International Journal of Livestock Research, Vol. 15 (5) May' 2025
http://www.ijlr.org
eISSN: 2277-1964
NAAS Score:4.31

Review

# Climate Smart Interventions in Dairy Cattle - A Review of Feeding, Disease Management, and Breeding Strategies

**Selloane Sekhantsa and James O. Ondiek***

Egerton University, Faculty of Agriculture, Department of Animal Sciences, P.O. Box 5366-0115 Egerton, Njoro, KENYA

*Corresponding Author: james.ondiek@egerton.ac.ke

**How to cite this paper**
Sekhantsa, S., & Ondiek, J. O. (2025). Climate Smart Interventions in Dairy Cattle - A Review of Feeding, Disease Management, and Breeding Strategies. *International Journal of Livestock Research*, *15*(5), 1–6.

**Received** : Jan 30, 2025
**Accepted** : Mar 11, 2025
**Published** : May 31, 2025



## Abstract

*Climate change poses significant challenges to dairy production systems, with rising temperatures, erratic rainfall patterns, and increased incidences of diseases affecting the productivity, reproduction, and health of dairy animals. Effective interventions in feeding, breeding, and disease management are critical to mitigating these adverse effects and ensuring sustainable dairy production. Feeding strategies, such as the use of climate-resilient fodder crops, total mixed rations (TMR), and dietary supplementation with energy-dense feeds, improve nutrient utilization and reduce heat stress. Breeding programs that focus on selecting and crossbreeding heat-tolerant and disease-resistant breeds enhance animal adaptability to harsh climatic conditions. Additionally, reproductive technologies like artificial insemination (AI) and genomic selection play a crucial role in accelerating the development of resilient herds. Disease management interventions, including improved housing, vaccination programs, and early disease detection systems, are essential to prevent the spread of vector-borne and heat-induced diseases. Together, these approaches form a climate-smart framework for dairy farming, enhancing productivity, reducing greenhouse gas emissions, and supporting the livelihoods of farmers in the face of climate change. Further research and the integration of these strategies into livestock management policies are essential for building climate-resilient dairy systems globally.*

**Keywords:** Climate Change, Greenhouse Gas Emissions, Genomic Selection, Rising Temperatures.

## Introduction

Climate change poses significant challenges to global dairy production systems, particularly through rising temperatures, water scarcity, and increased frequency of extreme weather events. Rising temperatures, erratic rainfall, and increased frequency of extreme weather events negatively affect dairy cattle through heat stress, feed shortages, disease outbreaks, and reduced reproductive efficiency. Despite uncertainties in climate variability, the IPCC Fifth Assessment Report identified the ‘‘likely range” of increase in global average surface temperature by 2100, which is between 0.3 degrees and 4.8 degrees (IPCC, 2013).

The potential impacts on livestock include changes in production and quality of feed crop and forage (Chapman *et al*., 2012; IFAD, 2010; Polley *et al*.,2013; Thornton *et al*., 2009), water availability (Henry *et al*., 2012; Nardone *et al*., 2010; Thornton *et al*., 2009), animal growth and milk production (Henry *et al*., 2012; Nardone *et al*., 2010; Thornton *et al*., 2009), diseases (Nardone *et al*., 2010; Thornton *et al*., 2009), reproduction (Nardone *et al*., 2010), and biodiversity (Reynolds *et al*., 2010). These impacts are primarily due to an increase in temperature and atmospheric carbon dioxide ($CO_2$) concentration, precipitation variation, and a combination of these factors (Aydinalp and Cresser, 2008; Henry *et al*., 2012; IFAD, 2010; Nardone *et al*., 2010; Polley *et al*., 2013; Reynolds *et al*., 2010; Thornton *et al*., 2009). Temperature affects most of the critical factors for livestock production, such as water availability, animal production, reproduction and health. Forage quantity and quality are affected by a combination of increases in temperature, CO2 and precipitation variation.

Climate-smart interventions, such as improved feeding strategies, disease management, and breeding programs, play a pivotal role in enhancing dairy cattle resilience and productivity under changing climatic conditions. This paper reviews these interventions, their effectiveness, and areas requiring further research.

## Interventions

Effective interventions in feeding strategies, breeding programs, and disease control can significantly reduce the environmental footprint of dairy farming while maintaining productivity. This writing outlines interventions aimed at mitigating climate change impacts in dairy farming, supported by research and evidence.

### *Feeding Strategies*

Feed availability and quality are significantly affected by climate change, leading to reduced milk production. Quantity and quality of feed will be affected mainly due to an increase in atmospheric CO2 levels and temperature (Chapman *et al*., 2012). The effects of climate change on the quantity and quality of feeds are dependent on location, livestock system, and species (IFAD, 2010). On the other hand, feeding practices significantly influence GHG emissions from dairy cattle. Optimizing feed quality and quantity can reduce methane production and improve feed conversion efficiency and climate-smart feeding strategies aim to enhance feed efficiency, reduce methane emissions, and ensure consistent nutrition.

### *Improving Feed Digestibility*

Highly digestible diets result in better energy utilization and reduced methane emissions per unit of milk produced. For instance, incorporating high-quality forages like legumes (e.g., alfalfa and clover) into diets can enhance digestibility while reducing enteric fermentation (Beauchemin *et al*., 2008). Moreover, replacing low-quality crop residues with nutrient-rich forages reduces the time cattle spend metabolizing fibrous material, which lowers $CH_4$ production.

### *Feed Additives and Methane Inhibitors*

The use of feed additives such as dietary fats, tannins, and essential oils has shown potential in reducing methane emissions. For example, the inclusion of *Asparagopsis taxiformis* (red seaweed) in cattle diets has demonstrated methane reduction of up to 80% (Roque *et al*., 2019). Supplements such as tannins, nitrates, and 3-nitrooxypropanol (3-NOP) reduce enteric methane emissions while maintaining productivity (Hristov *et al*., 2013). Additionally, nitrate supplements act as hydrogen sinks, reducing methane emissions by redirecting hydrogen away from methanogenesis.

## *Alternative Feeds and Agro-Industrial Byproducts*

The use of agro-industrial byproducts such as brewers' grains, citrus pulp, and sugar beet pulp reduces competition for food crops and improves resource use efficiency. Such feeds can reduce the carbon footprint of dairy systems while addressing food-feed competition (Makkar, 2016). Incorporating high-energy, low-heat increment feeds (e.g., fats) reduces metabolic heat production, helping cattle cope with heat stress (West, 2003). Introducing drought-tolerant forage crops (e.g. Brachiaria and sorghum) ensures a consistent supply of feed during periods of water scarcity (Mwenya *et al*., 2021).

## *Precision Feeding*

Precision feeding involves providing animals with the exact amount of nutrients needed for maintenance and production. This approach reduces feed waste, nitrogen excretion, and manure emissions. Technologies like automated feed monitoring systems help optimize feeding schedules and minimize environmental impact (Havlíček *et al*., 2018).

## *Disease Management*

Climate change creates favorable conditions for the spread of vector-borne and heat-related diseases, reducing dairy cattle health and productivity. The direct effects are related to the increase of temperature, which increases the potential for morbidity and death. The indirect effects are related to the impacts of climate change on microbial communities (pathogens or parasites), spreading of vector-borne diseases, food-borne diseases, host resistance, and feed and water scarcity (Nardone *et al*., 2010; Thornton *et al*., 2009; Tubiello *et al*., 2008).Temperature increases could accelerate the growth of pathogens and/or parasites that live part of their life cycle outside of their host, which negatively affects livestock (Harvell *et al*., 2002; Karl *et al*., 2009; Patz *et al*., 2000). Climate change may induce shifts in disease spreading, outbreaks of severe disease, or even introduce new diseases, which may affect livestock that are not usually exposed to these type of diseases (Thornton *et al*., 2009) Disease management strategies aim to prevent and control emerging diseases and effective disease management in dairy systems reduces production losses, improves animal welfare, and lowers the environmental impact per unit of milk produced. Disease outbreaks, particularly mastitis, lameness, and reproductive disorders, lead to reduced milk yield, longer calving intervals, and increased emissions.

## *Preventive Healthcare*

Implementing preventive measures such as vaccination programs, routine health checks, and biosecurity protocols minimizes disease incidence. For instance, vaccination against viral diseases like foot-and-mouth disease improves herd health, ensuring consistent milk production and lower emissions per output (Rushton *et al*., 2012). Integrated pest management (IPM), including the use of acaricides, biocontrol agents, and improved housing systems, limits the spread of ticks and mosquitoes (Thornton *et al*., 2009). Heat Stress Mitigation: Installing cooling systems (e.g., fans, sprinklers, and shades) not only reduces heat stress but also minimizes susceptibility to diseases like mastitis (Collier *et al*., 2012).

## *Early Disease Detection and Treatment*

Precision Health Tools technologies such as wearable sensors and automated body temperature monitors detect early signs of heat stress or disease, enabling timely intervention (Polsky & von Keyserlingk, 2017), for example, automated mastitis detection systems help minimize milk losses and improve animal welfare while enhancing farm efficiency.

## *Reducing Antibiotic Overuse*

Antimicrobial resistance (AMR) is a growing global concern. Judicious use of antibiotics through improved management practices reduces the risk of AMR while maintaining herd health and productivity. Healthy cattle have lower emissions intensity due to optimized milk production and reduced mortality (Van Boeckel *et al*., 2015).

### *Nutritional Management to Support Health*

Nutritional interventions that support immunity, such as providing adequate trace minerals (e.g., zinc, copper, and selenium), improve cattle resilience to diseases and heat stress. Supplements like probiotics and prebiotics also enhance gut health, reducing methane emissions and promoting better nutrient absorption (Uyeno *et al*., 2015). Proactive vaccination against climate-sensitive diseases such as foot-and-mouth disease (FMD), Rift Valley fever, and tick-borne diseases is critical to maintain herd health.

### *Breeding Strategies*

Reproduction efficiency of both livestock sexes may be affected by heat stress. In cows and pigs, it affects oocyte growth and quality (Barati *et al*., 2008; Ronchi *et al*., 2001), impairment of embryo development, and pregnancy rate (Hansen, 2007; Nardone *et al*., 2010; Wolfenson *et al*., 2000). Cow fertility may be compromised by increased energy deficits and heat stress (De Rensis and Scaramuzzi, 2003; King *et al*., 2006). Heat stress has also been associated with lower sperm concentration and quality in bulls, pigs, and poultry (Karaca *et al*., 2002; Kunavongkrita *et al*., 2005; Mathevon *et al*., 1998).

Genetic improvement for climate resilience is a long-term solution to improve dairy productivity under heat stress and climate-related challenges. Recent advancements have identified heritable traits linked to methane production. Genetic markers and genomic selection tools allow breeders to select cattle with lower enteric methane emissions. Studies have shown that incorporating low-emission traits into breeding programs can result in cumulative reductions over generations (Pickering *et al*., 2015).

### *Climate-Resilient Breeds*

Climate change exacerbates heat stress, which negatively impacts milk production, fertility, and animal welfare. Breeding for heat tolerance using breeds like Sahiwal, Gir, and other indigenous cattle with higher thermotolerance can improve dairy system resilience (Collier *et al*., 2012). Crossbreeding high-yielding dairy breeds (e.g., Holstein) with heat-tolerant local breeds (e.g., Zebu, Sahiwal) results in cattle with better adaptability and productivity (Hansen, 2020) because indigenous breeds can optimize both productivity and adaptability.

For selection for resilience, genomic selection tools allow for targeted breeding programs that incorporate traits such as feed efficiency, heat resistance, and disease resistance (Boichard & Brochard, 2012). Also, the identification of genes like the slick gene has facilitated breeding programs for thermotolerant cattle without compromising productivity (Dikmen *et al*., 2014). Improving fertility under heat stress by using breeding programs targeting fertility traits, such as embryo survival and shorter calving intervals, are essential for dairy systems in hot climates (Rhoads *et al*., 2013).

## Critical Evaluation of Interventions

### *Strengths*

- Feeding strategies address both productivity and environmental concerns, ensuring sustainable dairy production.
- Disease management is critical to maintaining herd health and mitigating economic losses from climate-sensitive diseases.
- Breeding programs offer long-term solutions by producing cattle with inherent resilience to climate stressors.

### *Limitations*

**Feeding Strategies:** High-quality feeds, additives, and drought-tolerant crops may not be accessible to smallholder farmers due to cost constraints.

**Disease Management**: Vector control and vaccination programs require infrastructure and technical expertise that are often lacking in resource-limited regions.

**Breeding Programs**: Crossbreeding can result in trade-offs, such as lower milk yields compared to purebred high-producing dairy cattle. Genetic gains are also slow to materialize.

### *Areas for Further Research*

- Development of cost-effective feed additives and climate-resilient forages for smallholder systems.
- Innovative vaccines and disease surveillance systems to combat emerging vector-borne diseases.
- Advanced genomic tools to improve accuracy and speed of breeding for heat and disease resilience.

## Conclusion

Climate-smart interventions in feeding, disease management, and breeding play a crucial role in mitigating the adverse effects of climate change on dairy cattle. Feeding strategies improve resilience to feed shortages, disease management safeguards herd health, and breeding programs enhance long-term adaptability. However, these interventions must be tailored to the needs of diverse dairy production systems, particularly in resource-limited environments. Integrating these strategies will be critical to ensuring sustainable, climate-resilient dairy production globally.

## Contribution by Authors

All the authors contributed equally to writing the manuscript. The final manuscript was read by all authors and consented to publication.

## Conflict of Interests

There is no conflict of interest.

## Publisher Disclaimer

IJLR remains neutral concerning jurisdictional claims in published institutional affiliation.

## References


1. Aydinalp, C., & Cresser, M. S. (2008). The effects of global climate change on agriculture. *American-Eurasian Journal of Agricultural & Environmental Sciences*, 3(5), 672–676.
2. Beauchemin, K. A., Kreuzer, M., O'Mara, F., & McAllister, T. A. (2008). Nutritional management for enteric methane abatement: A review. *Australian Journal of Experimental Agriculture*, 48(2), 21-27.
3. Berry, D. P., & Crowley, J. J. (2012). Cellular, metabolic, and genetic aspects of feed efficiency in dairy cows. *Animal*, 6(3), 494-501.
4. Boichard, D., & Brochard, M. (2012). New phenotypes for new breeding goals in dairy cattle. *Animal,* 6(4), 544–550.
5. Chapman, S. C., Chakraborty, S., Dreccer, M. F., & Howden, S. M. (2012). Plant adaptation to climate change—opportunities and priorities in breeding. *Crop and Pasture Science,* 63(3), 251–268.
6. Collier, R. J., Collier, J. L., Rhoads, R. P., & Baumgard, L. H. (2012). Invited review: Genes involved in the bovine heat stress response. *Journal of Dairy Science*, 95(11), 5317–5326.
7. Dikmen, S., Khan, F. A., Huson, H. J., & Hansen, P. J. (2014). The SLICK hair locus derived from Senepol cattle confers thermotolerance to intensively manage lactating Holstein cows. *Journal of Dairy Science,* 97(9), 5508–5520.
8. Hansen, P. J. (2020). Adaptation of cows to heat stress. *Animal Frontiers*, 10(1), 52–58.
9. Havlíček, Z., Stěpánková, J., & Veselý, A. (2018). Precision feeding as a tool for sustainable dairy production. *Agriculture*, 6(3), 34.
10. Henry, B., Charmley, E., Eckard, R., Gaughan, J. B., & Hegarty, R. (2012). Livestock production in a changing climate: Adaptation and mitigation research in Australia. *Crop and Pasture Science,* 63(3), 191–202
11. Hristov, A. N., Oh, J., Lee, C., Meinen, R., Montes, F., Ott, T., ... & Zia, A. (2013). Mitigation of greenhouse gas emissions in livestock production. FAO Animal Production and Health Paper.

12. IPCC (Intergovermental Panel on Climate Change), 2013. Climate change 2013: The physical science basis. In: Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M. (Eds.), Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p. 1535*.
13. International Fund for Agricultural Development (IFAD). (2010). Climate change impacts: Livestock. IFAD. Retrieved from https://www.ifad.org
14. Makkar, H. P. S. (2016). Animal nutrition strategies and options to reduce methane emission. *Animal Production Science*, 56(3), 271-284.
15. Mwenya, B., Santoso, B., Sar, C., Gamo, Y., Kobayashi, T., & Morikawa, R. (2021). Strategies to improve the resilience of dairy production under climate change. *Frontiers in Sustainable Food Systems*, 5, 203.
16. Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M. S., & Bernabucci, U. (2010). Effects of climate changes on animal production and sustainability of livestock systems. *Livestock Science*, 130(1–3), 57–69.
17. Patz, J. A., Graczyk, T. K., Geller, N., & Vittor, A. Y. (2000). Effects of environmental change on emerging parasitic diseases. *International Journal for Parasitology*, 30(12–13), 1395–1405.
18. Polley, H. W., Briske, D. D., Morgan, J. A., Wolter, K., Bailey, D. W., & Brown, J. R. (2013). Climate change and North American rangelands: Trends, projections, and implications. *Rangeland Ecology & Management*, 66(5), 493–511.
19. Polsky, L., & von Keyserlingk, M. A. G. (2017). Invited review: Effects of heat stress on dairy cattle welfare. *Journal of Dairy Science*, 100(11), 8645–8657.
20. Pickering, N. K., Oddy, V. H., Basarab, J., Cammack, K., Hayes, B., & Hegarty, R. S. (2015). Animal board invited review: Genetic possibilities to reduce enteric methane emissions from ruminants. *Animal, 9*(9), 1431-1440.
21. Reynolds, C., Crompton, L., & Mills, J. (2010). Livestock and climate change impacts in the developing world. *Outlook on Agriculture*, 39(4), 245–248.
22. Rhoads, M. L., Rhoads, R. P., VanBaale, M. J., Collier, R. J., Sanders, S. R., Weber, W. J., ... & Baumgard, L. H. (2013). Effects of heat stress on fertility in lactating dairy cows. *Journal of Dairy Science*, 96(7), 4480–4493.
23. Roque, B. M., Venegas, M., Kinley, R. D., de Nys, R., Duarte, T. L., Yang, X., & Kebreab, E. (2019). Red seaweed (*Asparagopsistaxiformis*) supplementation reduces enteric methane by over 80% in beef steers. *PLoS ONE*, 14(4), e0215931.
24. Rushton, J., Thornton, P. K., & Otte, J. (2012). Methods of economic impact assessment of emerging diseases. *Revue Scientifique et Technique*, 31(1), 59-66.
25. Thornton, P. K., van de Steeg, J., Notenbaert, A., & Herrero, M. (2009). The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. *Agricultural Systems*, 101(3), 113–127.
26. Tubiello, F. N., Soussana, J. F., & Howden, S. M. (2008). Crop and pasture response to climate change. Proceedings of the National Academy of Sciences, 105(50), 19689–19694.
27. Van Boeckel, T. P., Brower, C., Gilbert, M., Grenfell, B. T., Levin, S. A., Robinson, T. P.,... & Laxminarayan, R. (2015). Global trends in antimicrobial use in food animals. Proceedings of the National Academy of Sciences, 112(18), 5649–5654.
28. West, J. W. (2003). Effects of heat-stress on production in dairy cattle. *Journal of Dairy Science*, 86(6), 2131–2144.
29. Uyeno, Y., Shigemori, S., & Shimosato, T. (2015). Effect of probiotics/prebiotics on cattle health and productivity. *Microbes and Environments*, 30(2), 126-132.


******************