad Dev Veterinary and Animal Sciences University
GDP	Gross Domestic Product
GHG	Green House Gases
HF	Holstein Friesian
IISC	Indian Institute of Science
IOCL	Indian Oil Corporation Limited
IoT	Internet of Things
IVF	In-Vitro Fertilization
MGNREGA	Mahatma Gandi National Rural Employment Guarantee Act
MoFAHD	Ministry of Fisheries, Animal Husbandry and Dairying
NDDB	National Dairy Development Board
NGO	Non-Governmental Organization
NITI Aayog	National Institution for Transforming India
ONGC	Oil and Natural Gas Corporation
PAU	Punjab Agricultural University
PM KUSUM	Pradhan Mantri Kisan Urja Suruksha evam Utthaan Mahabhiyan
RBP	Ration Balancing Program
RFID	Radio Frequency Identification
TANUVAS	Tamil Nadu Veterinary and Animal Sciences University
TMR	Total Mixed Ration
TNAU	Tamil Nadu Agricultural University
UMMB	Urea Molasses Mineral Block

Executive Summary

The dairy sector plays a vital role in India's economy, serving as a key driver of rural livelihoods and agricultural growth while significantly boosting farmers' incomes. As the world's largest milk producer, India accounts for 25% of global milk production and the dairy sector contributes 5% to the national economy. Smallholder farmers, who own 2 to 5 animals, produce 62% of the country's milk supply are the backbone of India's dairy industry, empowering them and creating an enabling ecosystem will ensure the long-term sustainability of the sector. The sector's growth, largely driven by scaling production, has strained natural resources and contributed to increased greenhouse gas (GHG) emissions. Climate change affects animals by reducing milk yields, impairing reproductive health, and increasing vulnerability to diseases due to rising temperatures, erratic rainfall, and extreme weather events. Addressing these issues is critical to ensuring the sector's long-term sustainability. This report charts a path for promoting climate-resilient dairy practices in India, focusing on opportunities to enhance productivity while reducing emissions.

Effective feed and fodder management is fundamental to sustainable dairying. Balanced diets, supported by initiatives like the Ration Balancing Programme by NDDB, enhance livestock productivity and reduce emissions. Practices such as silage feeding, especially in water-scarce regions, and the use of crops like maize and sorghum are particularly beneficial for smallholders. Innovative solutions such as hydroponics and climate-resilient forage crops, including Bajra, Napier, and millets,

address fodder shortages in drought-prone areas. However, wider adoption of these practices requires accessible extension services, robust feed quality standards, and improved supply chain infrastructure.

Breeding management is another critical area, with artificial insemination using high-genetic-`merit bulls widely adopted to improve progeny. However, challenges such as repeat breeding and poor estrus detection necessitate multiple inseminations. Addressing these challenges through better animal health services, cold chain infrastructure, and staff training can enhance outcomes. Indigenous production of sex-sorted semen and advanced techniques like Embryo Transfer Technology (ETT) hold potential but require investments to boost productivity. Conservation of indigenous breeds through genomic tools and participatory programs can enhance resilience and genetic diversity.

Manure management practices, including timely drying of manure, composting/vermicomposting, and biogas/compressed biogas (CBG) production, significantly reduce methane emissions. Composting converts waste into organic fertilizers, reducing reliance on inorganic alternatives, its adoption can be promoted by creating awareness and creating market linkages. Biogas adoption provides access to renewable energy source, which can be scaled by integrating it into rural electrification initiatives and promoting it as clean cooking fuel.

Good animal husbandry practices, such as vaccination, deworming, biosecurity, and precision antibiotic use, enhance farm productivity and animal health. However, gaps in awareness, limited veterinary services, and cost concerns hinder widespread adoption. Addressing these challenges through region-specific biosecurity protocols, strengthened veterinary infrastructure, and regulatory enforcement can boost adoption.

Precision dairy farming technologies, including automated milking systems and climate-resilient sheds, offer significant potential for efficiency gains but are currently limited to larger farms due to high costs. Developing cost-effective solutions could facilitate scalability among smallholder farmers.

Sustainability in the supply chain is equally important. Initiatives such as using water-saving technologies, renewable energy, and circular packaging can reduce supply chain emissions. Solar-powered cold storage and agrivoltaics improve energy efficiency, while stronger policies and consumer awareness can promote sustainable packaging.

Refinement in breed- and feed-specific emission factors (EFs) are essential for accurately measuring GHG emissions from the sector, which can be addressed by promoting research and developing models that can accurately gather data.

India's dairy sector is already advancing toward sustainability, but continued efforts to support smallholder farmers in adopting climate-resilient practices are essential. These initiatives not only improve milk yields, reduce costs, and enhance farmer livelihoods but also strengthen brand value, attract environmentally conscious consumers, and align with India's climate goals. Achieving sustainable dairying requires coordinated efforts among industry players, government agencies, cooperatives, technology providers, and research institutions. Collaborative action will address on-ground challenges, accelerate the adoption of climate-resilient practices, and secure a sustainable future for India's dairy sector.

Smallholder farmers, who own 2 to 5 animals, produce 62% of the country's milk supply are the backbone of India's dairy industry.

Introduction

The dairy sector is a cornerstone of India's economy, serving as a critical driver to the rural livelihoods, and agricultural income. With over 300 million dairy cattle and buffaloes, India is the world's largest milk producer, contributing about 25% of global milk production (MoFAHD, 2023). The sector supports approximately 5% of India's national GDP (MoFAHD, 2023) and provides essential nutrition to millions of people, particularly through the production of milk, which is a primary source of protein and calcium for the population.

Smallholder farmers, who typically own between 2 to 5 animals, account for around 62% of the country's total milk production (Morgan, 2009). These farmers are the backbone of India's dairy industry, empowering them and creating an enabling ecosystem will ensure the long-term sustainability of the sector. One of the most pressing issues India's dairy sector facing is the low productivity of milch animals.

Despite a significant increase in the female bovine population—from 122.7 million in 1972 to 246.7 million in 2019—the average milk yield per cow remains low and accounts for only two-thirds of the global average, and far lower than in developed countries (Chand, 2023). This growth in bovine numbers has driven increased milk production, but largely through scale rather than productivity improvements.

This trend of scale-driven growth has placed immense strain on India's natural resources—such as land, water, and feed—and has exacerbated environmental

pressures, particularly in terms of greenhouse gas (GHG) emissions. Over the past 50 years, the doubling of the female bovine population has led to a corresponding doubling of GHG emissions from dairy animals (Chand, 2023). Projections suggest that by 2050, India's livestock sector will account for approximately 15.7% of global enteric methane emissions. This highlights the urgent need for more sustainable dairy practices that address both productivity and environmental impacts.

Moreover, climate change is already having a direct impact on dairy farming. Rising temperatures, unpredictable rainfall patterns, and extreme weather events such as droughts and floods are adversely affecting dairy productivity and livestock health. Heat stress is reducing milk yields, impairing reproduction, and increasing the risk of disease. Water scarcity, exacerbated by erratic weather patterns, is further challenging farmers who rely on irrigation for feed crops, while the rising costs of feed and water place additional financial pressures on smallholder farmers, many of whom are already struggling to maintain their livelihoods.

To ensure the continued growth and sustainability of the dairy sector, dairy farmers need support to adopt climate resilient dairying practices that improve both productivity and resilience. These practices focus on enhancing milk productivity, safeguarding the livelihoods of farmers, and reducing the sector's carbon footprint. Key strategies include optimizing livestock nutrition to reduce methane emission intensity, improving manure management, adopting water-efficient irrigation systems, and utilizing renewable energy for dairy operations. Additionally, improved housing and introducing cooling systems to mitigate heat stress on animals can help maintain productivity in the face of rising temperatures.

The need for increased investment in climate-resilient dairy practices is critical. While past initiatives, such as Operation Flood, have played a significant role in establishing India as the world's largest milk producer, recent years have seen a slowdown in the growth of the dairy sector due to a decline in investment. Sustained investments are needed to modernize the sector and implement climate resilient practices.

This report will explore the path forward for promoting climate-resilient dairy practices in India by highlighting opportunities and their potential impact on improving productivity, reducing emissions, and ensuring the long-term sustainability of India's dairy sector. It will be a guiding tool for policy makers, startups, industry and research institution to support dairy farmers in this transition.

With over 300 million dairy cattle and buffaloes, India is the world's largest milk producer, contributing about 25% of global milk production (MoFAHD, 2023).

Methodology

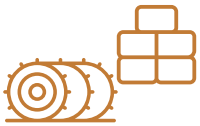
The study initiated with regional stakeholder consultations in Delhi (Northern Region), Patna (Eastern Region), Bangalore (Southern Region) and Ahmedabad (Western Region) that involved diverse group of participants, representing dairy processing units, startups, feed and fodder companies, climate finance organizations, research institutions, academic bodies, and extension networks. These discussions aimed to capture valuable insights into ongoing sustainability initiatives, innovative solutions developed by startups, and research projects focused on enhancing sustainability from the grassroots level. The findings from these regional consultations provided a comprehensive understanding of the critical areas for promoting climate resilience and sustainability in India's dairy sector.

State deep dives were undertaken in the states of Punjab, Maharashtra and Tamil Nadu for their contribution in India's dairy sector and their unique agricultural and climate profiles. A qualitative research approach was undertaken, where sustainable and climate resilient practices were explored through field visits and one to one stakeholder interviews. On-site visits were conducted to observe dairy farming practices, infrastructure, and resource management firsthand. These observations provided valuable context and facilitated a deeper understanding of the operational challenges and innovative practices employed by local farmers.

Major Findings and Potential for Adoption

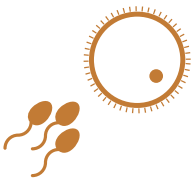
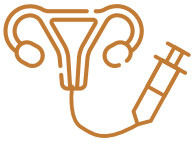
The regional consultations and state-level deep dives have shed light on ongoing climate-resilient practices that had potential for adoption in other regions as well. These practices span various sectors, including feed and fodder management, breeding management, manure management, animal husbandry, and supply chain practices. Factors hindering the implementation and wider adoption of these practices, were discussed at length along with the potential steps that can accelerate the adoption. Tables 1 to 6 provide a detailed overview of these practices, highlighting their adoption potential, the supporting intervention required for broader implementation, and their associated environmental benefits.

Table 1: Feed & Fodder Management Practices for Climate Resilient Dairy Development

Feed & Fodder Management Practices	Potential of Adoption	Adoption catalysts	Environmental Impact
 **Balanced Diet, Mineral Mixture & UMMB** Use high-quality concentrates (e.g., maize, barley, oil cakes) and roughage (e.g., Hybrid Napier, Bajra Napier). Supplement with mineral mixture (50-60g/day) and Urea Molasses Mineral Block (UMMB) to improve digestibility. Monitor and avoid over/underfeeding.	**High** Ration Balancing Programmes by National Dairy Development Board (NDDB) gaining traction in 18 major dairying states in India. Requires extension services and development of the business infrastructure to make affordable balanced feed available.	Formulation of National Fodder Security Policy and setting of feed quality standards. Supporting Farmer Producer Organizations (FPOs) to boost local fodder production. Building supply chains for quality feed and fodder, promoting collaboration of FPOs and industry for local production. Promotion of Ration Balancing Program (RBP). Providing support to digital platforms for feed traceability and GHG tracking. Promoting innovative tools for tailored feeding and feed monitoring.	Balanced diets- Improves productivity of the cattle and lowers reproductive disorders, while cutting emissions.
 **Silage Feeding** Promote silage making using less water-intensive crops like maize and sorghum. Train smallholders in compact methods like barrel silage.	**High** During the flush season, surplus fodder can be converted into silage for use in the lean season. Silage feeding can be a sustainable solution for water-scarce regions. Compact methods like barrel silage enhance scalability, making it a viable option for smallholders.	Providing support for silage-making infrastructure (e.g., silage bags), and accessing high-yielding fodder seeds can enhance adoption rates among dairy farmers. Developing innovative storage solutions and implementing measures to prevent aflatoxin contamination in silage will significantly reduce the risk of aflatoxin entering the milk.	Silage helps mitigate enteric methane emissions by boosting productivity and lowering greenhouse gas emissions per kg of product (Aby et al., 2019; Van et al.,2013).

Feed & Fodder Management Practices	Potential of Adoption	Adoption catalysts	Environmental Impact
 **Hydroponics/ Climate Resilient Forage Feeding** Establish water-efficient hydroponic systems for high-quality fodder production. Climate-Resilient Forage Varieties (Bajra , Napier and millets) feeding.	**High** Drought-prone regions need cost-effective solutions and better access to technology, making hydroponics an ideal option for water-efficient and sustainable fodder production. Developing climate resilient forage varieties will be beneficial for fodder-deficient regions (e.g., East, South). Suitable for water-scarce smallholder farms.	Developing cost-effective hydroponic solutions for smallholder farmers. Supporting development and promotion of climate-resilient fodder varieties (Bajra Napier and sorghum). Developing high-yielding, low-water intensive fodder crops, offering support for seeds and training programs, and establishing buy-back arrangements for fodder crops. Promoting its use in drought-prone areas.	Hydroponics, powered by renewable energy, reduces GHG emissions, supporting efficient use of land resources. Hydroponics uses up to 90% less water than traditional farming (Rajaseger et al., 2023). Climate-resilient forage varieties reduce GHG emissions by ensuring consistent feed, improving forage quality, and enhancing soil health thereby optimizing livestock nutrition and mitigating climate change (Tulu et al., 2023).
 **Feed Additives & Probiotics** Introduce cost-effective additives like tannins, nitrates, and herbal alternatives.	**High** Accessibility and cost are key barriers. Adoption can increase with localized production and education.	Researching on indigenous and affordable additives for local and economic production. Promoting proper usage of additives by providing education and incentives.	Feed additives can reduce enteric methane emissions from ruminants by inhibiting methane producing microbes (Hodge et al., 2024).

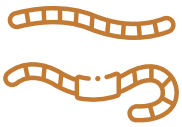
Table 2: Breeding Management Practices for Climate Resilient Dairy Development

Breeding Management Practices	Potential of Adoption	Adoption catalysts	Environmental Impact
 **Artificial Insemination (AI)**	**High** However, repeat breeding and the need for multiple inseminations due to poor estrus detection or semen quality are significant challenges. Improving Cold Chain Infrastructure, training of field staff and improving health status of the animal can help.	Expanding AI programs with quality semen (indigenous/crossbred). Strengthening infrastructure and training.	Enhances productivity by using high-genetic-merit bulls that produce superior progeny, enhances milk production by reducing unproductive days, thereby lowering GHG emissions per unit of milk produced.
 **Sex-Sorted Semen**	**Moderate** Farmers especially in Punjab, Haryana, and Maharashtra show significant interest in adopting sexed sorted semen due to its ability to ensure a higher proportion of female progeny. However, the high cost of these straws often restricts widespread adoption.	Supporting in making sex-sorted semen more affordable for small holder farmers. Investing more in indigenous sex sorted semen production for cost-effective production.	Ensure higher birth rates of female calves, directly increasing milk production capacity. Reduces non-productive male population, lowering environmental burden.
 **Embryo Transfer Tech (ETT)**	**Low** Large-scale adoption of ETT is feasible through government-supported infrastructure and private partnerships. This technology is costly for adoption and also need trained personnels.	Establishment of infrastructure with public-private partnerships. Utilizing superior sires/dams for genetic improvement. Training awareness and capacity building of technicians.	Accelerates genetic improvement, milk yield potential and reduces methane emission.

Breeding Management Practices	Potential of Adoption	Adoption catalysts	Environmental Impact
 **Indigenous Breed Improvement & Conservation**	**Moderate** Widespread adoption faces challenges at the grassroots level, as improved indigenous cattle are often perceived as not financially beneficial as compared to crossbreds that delivers higher milk yields quicker.	Improving the productivity of indigenous breeds at government farms followed by promoting amongst small holder farmers. Adoption of genomic tools (like genome selection) to identify superior indigenous animals for breeding programs. Establishing gene banks, breeding farms, and participatory breeding programs involving farmers, researchers, government, NGOs & other stakeholders.	Their adaptability to local climates ensures consistent production with reduced maintenance costs. Preserves genetic diversity.

Table 3: Manure Management Practices for Climate Resilient Dairy Development

Manure Management Practices	Potential of Adoption	Adoption catalysts	Environmental Impact
 **Timely Drying of Manure**	**High** Suitable for small and medium-scale farmers due to minimal infrastructure requirements and immediate benefits.	Enhancing farmer's awareness about the benefits of timely drying, as it inhibits anaerobic conditions that promote methane production. Building capacity of farmers on manure handling practices for proper transportation and preparation of compost.	Lower moisture content inhibits methane and nitrous oxide emissions. 90% methane emission reduction potential (United Nation Environmental Protection Agency).

Manure Management Practices	Potential of Adoption	Adoption catalysts	Environmental Impact
 **Composting/ Vermicomposting**	**Moderate** Farmers face market challenges for selling compost. Adoption is limited due to small landholdings, less reliance on compost in non-organic farming, and low market value and demand.	Developing of region-specific techniques requiring less space. Promoting usage of organic fertilizers through awareness and training. Building distribution networks/market linkage for compost products. Promoting collective composting units.	Reduces methane emissions via aerobic decomposition. Converts waste into a valuable resource, lowering reliance on synthetic fertilizers. 90% methane emission reduction potential. (United Nation Environmental Protection Agency).
 **Biogas/ Compressed Biogas (CBG)**	**Biogas** **High** If upfront costs are reduced and maintenance simplified. Centralized models like those in Tamil Nadu enhance feasibility for small farmers. **CBG** **Low** High initial costs and infrastructure challenges.	**Biogas** Inclusion of biogas plants in rural electrification initiatives and its promotion as renewable energy source. Promoting biogas as clean cooking source. Facilitating centralized slurry collection systems through dairy cooperatives to enable biogas production at common facilities, benefiting all member farmers. **CBG** Conducting cost-effective pilot studies. Offering incentives for CBG use in vehicles and industry.	Biogas and CBG plants, facilitates methane capture from manure to be used as clean cooking fuel and renewable energy source. Reduces dependency on fossil fuel usage. Although leakage is an issue, the biogas digesters still contribute to capturing a substantial percentage of methane which would have contributed to climate change due to improper manure management.

Manure Management Practices	Potential of Adoption	Adoption catalysts	Environmental Impact
		Industries/Startups can partner with government to establish CBG plants and integrate into fuel networks.	
 **Traditional Uses (Panchgavya/ Jeevamrutham/ Insecticides)**	**Moderate to High** Culturally accepted practices like Panchgavya/Jeevamrutham are scalable with scientific validation and better market linkages.	Validating traditional practices scientifically. Certifying organic products and develop niche markets. Scaling production with branding. Promoting awareness and building market linkages for farmers.	Promotes sustainable pest and nutrient management, reducing emissions from chemical inputs. Provides an organic alternative to synthetic inputs.

Table 4: Animal Husbandry Practices for Climate Resilient Dairy Development

Animal Husbandry Practices	Potential of Adoption	Adoption catalysts	Environmental Impact
 **Good Animal Husbandry Practices** Good Animal Husbandry Practices (Preventive medicine, Vaccination, Deworming, Biosecurity, Antibiotic Withdrawal Period, Precision use of antibiotics).	**High** Adoption varies due to awareness gaps, limited access to veterinary services, and cost concerns. Antibiotic misuse persists, and high initial costs hinder climate-resilient shed adoption.	Preparation of region-specific biosecurity protocols. Strengthening veterinary infrastructure, enforcing regulations on precision use of antibiotics. Strengthening veterinary services. Awareness and training for adoption of good practices.	Improves productivity and reduces disease-related mortality, leading to lower methane intensity per unit of milk. Biosecurity minimizes disease outbreaks, and climate-resilient sheds improve ventilation, reducing stress and improve productivity.

Animal Husbandry Practices	Potential of Adoption	Adoption catalysts	Environmental Impact
 **Precision Dairy Farming/Dairy Farm Automation** (Digital Neck Collars, Milking Machines, TMR Machines, Climate-Resilient Sheds, etc.).	**Moderate** Adoption is limited to larger farms due to high initial costs and low awareness among smallholders. Climate-resilient sheds face similar barriers but have strong potential for high-heat stress regions.	Developing cost-effective tools and climate-resilient shed designs. Supporting for automation tools and shed construction. Encouraging partnerships between startups and cooperatives. Providing training on precision farming and rental models for equipment. Facilitating collective ownership or access to automation tools, ensuring scalability for smallholders.	Enhances resource efficiency, reduces feed wastage, and ensures precision in feeding and milking, lowering methane emissions. Climate-resilient sheds improve ventilation and reduce stress-induced emissions.

Table 5: Sustainable Dairy Supply Chain Initiatives

Supply Chain Initiatives	Potential of Adoption	Adoption catalysts	Environmental Impact
 **Water Management**	**Moderate** Limited awareness of water-saving technologies. Initial investment required for advanced systems. Lack of policy incentives for water efficiency.	Promoting low-cost water-saving technologies and wastewater recycling systems. Incentivizing rainwater harvesting systems and promoting water audits in dairy plants. Promoting investment in water-efficient processing units and smart water monitoring systems.	Improves water use efficiency, reducing energy-intensive processes like water extraction and pumping, which improves on-farm sustainability and indirectly lowers emissions.

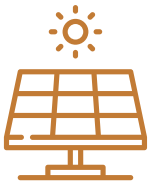
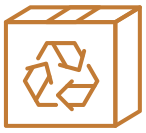
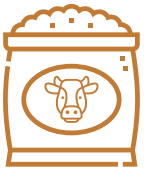
Supply Chain Initiatives	Potential of Adoption	Adoption catalysts	Environmental Impact
		Conduction of workshops to educate members on water conservation practices at farm and processing levels.	
 **Agrivoltaics and Renewable Energy**	**Low to Moderate** High capital costs for solar installations. Space and technical constraints such as maintenance of the panel limit adoption among small scale setups. Limited renewable energy integration in supply chains.	Developing cost-effective agrivoltaics systems tailored to local conditions leveraging PM KUSUM. Promoting renewable energy adoption and offer incentives for feed-in tariffs for excess power generation. Investing in solar-powered cold storage.	Replaces fossil fuels with renewable energy, significantly reduces non methane emissions. Agrivoltaics enhance land use efficiency, combining solar energy generation with agriculture to reduce the carbon footprint. Provides farmers with revenue for selling the excess generated power.
 **Circular and Recycled Packaging**	**Moderate** High costs of recycling infrastructure. Consumer awareness about sustainable packaging is limited. Evolving regulatory standards for recycled food-grade packaging.	Creating policy instruments for developing affordable biodegradable or recyclable packaging materials. Strengthening Extended Producer Responsibility (EPR) policies. Facilitating transition to circular packaging through investments in closed-loop systems and partnerships with recyclers. Promoting bulk milk vending machines and recyclable packaging models.	Minimizes virgin material usage and reduces landfill emissions. Circular packaging enhances resource efficiency.

Table 6: Emission Tracking and Reduction in Indian Dairy Sector

Emission Tracking and Measurement	Potential of Adoption	Adoption catalysts	Environmental and Social Impact
 **Breed- and Feed-Specific Emission Factors** Refinement in emission factors (EFs) values as per the feeding practices in region and genetics of the cattle.	**High** Aligns with national climate goals and supports Environmental, Social and Governance (ESG) compliance for industries.	Promoting research on assessing the accurate EFs by pilot studies in different regions. Developing feeding models to gather data on gross energy intakes.	Indigenous cattle have lower gross energy intake due to unique feed and genetics. Studies suggest Emission Factor values could be 12-14% lower when Indian feed values are factored in (Swamy & Bhattacharya, 2006).

State Deep Dive Findings

Punjab

Punjab, renowned for its robust agricultural practices, is a significant contributor to India's dairy sector. Dairy sector in the state provides a reliable source of income and employment, particularly for small and marginal farmers, while meeting the growing demand for milk and dairy products. Despite its decline in national ranking—from second in milk production during the 1990s to seventh in 2022-23—Punjab still contributes around 6.2% to India's milk output. Additionally, it boasts the highest per capita milk availability in the country, with 1,181 grams per person per day (BAHS 2023). Punjab's success in dairy farming is attributed to its high livestock productivity and the adoption of modernized farming techniques. Districts like Ludhiana and Moga showcase the state's advancements in dairy infrastructure, supported by key institutions such as Guru Angad Dev Veterinary and Animal Sciences University (GADVASU) and Punjab Agricultural University (PAU). These institutions emphasize feed and fodder management, housing management, integrated farming systems, and the empowerment of women

farmers, driving the state's dairy progress. Additionally, Punjab boasts a robust extension service network, backed not only by government institutions but also by major dairy companies like Nestlé, Danone, and cooperatives like Verka. This collaborative support has made Punjab a frontrunner in adopting best practices in dairy farming, achieving remarkable success in a short period.

Common Practices Adopted by Dairy Farmers in Punjab

Feed and Fodder Management: Punjab is a green fodder surplus state, with most farmers cultivating their own feed and adopting silage-making to ensure steady fodder supply. Small farmers depend on purchased silage. Medium and large farmers prepare silage using kaccha or pakka silo pits. Total Mixed Ration (TMR) machines are gaining popularity among medium and large-scale farmers.

Breeding Management: Advanced technologies like Artificial Insemination (AI), sex-sorted semen, and frozen semen are widely used to improve livestock genetics. Most cattle are crossbred (e.g., Holstein Friesian), with yields reaching up to 40 Liters per day.

Manure Management: Farmers are increasingly adopting biogas plants as a sustainable solution for managing livestock waste. This shift is being supported by major companies like Nestlé and Danone, which are guiding farmers towards more climate resilient practices. However, more research is needed into the potential for methane leakage and methods to reduce such leakage.

Automation: Punjab has embraced climate-resilient dairy practices such as climate-adaptive sheds, farm automation tools like digital neck collars, automated milking systems, and manure collection machinery. These innovations help optimize farm operations, reduce labour requirements, and enhance the overall efficiency of dairy production.

Challenges Faced by Punjab Dairy Farmers

Securing loans and subsidies poses a significant challenge for dairy farmers. Although subsidies are typically available for specific components like shed construction, farmers must self-finance other essential costs, such as fodder. Adopting a more integrated subsidy model that provides comprehensive support across all facets of dairy farming can be looked into to address this issue. Manure management has become a critical issue for large (> 50 Dairy Animals) dairy farmers in Punjab. Effective management of manure and biogas systems requires significant land, labour, and year-round planning, which can be challenging for farmers with limited resources. Larger-scale farms, on the other hand, often produce a substantial amount of dung, making it difficult to manage efficiently.

Best Practices and Innovations Observed

Climate-Resilient Sheds and Automation: Farmers are investing in sheds with foggers, neck collars for monitoring cattle, grooming machine, and automated waterers, ensuring better animal wellbeing and productivity.

Milk Vending Machine & Milk Credit Cards: Bulk Milk Coolers (BMCs) and vending machines allow farmers to supply milk efficiently, reducing packaging waste and promoting cashless transactions.

Compressed Biogas (CBG): While still in development, CBG has the potential to replace diesel and petrol, making farm machinery more sustainable.

Integrated Farming System: Incorporating crop-livestock systems ensures efficient resource use and better financial returns.

Tamil Nadu

Tamil Nadu, with its tropical climate and reliance on the Kaveri River for water, faces unique challenges and opportunities in its dairy sector. While dairy farming is often considered a secondary livelihood, the state's dairy industry provides significant economic support, especially for small and marginal farmers. However, milk consumption in Tamil Nadu is lower compared to northern states, and the demand for eggs and poultry surpasses that of milk.

Common Practices Adopted by Dairy Farmers in Tamil Nadu

Feeding and Fodder Management:
Green fodder cultivation is gaining traction in Tamil Nadu, with farmers encouraged to grow their own to reduce input cost. Low productivity feed like Paddy straw and hybrid Napier grass are commonly fed to livestock while some farmers also rely on specialized feed types provided by institutions like Tamil Nadu Veterinary and Animal Sciences University (TANUVAS). Alternative feeds, such as seaweed and industrial by-products, are being explored to mitigate methane emissions by TANUVAS.

Manure Management: Traditional practices like Panchagavya, a mixture of cow dung, cow urine, milk, curd, and other ingredients, are being used for fertilization. Panchagavya is particularly popular among farmers with an integrated farming system and is mostly prepared for personal agricultural use. This method, along with vermicomposting, helps enhance soil health and reduce dependency on chemical fertilizers. Vermicomposting is especially common in areas near the Kerala border, where it is in demand from cash crop farmers growing crops like cashews and spices, as well as in suburban areas where kitchen gardens and rooftop farming are popular. Though biogas plants were once popular, their adoption has declined due to maintenance costs and inconsistent methane production.

Breeding and Genetics in Tamil Nadu: Tamil Nadu is rich in livestock biodiversity. The buffalo population remains small in the state. In recent years, Tamil Nadu has seen a shift toward crossbred cattle, particularly the Jersey and Holstein Friesian (HF) breeds. However, experts also emphasize the benefits of indigenous cattle breeds and stress the need to promote their preservation, especially in rural and tribal areas.

Climate Resilient Practices: Climate-resilient sheds are rare due to high investment costs, also automated farms and own fodder production practices are rare to be seen in Tamil Nadu. The state's warm climate makes heat-tolerant breeds like Jersey more popular than Holstein Friesian, as they are better suited to the region's tropical conditions.

Research and Innovation: Research initiatives, particularly from TANUVAS, focus on alternative feed sources such as seaweed to reduce methane emissions and improve livestock productivity. TANUVAS and Tamil Nadu Agricultural University (TNAU) also promotes sustainable practices such as green fodder cultivation and the use of methane-reducing feed supplements. The state's livestock sector benefits from ongoing research to enhance productivity while mitigating environmental impacts.

Challenges Faced by Tamil Nadu Dairy Farmers

Water Scarcity: To address water scarcity, it is crucial to popularize methods like drip irrigation, micro-irrigation, and other precision farming techniques. These approaches can significantly increase crop yield per drop, helping mitigate water scarcity to a large extent.

Green Fodder Shortage: In Tamil Nadu, the period from April to September is the flush season, while October to March is the lean season. There is a need for increased support and training on silage production to bridge the gap during the lean season and ensure a consistent supply of green fodder. Tamil Nadu's dairy farmers face challenges such as fodder scarcity and high feed costs, leading to suboptimal feeding practices.

Best Practices and Innovations Observed

Steel Body Biogas Plant: A few successful cases of high-quality steel body (as opposed to cement, which can crack under pressure and cause gas leaks) long-term biogas plant use highlights its potential in manure management. This type of biogas plant has negligible maintenance cost and least leakage of methane gas. Pre-fabricated biogas plants are yet to get traction in Tamil Nadu.

Manure Value Chain: Tamil Nadu has a unique manure value chain, which involves partnerships between farmers and companies like Hatsun. Unlike traditional biogas systems where each farmer prepares biogas on their own farm, this model centralizes biogas production at a company level, simplifying the process for small-scale farmers and enabling efficient utilization of manure resources.

Maharashtra

Maharashtra is one of the leading milk producing state in India, with production of 14,300 thousand tonnes of milk in 2021-22. The dairy infrastructure in Maharashtra is supported by a complex network of cooperatives, government agencies, and financial institutions. The dairy cooperative ecosystem in Maharashtra is a significant part of the state's agricultural and economic landscape.

Common Practices Adopted by Dairy Farmers in Maharashtra

Feeding and Fodder Management: The feed and fodder practices in the state have evolved over time, adapting to changing needs and technological advancements. Key strategies include total mixed ration (TMR) feeding, a balanced blend of minerals, proteins, and vitamins tailored to the cows' needs. Many farmers grow their own fodder, such as hybrid Napier, maize silage, and jowar, ensuring a pesticide-free and nutritious feed source. Some progressive farmers in regions are also exploring hydroponics for round the year fodder availability. Additionally, milk cooperatives and private dairy companies are actively supporting farmers by offering training on feed and fodder management, ration balancing, and silage preparation. The National Dairy Development Board (NDDB) has played a key role in raising awareness about effective feed and fodder management through training and capacity-building programs. Farmers are being supported with subsidized inputs such as fodder seeds (e.g., maize, Napier), mineral mixtures (both chelated and non-chelated), and chaff cutters. Additionally, the formation of Fodder (FPOs) is gaining momentum across the state.

Manure Management: Farmers in the districts are actively implementing sustainable manure management practices. Many farms collect manure to produce biogas, which is used as a clean cooking fuel and slurry which is utilized as a fertilizer for crops. Additionally, dairy cooperatives are promoting the installation of backyard biogas generation units among farmers, providing subsidies to encourage adoption. By adopting these practices, farmers are trying to reduce their GHG emissions and promote circular economy.

Breeding and Genetics in Maharashtra: Dairy farms in the region are focused on improving cattle genetics to enhance milk production and reduce GHG emissions. To achieve this, they are employing various strategies such as artificial insemination (AI) with semen from elite bulls, both domestic and international. Some farms are even exploring advanced reproductive technologies like In-Vitro Fertilization (IVF) and embryo transfer. Additionally, cooperatives are actively supporting farmers in improving their herds through AI services and genetic counseling. By prioritizing genetic advancements, these dairy farms are working towards a more sustainable and productive dairy industry.

Climate Resilient Practices: Most of farms in the region predominantly practice loose housing systems, providing cows with spacious barns, fresh water, and natural bedding. Pregnant cows receive special care in dedicated areas. To monitor animal health and behaviour, many farms utilize Radio Frequency Identification (RFID) technology and Internet of Things (IoT). Cooperatives are playing a vital role in promoting loose housing among their members, emphasizing the link between animal welfare and productivity. Additionally, efforts are underway to build climate-resilient housing structures to protect cattle from adverse weather conditions.

Research and Innovation: The dairy industry is embracing technology in Maharashtra to enhance sustainability and efficiency. Innovations like IoT-powered cow health monitoring systems are being used improve milk yield and animal welfare. Digital supply chain management is also being used by some of the private dairy players, which ensures quality and traceability from farm to table. Additionally, platforms connecting consumers to producers foster transparency and support for farmer are also being used.

Challenges Faced by Maharashtra Dairy Farmers

Unavailability of market linkages for manure value added products: Since most of the farmers are already practicing manure management through biogas generation, they were also looking for avenues to prepare and sell manure value added products can be explored by strengthening the. market linkages for the same.

Best Practices and Innovations Observed

Backyard Biogas Plants Supported by Cooperatives: Dairy cooperatives in Maharashtra are empowering small-scale farmers by promoting biogas plant installation. Pune-Katraj Dairy Cooperative collaborated with Sistema.bio for installation of biogas plants and with NDDB to facilitate subsidies through generation of carbon credits, to make the process more affordable. This model allows farmers to significantly reduce cooking fuel costs by utilizing the biogas generated for their needs. Farmers were given proper training to maintain their biogas plants.

Training and Capacity Building: A strong emphasis is placed on farmer training and capacity building in state. Both cooperatives and private dairy companies offer comprehensive programs on various aspects of dairy farming. These programs cover animal nutrition, health, breeding, and sustainable practices like silage preparation and manure management. Additionally, cooperatives organize awareness camps on animal diseases and treatments. By equipping farmers with the necessary knowledge and skills, these initiatives contribute to the overall resilience and sustainability of the dairy sector.

Why Dairy Industry Must Continue to Champion Sustainable Practices in India?

The adoption of sustainable dairy farming practices is not just a necessity for environmental stewardship but also a strategic move for driving economic growth, enhancing social impact, and ensuring long-term competitiveness. Private dairy industries are already making commendable strides in this direction, as observed through regional consultations and state-level deep dives. However, to achieve transformative outcomes, these efforts must accelerate. The benefits of supporting small scare farmers in adopting climate resilient dairy practices includes:

Economic Benefits

Increased Productivity and Reduced Costs: Sustainable practices such as improved feed management, vaccination, and disease prevention reduce disease incidences among livestock, enhancing milk yield. Companies can procure larger milk quantities from individual farms, thereby lowering logistical costs associated with milk collection from dispersed locations.

Achieving Sustainability Goals: By supporting smallholder farmers in adopting climate-resilient practices and also adopting sustainable practices at processing plants, companies can reach closer to their sustainability goals and can enhance their brand value for sourcing sustainable milk.

Social Benefits

Improved Livelihoods for Farmers: Collaborating with smallholder farmers towards sustainable dairying ensures better income stability. This fosters rural economic development and reduces poverty among marginal farmers.

Environmental Benefits

Climate Resilience: Sustainable practices mitigate environmental impacts through reduced emissions, better manure management, and efficient resource use (like water recycling and conservation). These efforts contribute significantly to achieving India's climate goals and support global environmental commitments.

Sustainable Fodder Production: Sustainable fodder production and optimized usage play a pivotal role in improving livestock health and productivity while delivering significant environmental benefits. By enhancing the nutritional quality of fodder, methane emission intensity from enteric fermentation is reduced, contributing to lower greenhouse gas emissions per Liter of milk. Additionally, sustainable practices in fodder cultivation—such as water-efficient cropping, agroforestry integration, and use of organic fertilizers—ensure resource conservation, mitigate soil degradation, and support biodiversity.

Way Forward

Holistic Engagement of Farmers and Farm Systems to Enhance Resilience

In India, smallholder farmers form the backbone of the dairy industry, significantly contributing to the national milk pool. However, a large portion of these farmers remains outside the organized sector, presenting both challenges and opportunities for sustainable dairying. Engaging smallholders is complex due to their widespread dispersion in rural areas, making mobilization and awareness efforts logistically demanding. Limited financial resources and technical knowledge further hinder their ability to adopt climate resilient practices. Additionally, the fragmented and unorganized nature of their supply chains restricts traceability and accountability, while deeply rooted traditional practices create resistance to change.

Despite these hurdles, smallholder farmers offer immense potential for transforming the dairy sector. With over 80 million dairy farmers, even small-scale interventions can create a substantial positive environmental impact. Affordable and straightforward solutions, such as improved fodder and

manure management, can boost productivity without imposing financial strain. Supporting smallholders with resources such as infrastructure, training, and financial assistance not only aids the adoption of climate-resilient practices but also improves milk yields and farmer incomes. Moreover, fostering a sustainable ecosystem enhances the reputation of collaborating companies, positioning them as ethical and environmentally responsible in the eyes of consumers and global markets.

This report outlines the on-ground challenges impeding the adoption of sustainable practices and identifies key interventions to accelerate their uptake. Achieving widespread success will require strong coordination among diverse stakeholders, including industry players, government agencies, cooperatives, technology and solution providers, and research institutions. Together, these efforts can advance climate-resilient dairy initiatives, mitigate the impacts of climate change, and drive the sector toward a sustainable future.

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- Invest in capacity building initiatives and skill development for supply chain participants across the value chain
- Strengthen linkages across the value chain through market access initiatives, thereby reducing losses and increasing farmer incomes

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