



NextVets Magazine

Volume1(Issue1) June – August 2026

Designing the Next-Generation Climate-Smart Animal Health System for Indian Conditions

Manisha Choudhary and *Ajay Kumar

Dang

Animal Physiology Division

ICAR - National Dairy Research Institute

Karnal, Haryana, India

Email id: ajaydang@icar.gov.in

Received: July 2026

Published: July 2026

©All rights are reserved by **Dr. Manisha Choudhary**

Introduction:

Climate change has emerged as one of the most significant global challenges influencing agriculture, livestock production, and food security, with rising ambient temperatures, erratic rainfall, prolonged droughts, floods, and more frequent extreme weather events disrupting livestock production systems worldwide; India, home to the world's largest livestock population, is particularly vulnerable because a substantial share of its dairy and livestock sector is managed by smallholder farmers who depend heavily on natural resources, and since livestock underpins rural livelihoods, nutritional security and the national economy, safeguarding animal

health under changing climatic conditions has become a national priority. Climate change affects animal health through both direct and indirect pathways: direct effects include heat stress, dehydration, altered metabolic function, reproductive inefficiency and increase mortality during extreme weather events, while indirect effects stem from shifting distributions of vectors and pathogens, deteriorating feed and water quality, shrinking fodder availability, and rising antimicrobial resistance driven by disease pressure, and together these pressures erode productivity, profitability, animal welfare, and the overall resilience of livestock farming systems, making traditional animal healthcare

approaches insufficient to address the rapidly evolving climate-related risks. The concept of a Climate-Smart Animal Health System (CSAHS) responds to this gap by integrating climate adaptation, disease prevention, precision livestock management, sustainable resource use, and digital technologies to strengthen livestock resilience while minimizing environmental impact, aligning with the broader goals of climate-smart agriculture by improving productivity, enhancing adaptation to climate variability, and reducing greenhouse gas emissions; for a country like India, where livestock production is diverse and largely smallholder-driven, the next-generation climate-smart animal health system must therefore combine advanced technologies with indigenous knowledge, policy support, and farmer-centred extension services.

Climate Change and Animal Health Challenges in Indian Conditions

Heat Stress and Declining Productivity:

Heat stress represents one of the most critical climate-induced challenges affecting Indian livestock, particularly dairy cattle and buffaloes. Elevated temperature-humidity index (THI) reduces feed intake, milk yield, reproductive efficiency, immune competence, and overall animal welfare. High-producing crossbred dairy cattle are especially

susceptible because of their greater metabolic heat production than indigenous breeds. Heat stress also alters endocrine and metabolic pathways, increases oxidative stress, and suppresses immune responses, making animals more vulnerable to infectious diseases. With climate projections indicating more frequent and prolonged heat waves across India, effective heat stress mitigation will become increasingly important for sustaining dairy production.

Emerging and Re-emerging Infectious Diseases:

Climate change is altering the epidemiology of infectious diseases by modifying the survival, transmission, and geographical distribution of pathogens and vectors. Increasing temperatures and changing rainfall patterns facilitate the expansion of vector populations such as ticks, mosquitoes, and biting flies, leading to a higher incidence of diseases including babesiosis, theileriosis, anaplasmosis, bluetongue, Japanese encephalitis, and lumpy skin disease. Extreme weather events also disrupt biosecurity measures and animal movement patterns, increasing the risk of disease outbreaks. Strengthening surveillance systems and predictive disease forecasting has therefore become essential for early detection and rapid response.

Water Scarcity, Feed Shortages, and Nutritional Stress:

Erratic rainfall, droughts, and land degradation reduce the availability and quality of fodder resources, resulting in nutritional deficiencies and impaired animal health. Heat stress further increases water requirements while reducing voluntary feed intake, creating a negative energy balance that affects growth, milk production, and reproductive performance. Climate-induced fluctuations in crop production also influence feed prices and availability, disproportionately affecting resource-poor livestock keepers. Ensuring year-round access to climate-resilient fodder resources, efficient water management, and balanced nutrition is therefore fundamental to climate-smart livestock production.

Antimicrobial Resistance and Biosecurity Challenges:

Climate-related disease outbreaks often lead to indiscriminate use of antibiotics, accelerating the development of antimicrobial resistance (AMR). The emergence of resistant pathogens threatens both animal and public health and highlights the need for judicious antimicrobial use, improved vaccination strategies, strengthened biosecurity, and disease prevention programs. Climate-smart animal health systems should

prioritize preventive healthcare rather than relying primarily on therapeutic interventions.

Constraints of Smallholder Livestock Farming:

More than two-thirds of India's livestock is reared by small and marginal farmers who have limited access to veterinary healthcare, climate information, quality breeding services, and modern technologies. Financial constraints, fragmented landholdings, poor infrastructure, and inadequate extension services further reduce their capacity to adapt to climate change. Consequently, climate-smart animal health interventions must be affordable, scalable, locally adaptable, and supported by strong institutional mechanisms to ensure widespread adoption across diverse agro-climatic regions.

Components of a Next-Generation Climate-Smart Animal Health System

Climate-Resilient Livestock Breeding:

Developing livestock populations that can withstand climatic stress while maintaining productivity is fundamental to a climate-smart animal health system. Indigenous Indian breeds such as Sahiwal, Gir, Tharparkar, Red Sindhi, and Murrah buffalo possess superior thermotolerance, disease resistance, and adaptability to harsh environments compared with many exotic

breeds. Future breeding programs should integrate conventional selection with genomic tools to identify genetic markers associated with heat tolerance, disease resistance, feed efficiency, and reproductive performance. Marker-assisted selection, genomic selection, and gene-editing technologies can accelerate the development of climate-resilient animals without compromising productivity. Conservation of indigenous germplasm should remain a national priority because these breeds represent valuable genetic resources for climate adaptation.

Precision Livestock Farming and Smart Monitoring:

The rapid advancement of digital technologies has transformed livestock management through Precision Livestock Farming (PLF). Smart sensors, wearable devices, accelerometers, rumination monitors, GPS collars, and automated milk recording systems enable continuous monitoring of animal behaviour, physiology, and production. These technologies provide real-time information on body temperature, activity patterns, feed intake, rumination, heart rate, and milk yield, allowing farmers to detect health problems before clinical symptoms become evident.

Infrared thermography (IRT) has emerged as a promising non-invasive tool for

monitoring thermal stress, inflammation, mastitis, lameness, and animal welfare. By detecting subtle changes in body surface temperature, IRT facilitates early diagnosis while minimizing animal handling and stress. Artificial intelligence (AI) algorithms integrated with thermal imaging, wearable sensors, and farm management software can automatically identify abnormal physiological responses and generate timely alerts for farmers and veterinarians. Such precision technologies improve disease detection, reduce economic losses, and support evidence-based management decisions.

Early Disease Surveillance and Climate Forecasting:

Climate change increases the frequency of emerging and re-emerging animal diseases, making proactive surveillance systems essential. The next-generation animal health system should integrate meteorological information, remote sensing, Geographic Information Systems (GIS), epidemiological databases, and AI-based predictive models to forecast disease outbreaks before they occur. Weather variables such as temperature, humidity, rainfall, and vegetation indices can be combined with disease surveillance data to predict the seasonal occurrence of vector-borne and infectious diseases.

Digital disease reporting through mobile applications, cloud-based databases, and centralized surveillance platforms can facilitate rapid communication between farmers, veterinarians, diagnostic laboratories, and government agencies. Such integrated surveillance systems would enable early warning, targeted vaccination campaigns, and timely implementation of biosecurity measures.

Digital Veterinary Services and Telemedicine:

Digital veterinary healthcare has become increasingly important, particularly in remote rural areas where veterinary infrastructure is limited. Telemedicine platforms, mobile veterinary applications, video consultations, electronic health records, and decision-support tools allow farmers to obtain expert advice without travelling long distances. Mobile-based advisory services can also provide real-time recommendations regarding heat stress management, disease prevention, vaccination schedules, nutrition, and reproductive management based on prevailing weather conditions. The integration of digital platforms with livestock identification systems and electronic medical records will improve continuity of healthcare while facilitating

nationwide disease surveillance and livestock management.

One Health Approach:

Climate change affects the health of animals, humans, and ecosystems simultaneously. Therefore, the One Health framework should form the foundation of future climate-smart animal health systems. This interdisciplinary approach promotes collaboration among veterinarians, physicians, environmental scientists, epidemiologists, wildlife experts, and policymakers to address zoonotic diseases, antimicrobial resistance, food safety, and environmental sustainability.

Strengthening coordination between the animal health, public health, wildlife, and environmental sectors will improve preparedness for emerging zoonotic diseases while supporting national and global health security.

Vaccination, Biosecurity, and Preventive Healthcare:

Preventive healthcare remains the most cost-effective strategy for climate resilience. Climate-smart animal health systems should prioritize strategic vaccination programmes, routine health monitoring, quarantine procedures, vector control, sanitation, and farm biosecurity to minimize disease transmission. AI-assisted risk assessment models can help identify high-risk areas and optimize vaccination

schedules according to climatic conditions and disease forecasts. Reducing unnecessary antibiotic use through preventive health programmes will also contribute to controlling antimicrobial resistance and improving food safety.

Climate-Smart Housing, Welfare and Nutrition:

Improved housing design plays a critical role in reducing heat stress and enhancing animal welfare. Climate-smart livestock shelters should incorporate adequate ventilation, thermal insulation, shaded resting areas, evaporative cooling systems, foggers, sprinklers, fans and access to clean drinking water. These interventions reduce physiological stress, improve feed intake, and sustain milk production during hot weather.

Nutritional management is equally important for enhancing resilience.

support systems. These platforms can predict heat stress risk, optimize feeding schedules, recommend cooling strategies, identify disease outbreaks, and assist veterinarians in diagnosis and treatment planning.

Machine learning algorithms continuously improve prediction accuracy by analysing large datasets generated from commercial farms. Such intelligent systems reduce management costs, improve resource utilization, and support climate-

Precision feeding strategies involving balanced ration formulation, climate-resilient fodder crops, silage production, hydroponic fodder, feed additives, antioxidants, electrolytes, probiotics, and methane-mitigating supplements can improve health, productivity, and environmental sustainability. Integration of nutritional interventions with precision livestock technologies enables individualized feeding programmes based on animal requirements, physiological status, and environmental conditions.

Artificial Intelligence-Based Decision Support Systems

Artificial intelligence has the potential to revolutionize animal healthcare by integrating weather forecasts, sensor data, production records, disease surveillance information, and genomic databases into comprehensive decision-resilient livestock production under diverse Indian farming conditions.

Future Roadmap:

The future climate-smart animal health system should be proactive, predictive, and data-driven. Artificial intelligence (AI), machine learning, big data analytics, cloud computing, and the Internet of Things (IoT) will increasingly support continuous health monitoring and precision decision-making at both farm and national levels. AI-powered algorithms

capable of integrating physiological data, environmental conditions, and production records can provide early warnings for heat stress, disease outbreaks, and reproductive disorders, allowing timely interventions. The concept of Smart Livestock Villages can play a transformative role by integrating digital veterinary services, renewable energy, climate-resilient infrastructure, precision feeding, and automated environmental monitoring into rural livestock production systems. Such villages would demonstrate sustainable livestock farming while improving farmers' incomes and resilience to climate variability.

Conclusion:

Climate change presents unprecedented challenges to animal health, livestock productivity, and food security in India. Rising temperatures, changing disease dynamics, feed and water scarcity, and increasing environmental stress require a paradigm shift from conventional veterinary healthcare toward integrated climate-smart animal health systems. The

next-generation of animal healthcare must combine climate-resilient breeding, precision livestock farming, artificial intelligence, digital disease surveillance, One Health principles, preventive healthcare, climate-smart nutrition, and animal welfare-oriented management practices.

India possesses unique strengths in its rich indigenous livestock genetic resources, extensive veterinary infrastructure, and expanding digital ecosystem. Harnessing these resources through coordinated policies, technological innovation, interdisciplinary research, and farmer-centred extension programmes will be essential for building resilient livestock production systems. Ultimately, designing a climate-smart animal health system is not only an investment in livestock productivity but also a strategic step toward achieving sustainable agriculture, rural prosperity, environmental conservation, and national food and nutritional security in an era of climate change.

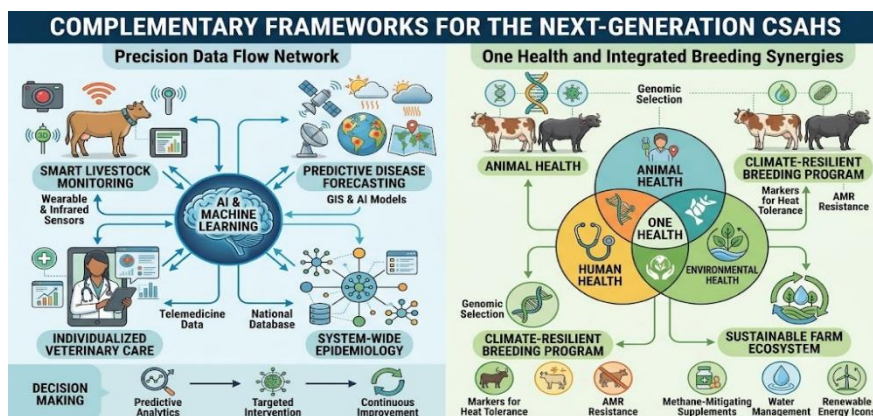


Figure 1. A comprehensive framework mapping real-time data, AI analytics, and One Health principles to build a climate-resilient animal health system (CSAHS) for India

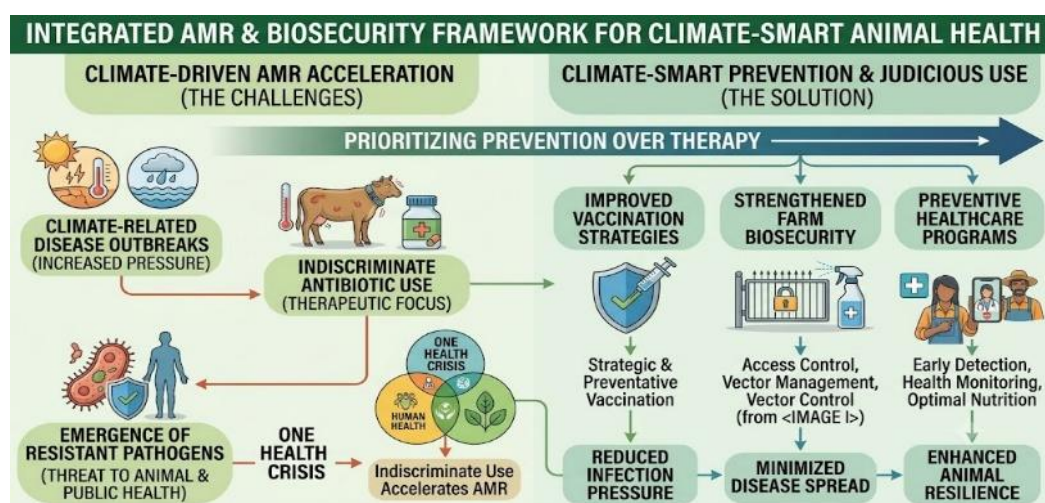


Figure 2. An integrated framework shifting from climate-driven antimicrobial overuse toward proactive biosecurity, strategic vaccination, and preventive animal healthcare

References:

Please contact the corresponding author.