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RESHAPING ANIMAL HEALTH MANAGEMENT

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TRANSFORMING LIVESTOCK MANAGEMENT IN INDIA

Livestock sector is the backbone of the rural economy. Besides contributing to the national GDP, the sector has been a strong pillar of livelihood to millions of small and marginal farmers. However, disease outbreaks, poor veterinary access, and low productivity remain pressing challenges. Although India is vehemently fighting against these threats through government funded vaccinations, mobile veterinary units and bridging infrastructural lacunae, more focus must be laid on screening, monitoring and evaluation. In this context, digital technologies are emerging as game-changers in monitoring and managing animal health, offering scalable solutions to enhance disease surveillance, treatment, and productivity. One of the most promising advancements is the use of Artificial Intelligence (AI) and Big Data in disease prediction and early detection. Start-ups and research institutions are leveraging AI-powered algorithms to analyse animal behaviour, predict disease outbreaks, and suggest timely interventions. For instance, machine learning models can process data from wearable health trackers on dairy cattle, helping farmers detect early signs of mastitis or metabolic disorders.

Blockchain technology is also being explored to ensure transparency in vaccine distribution and supply chain management. By providing a tamper-proof record of vaccination histories, blockchain can help track disease outbreaks and prevent counterfeiting of veterinary drugs. Additionally, Internet of Things (IoT) sensors are transforming animal husbandry by enabling continuous monitoring of livestock health and environment conditions. IoT-enabled smart collars can track vital health parameters like body temperature and activity levels, sending alerts to veterinarians if abnormalities are detected.

Government initiatives are also playing a crucial role in integrating digital solutions into animal healthcare. The National Animal Disease Control Programme (NADCP) has incorporated digital record-keeping for livestock vaccination and disease surveillance, ensuring better disease management. Furthermore, telemedicine services for livestock, introduced in various states, allow farmers to consult veterinarians through video calls, reducing treatment delays.

Despite these advancements, challenges such as digital illiteracy, lack of infrastructure, and affordability hinder widespread adoption. To bridge this gap, public-private partnerships and policy incentives are essential for scaling up digital veterinary solutions.

The future of India's livestock sector lies in the successful integration of technology-driven animal healthcare that has the potential in ensuring higher productivity, disease prevention, and economic stability for millions of farmers. As digital innovations continue to evolve, India has a unique opportunity to lead the way in smart livestock management, transforming its rural economy through enhanced animal health.

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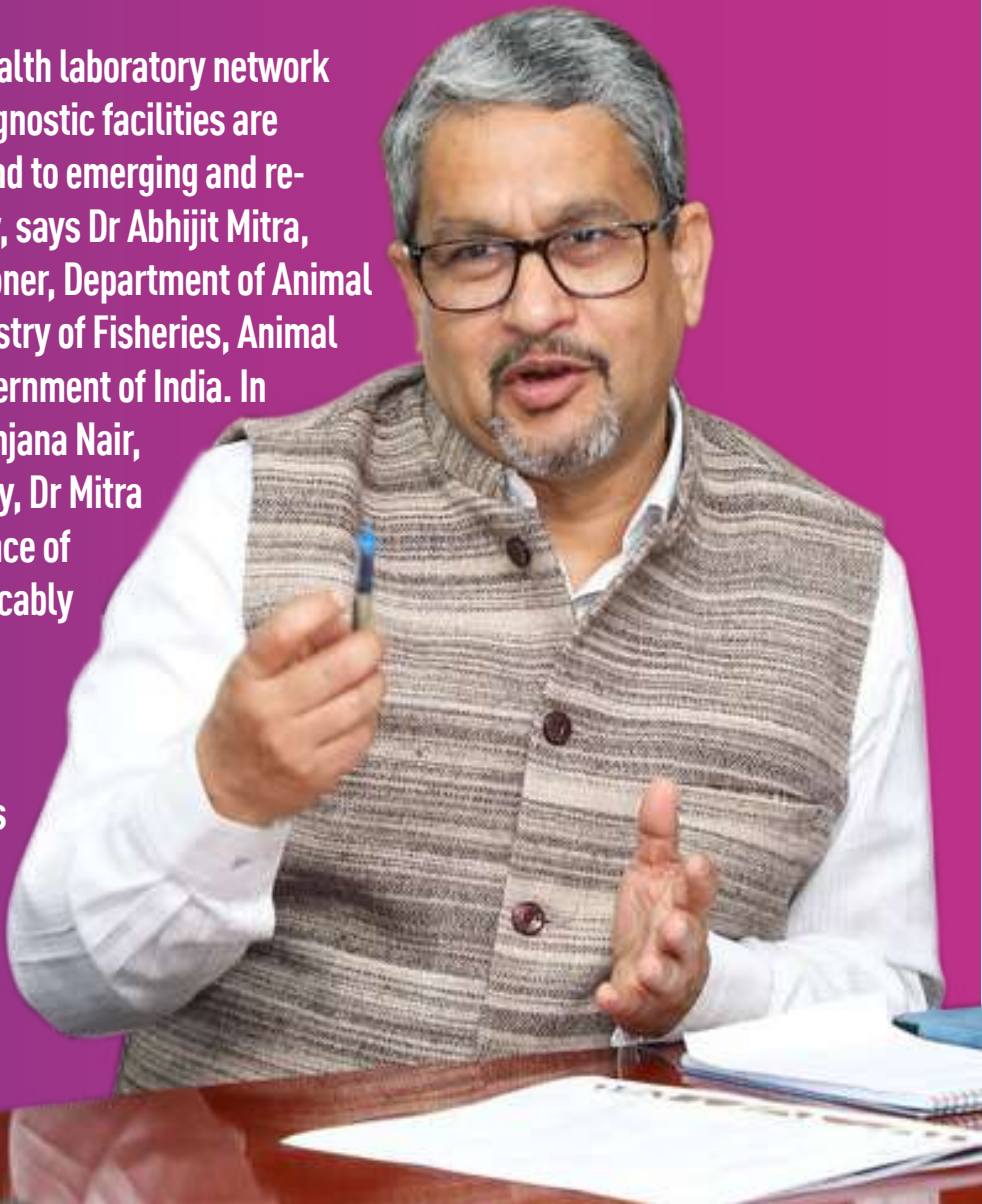
tête-à-tête with Anjana

'VACCINATION AND SURVEILLANCE PROGRAMS - CENTRAL TO INDIA'S ANIMAL HEALTH STRATEGY'

"Strengthening the animal health laboratory network is a priority, ensuring that diagnostic facilities are upgraded to detect and respond to emerging and re-emerging diseases effectively, says Dr Abhijit Mitra, Animal Husbandry Commissioner, Department of Animal Husbandry and Dairying; Ministry of Fisheries, Animal Husbandry, and Dairying, Government of India. In an exclusive interview with Anjana Nair, Group Editor, Agriculture Today, Dr Mitra delves deeper into the relevance of animal health and how inextricably it is linked to the livestock production and productivity. He also elaborates on the various government initiatives and proposes a slew of recommendations to further strengthen the segment.



tête-à-tête with Anjana

How does animal health directly impact livestock production and productivity?

Livestock production and productivity depend on key factors such as breeding, nutrition, management, and animal health. While animal husbandry is economically viable, disease outbreaks can severely impact farmers' earnings. Disease outbreak can either lead to mortality or morbidity. Diseases cause mortality or reduce productivity, turning animals into liabilities by consuming resources without yielding returns. Losses from diseases such as Foot and Mouth Disease (FMD) and Brucellosis are substantial, making disease prevention a priority. According to available literature, FMD alone causes an annual economic loss of up to ₹200 billion, while Brucellosis results in losses of ₹32 billion. Improved feeding, good animal husbandry practices, and vaccination play a significant role in mitigating these losses.

What is the extent of vaccination coverage in India?

India is among the few countries funding 100% vaccination for four major livestock diseases—FMD and Brucellosis in bovines, Peste des Petits Ruminants (PPR) in goats, and Classical Swine Fever (CSF) in pigs. Under the LHDCP program, the government centrally procures vaccines and supports vaccination logistics, awareness, and cold chain infrastructure.

As per recent data, 107.34 crore, 4.39 crore, 20.40 crore, and 0.67 crore vaccine doses have been administered for FMD, Brucellosis, PPR, and CSF, respectively. We have completed four rounds of FMD vaccination, achieving over 96% coverage in Round IV. Further, FMD Rounds V and VI are ongoing in various States with nearly 14.89 Crores and 2.29 Crores vaccinations done respectively.

India has a strong sero-monitoring and sero surveillance mechanism. Incidence of FMD has been significantly reduced, particularly in the last 5 years. So is the case with Brucellosis, PPR and CSF.

Could you elaborate on the key government policies and schemes aimed at enhancing animal health in India?

India is among the few countries funding 100% vaccination for four major livestock diseases—FMD and Brucellosis in bovines, Peste des Petits Ruminants (PPR) in goats, and Classical Swine Fever (CSF) in pigs

The Livestock Health and Disease Control Programme (LHDCP) is the key scheme that ensures animal health. Apart from the vaccination initiatives described earlier, the Assistance to States for Control of Animal Diseases (ASCAD) supports the control of state-prioritized exotic, emergent, and zoonotic animal diseases. The funding pattern is 60:40 between the Centre and State, 90:10 for hilly and North Eastern States, and 100% for Union Territories (UTs). As of January 2025, more than 27.21 crore cattle have been vaccinated/re-vaccinated against Lumpy Skin Disease across the country.

Through awareness programs, the Department of Animal Husbandry and Dairying (DAHD) has been relentlessly working to promote good animal husbandry practices and biosecurity measures.

Mobile Veterinary Units (MVUs) have revolutionized doorstep veterinary services, with each unit staffed by a veterinarian and capable of performing minor procedures. Under the scheme, the cost of the vehicle and the recurring expenses for the veterinary doctor, attendant, driver, and call centre are covered. Currently, around 4,016 MVUs operate nationwide, and efforts are underway to expand this through a Public-Private Partnership (PPP) model.

Pashu Aushadhi is a new component added to the recently approved realigned LHDCP scheme. It includes a provision of ₹75 crore for two years (2024-25 and 2025-26) to ensure the availability of high-quality and affordable generic veterinary medicines and to provide incentives for the sale of medicines under the *Pashu Aushadhi* component.

Besides these efforts, we are also exploring the feasibility of creating disease-free zones, particularly for Foot and Mouth Disease (FMD), to facilitate safe trade and enhance livestock productivity. Additionally, India has already established nearly 32 WOAH-endorsed Highly Pathogenic Avian Influenza (HPAI)-free poultry compartments, promoting international trade and exports. India is also firmly committed to the global initiative of eradicating Peste des Petits Ruminants (PPR) by 2030, aligning with international disease control strategies.

A robust disease control strategy requires a well-equipped laboratory network for timely diagnosis and surveillance. Strengthening the animal health laboratory network is a priority, ensuring that diagnostic facilities are upgraded to detect and respond to emerging and re-emerging diseases effectively. India is also focusing on increasing the number of WOAH/FAO reference laboratories, which will not only enhance national diagnostic capabilities but also establish India as a global leader in veterinary diagnostics and disease management.

Please elaborate on skill development in this sector.

The Government of India has been proactive in strengthening the skills of veterinary professionals. Besides continued veterinary education, the department has developed a structured skill framework to enhance capacity building in the sector.

The department is engaging *Pashu Sakhis* and equipping them with additional training to serve as A-HELP workers (Agent for Health and Extension of Livestock Production) under the nationwide A-HELP model. As of now, a total of 6,398 A-HELP workers have been trained across 15 states and are actively serving in their respective jurisdictions.

This community-driven approach not only enhances last-mile veterinary service delivery but also empowers women by providing them with technical training and continuous support. By equipping them with the necessary skills, the initiative enables them to generate demand for inputs and deliver essential primary veterinary services to farmers, fostering both rural entrepreneurship and improved animal health management.

What is the feed situation for the livestock sector?

India continues to face with a significant feed and fodder shortage, with the area under fodder cultivation remaining stagnant for decades. Despite the rising demand for livestock feed, fodder crops occupy only 4-5% (8.47 million hectares) of the total cropped area, as food and cash crops dominate agricultural land use. Low productivity remains a concern due to suboptimal agronomic practices and outdated fodder varieties. A key challenge is the limited availability of quality certified fodder seeds. Against an estimated demand of 2.7 lakh tons, only 45,000–50,000 tons are available, meeting just 25-30% of the requirement. Expanding the adoption of high-yield fodder varieties and boosting certified seed production could significantly enhance productivity, as certified seeds have demonstrated a 25–30% yield increase. Furthermore, nearly 200 million hectares of non-arable land hold untapped potential for fodder production.

To address these challenges, the National Livestock Mission (NLM) under the Department of Animal Husbandry and Dairying is actively promoting entrepreneurship in feed and fodder production, including silage and Total Mixed Ration (TMR), grading and seed processing infrastructure, quality fodder seed production, and fodder cultivation on both non-forest and forest lands. Under the Quality Fodder Seed Production initiative, 1.03 lakh tons of quality fodder seed have been produced since 2021-22, covering 20.63 lakh hectares, with an expected yield of 1,134.65 lakh metric tons of nutritious green fodder.

The Entrepreneurship Development Programme (EDP) under NLM provides up to 50% subsidy to entrepreneurs establishing fodder processing units to bridge the demand-supply gap. So far, 116 feed and fodder units have been promoted with a total investment of ₹108 crore, creating a production capacity of 4.34 lakh metric

tons per annum. Additionally, the Animal Husbandry Infrastructure Development Fund (AHIDF) facilitates large-scale feed manufacturing by offering loans covering up to 90% of project costs, with a 3% interest subvention for up to eight years.

The impact of these initiatives has been significant. A total of 160 feed plants have been established, contributing to a total feed production capacity of 115.70 lakh metric tons per annum. Investments amounting to ₹2,931.38 crore have been leveraged in the sector and a total of 11 fodder plants have been established, contributing to a fodder production. capacity of 70,451 metric tons per annum. Investments amounting to ₹22.06 crore have been leveraged. The direct employment generated under the AHIDF scheme is 17,030 and farmers benefitted are 7.21 Lakhs. These efforts collectively aim to bridge the fodder deficit, improve feed availability, and enhance livestock productivity, ensuring a more resilient and sustainable livestock sector.

The One Health approach emphasizes the interconnectedness of human, animal, and environmental health. How is India integrating this concept into its animal health policies to tackle zoonotic diseases and antimicrobial resistance?

65% of diseases are zoonotic, and every pandemic in the past century has had an animal link. To enhance animal health security and pandemic preparedness, the department has launched a $25 million G20 Pandemic Fund project focused on preventing and responding to zoonotic threats. Key interventions include integrated disease surveillance, early warning systems, and strengthened diagnostic capabilities through advanced Laboratory Information Management Systems (LIMS) and Laboratory Quality Management Systems (LQMS). Meta-genomic and environmental surveillance are being expanded for early pathogen detection. Capacity-building efforts emphasize data analytics, risk assessment, and communication to support informed decision-making. Regional cooperation is being reinforced through cross-border collaborations, while community engagement empowers local stakeholders in disease prevention.

India has integrated digital animal identification through Pashu Aadhaar, enabling real-time tracking and efficient livestock management.

To combat the growing challenge of antimicrobial resistance (AMR), the department is actively working with stakeholders and ministries under the leadership of NITI Aayog to finalize NAP 2.0. Strengthening antimicrobial stewardship, the Standard Veterinary Treatment Guidelines (SVTGs) promote best practices in veterinary care and responsible antimicrobial use. The Poultry Disease Action Plan prioritizes biosecurity, surveillance, and vaccination, while the Crisis Management Plan (CMP) ensures rapid outbreak response. National Action Plans for Avian Influenza, Glanders, and African Swine Fever further reinforce targeted control strategies.

Addressing existing gaps in surveillance, laboratory infrastructure, risk assessment, and community engagement remains a priority. A joint task force, comprising the Department of Animal Husbandry, Ministry of Health & Family Welfare, and Ministry of Environment, Forest and Climate Change, is working to handle HPAI outbreaks under a unified One Health approach.

What role do emerging technologies such as artificial intelligence, biotechnology, and digital monitoring play in improving disease surveillance and overall livestock health management in India?

India has integrated digital animal identification through Pashu Aadhaar, enabling real-time tracking and efficient livestock management. The Bharat Pashudhan Livestock Data Stack further enhances this system by streamlining vaccination records, artificial insemination, ownership changes, disease reporting, and e-prescriptions. This robust digital infrastructure allows field workers to upload and monitor crucial livestock data in real time, ensuring seamless tracking through unique animal IDs.

ICAR-NIVEDI has developed the National Animal Disease Referral Expert System (NADRES v2), an advanced software application that provides early warnings on disease outbreaks and climate-related risks. Leveraging artificial intelligence and machine learning, the system forecasts livestock disease outbreaks across all Indian districts, enabling stakeholders to implement timely prevention and control measures.

Vaccination and surveillance programs remain central to India's animal health strategy, reinforcing disease control efforts. By integrating digital innovations with advanced forecasting tools, India is fortifying its livestock sector, ensuring proactive disease management, and enhancing overall productivity.

What is your outlook about the country's livestock sector?

I see many opportunities. Our livestock is unique. Most of the livestock farmers in India are small holders. India's livestock sector holds immense potential. Future priorities include increasing farmer awareness, strengthening doorstep veterinary services, improving biosecurity, and integrating digital traceability systems. Expanding veterinary infrastructure, training community-level health workers, and establishing a **comprehensive national disease surveillance program** with an advanced lab network will further strengthen the sector.

ONE WORLD ONE HEALTH HEALTHY ANIMALS MEAN HEALTHY HUMANS

The earliest human contact with animals, besides being a struggle for survival in search of food, is also a saga of bravery; taming and then domesticating the wild. What is less known is that this symbiotic relationship with the animals is the historical onset of most human diseases.

One Health – Past & Present

The ancient Greek philosopher and physician Hippocrates, considered one of the most outstanding figures in the history of medicine and traditionally referred to as the "Father of Medicine" in recognition of his lasting contributions to the field, was the first in the recorded history of civilization to recognise the relationship between human and animal health. The central idea of Hippocratic philosophy is the principle of wholeness, that knowledge of nature is possible only when it is correctly approached as a whole; in a nutshell it recognizes that human health, animal health and environmental health are part of a whole body. Hippocrates advocated that administration of medicine should rest on the foundation of this holistic understanding. The concept of "One Health", though a recent entrant in the medical lexicon is, in fact, a recognition of what Hippocrates said circa 400 BC in his treatise "*On Airs, Waters and Places*" urging physicians to consider all aspects of a patient's life including the environment. Disease, according to him, was an outcome of an imbalance between man and environment. "One Health" is an approach that recognizes that the health of people is closely connected to the health of animals and our environment which is shared by all.

It is estimated that zoonotic diseases account for nearly two billion cases per year resulting in more than two million deaths; more than HIV/AIDS and diarrhoea.

Tarun Shridhar
Director General, Indian Chamber of Food and Agriculture
Former Secretary, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India

The recent Covid pandemic should serve as a powerful lesson that animals, which act as hosts, agents, and carriers of disease, are the important medium causing and perpetuating human illness. According to the World Health Organisation (WHO), as also the World Organisation for Animal Health (WOAH), 60% of existing human infectious diseases are zoonotic i.e., they are transmitted to humans from animals either through direct contact or through food, water and environment; 75% of emerging infectious human diseases have an animal origin. Of the five new human diseases appearing every year, three originate in animals. If this is not scary enough, 80% of biological agents with potential bio-terrorist use are zoonotic pathogens. It is estimated that zoonotic diseases account for nearly two billion cases per year resulting in more than two million deaths; more than HIV/AIDS and diarrhoea. One fifth of premature

deaths in poor countries are attributed to diseases transmitted from animals to humans. And all the pandemics in recent history, including the recent one which threw our lives out of gear, have an origin in a zoonotic pathogen.

Health and Disease Surveillance

This should surely build a strong case for strengthening the veterinary institutions and services. The most effective and economic approach to protecting human health is to control zoonotic pathogens at their animal source. Not only does it call for close institutionalized and harmonized collaboration at local, regional and global level between the veterinary, health and environmental governance, but also greater investment in the animal health infrastructure. Developing countries like ours have much greater stakes in strong One Health systems on account of small agricultural holdings and mixed farming systems resulting in uncomfortably close proximity of animals and humans. This builds a strong case for health and disease surveillance to incorporate domestic animals, livestock and poultry.

Role of Veterinarians

Humans require a regular diet of animal protein from milk, eggs, meat etc. Protein deficiency is a public health concern. Thus loss of food animals on account of their poor health or disease too becomes a public health issue even though there may not be any disease transmission; we lose 20% of our animals this way. A veterinarian today, therefore, protects the health of both animals and people. Moreover, as a manager of animal husbandry, he also plays critical roles in rural livelihoods and economy, environmental protection, food safety, and hence public health.

Where do we stand in attaining the goal of a robust "One Health" regime; and how strong and adequate is our animal health governance, especially in comparison with the health sector? After all "One Health" calls for a hand in hand relationship.

We have about 13.90 lakh doctors at a doctor:patient ratio of 0.74:1000 for a population of 1.40 billion. The WHO recommendation is a minimum doctor patient ratio of 1:1000. However, if we include the registered AYUSH doctors, we have one doctor for every 834 people, thus having a much better ratio than recommended. Against this we have a meagre about 82,000 veterinarians tending to the health and disease management of an identical size of livestock and poultry population.

Animal health impacts everyone's health and hence should be at the heart of public health systems

What should be the ideal or even reasonable ratio is a question no one has asked, much less answered since the year 1976 when the National Commission on Agriculture recommended one veterinary doctor per 1000 adult cattle/animal unit (ACU). Please note that unlike doctors, the ratio in case of veterinarians is not per animal but determined per cattle/animal unit. What is this artificially and quite illogically created unit? Here is what it says. One ACU equals one cattle or buffalo; ten sheep/goats constitute one unit, and similarly five pigs are equivalent to one cattle unit. Not a whiff of poultry or camels or ponies or mules or dogs. How crazy would it sound if planning for health services were to be based on such an assumption, say five children or ten infants equal one adult? (Paediatricians may suddenly be left with little to do). Size of the animal appears to have been the only criterion for fixing this norm. Is it not a high time to shed this unscientific burden of 1976 and establish norms based on science and rationale? Even if the 1976 norms were to be applied, in the absence of anything better, we require more than 1.25 lakh veterinarians as against the 82,000 today. Further, this figure has been computed to the exclusion of poultry. Why? Human concern, in recent times, has been dominated by diseases affecting poultry. And what is our response? Culling? Do we need a doctor to tell us that to kill is the treatment? And what about fish? Is it not an animal? Who is authorised to cure it? It is the veterinarian. But we don't even train him for this.

Vasudhaiva Kutumbakam

Over two lakh health institutions exist in the government sector supported by a vast network of private medical facilities. On the other hand, there are only about 68,000 veterinary institutions across India, half of them rudimentary and the presence of the private sector is as negligible as being non-existent. More than 700 medical colleges but only 56 veterinary colleges. Against this backdrop, it is a Herculean challenge to augment and strengthen the veterinary infrastructure and services in the country, but we need to do so nonetheless, in right earnest; to protect human health and secure the nutritional requirements of our burgeoning population. Animal health impacts everyone's health and hence should be at the heart of public health systems. One Health concept is a reiteration of the principle of *Vasudhaiva Kutumbakam.*

Revolutionizing ANIMAL HEALTH THROUGH TECHNOLOGICAL ADVANCEMENTS

Animal husbandry is crucial sector in ensuring food and nutritional security, public health, and economic stability. In recent decades, technological innovations have revolutionized veterinary medicine and livestock management, providing advanced tools for disease detection, monitoring, and prevention. However, these advancements also bring challenges, including affordability, ethical considerations, and regulatory complexities. Moreover, climate change and the increasing prevalence of trans-boundary animal diseases (TADs) add another layer of complexity to animal health management. Given these factors, the integration of advanced technology is essential for managing animal health in a rapidly changing world.

Impact of Climate Change and TADs on Animal Health

Climate Change and Emerging Disease Risks: Climate change has exacerbated disease outbreaks in livestock by altering vector populations, modifying pathogen distribution, and increasing heat stress in animals. The IPCC report warns that rising temperatures and extreme weather events could intensify disease transmission rates, necessitating climate-adaptive strategies in animal health management.

The Growing Threat of TADs: TADs such as FMD, ASF, and Avian Influenza continue to pose major threats to global livestock production. India, in particular, has witnessed recurring outbreaks of these diseases, leading to mass culling, economic losses, and trade restrictions.

About the **AUTHORS**

Dr Praveen Malik, CEO Agrinnovate India Ltd., Former Animal Husbandry Commissioner, DAHD and Ashav-veer Singh Pannu, Business Manager, Agrinnovate India Ltd

Efforts to control TADs require international collaboration, digital disease surveillance systems, and coordinated vaccination programs. Blockchain technology and AI-driven disease modelling can enhance response strategies and improve outbreak prediction capabilities.

Challenges in Animal Health

The integration of advanced technologies in animal health faces significant challenges, including high implementation costs and economic barriers. Initial investments in Artificial Intelligence and Machine Learning (AI/ML), Internet of Things (IoT), genomic selection and genetic engineering are substantial, making these technologies inaccessible to small-scale farmers and clinics in developing regions. Ongoing maintenance and software upgrades add to the financial burden, limiting widespread adoption. Data security and ethical concerns also pose hurdles, with vast amounts of data generated by IoT and blockchain raising issues about secure storage and ethical use. Ethical debates around genetic modifications and AI-driven management further complicate public acceptance. Regulatory compliances involve complex and time-consuming approval processes, vary by country, complicating global adoption and adding administrative burdens. Climate change exacerbates these challenges by altering disease patterns and necessitating adaptive strategies, while the need for environmental sustainability requires efficient resource management and reduced carbon footprints.

Addressing these challenges is essential for the successful integration of advanced technologies in animal health.

Building consumer trust through transparency and education is crucial to overcoming resistance to new technologies. Engaging stakeholders, including farmers and local communities, in the development and implementation of these technologies can foster support and address concerns. By investing in research, education, and regulatory harmonization, the global community can work towards a sustainable and technologically advanced future for animal health.

Opportunities in Global Animal Health Technology

Artificial Intelligence and Machine Learning in Veterinary Medicine

AI and machine learning have revolutionized animal diagnostics, disease modeling, and treatment planning. AI-powered imaging tools now enable veterinarians to detect diseases such as infections, tumors, and musculoskeletal disorders with greater accuracy than traditional methods. Additionally, predictive analytics, based on machine learning algorithms, help identify disease outbreaks before they occur, enabling proactive interventions.

In livestock farming, AI-driven wearable devices continuously monitor animal health metrics such as body temperature, movement, and feeding behaviour. These real-time insights help detect early signs of illness, thereby reducing economic losses and improving animal welfare.

Internet of Things (IoT) and Precision Livestock Farming

IoT technologies facilitate precision livestock farming by integrating sensors, automated feeding systems, and real-time health monitoring tools. These systems track vital parameters, such as heart rate, hydration levels, and nutritional intake, providing farmers with crucial insights for disease prevention and productivity enhancement.

Smart collars equipped with GPS and biometric sensors help monitor free-ranging animals, reducing the risk of disease transmission and predation. IoT-based solutions also play a key role in mitigating the effects of climate change on livestock by optimizing ventilation, temperature control, and water usage while improving the productivity by precise monitoring of oestrous cycle and other physiological parameters.

AI-powered imaging tools now enable veterinarians to detect diseases such as infections, tumors, and musculoskeletal disorders with greater accuracy than traditional methods.

Blockchain for Traceability and Food Safety

Blockchain technology is enhancing transparency and accountability in animal health management. By maintaining immutable records of vaccination history, disease monitoring, and livestock movement, blockchain ensures the authenticity and safety of animal products in global supply chains.

In the meat and dairy industries, blockchain provides consumers with verifiable data on product origins, fostering trust in food safety standards. Moreover, regulatory agencies use blockchain to monitor livestock movement and enforce disease control measures, reducing the risk of cross-border disease transmission.

Biotechnology and Genetic Engineering for Disease Resistance

Advancements in genetic engineering, such as CRISPR-based genome editing, are paving the way for disease-resistant livestock. Researchers have successfully modified animal genes to enhance resistance against viral infections, thereby reducing the need for antibiotics and mitigating antimicrobial resistance.

In vaccine development, biotechnology has enabled the creation of highly effective vaccines for diseases such as Foot-and-Mouth Disease (FMD), African Swine Fever (ASF), and Avian Influenza. These innovations contribute to global efforts in disease eradication and animal health security.

Telemedicine and Remote Veterinary Care

Telemedicine is transforming veterinary care by enabling remote consultations and diagnostic assessments. Mobile applications and online platforms allow farmers and pet owners to access expert veterinary advice without requiring physical visits to clinics.

During disease outbreaks, telemedicine plays a crucial role in providing real-time guidance on disease management, reducing the risk of pathogen spread. This technology is particularly beneficial in remote and underserved regions, where veterinary resources are limited.

Challenges in Implementing Animal Health Technologies

High Implementation Costs and Economic Barriers

Advanced technologies in veterinary medicine and livestock farming often require substantial investment, making them inaccessible to small-scale farmers in developing regions. The costs associated with AI-driven diagnostics, IoT-enabled monitoring systems, and genetic engineering tools remain a significant barrier to widespread adoption.

Data Security and Ethical Concerns

As IoT and blockchain generate vast amounts of animal health data, concerns over data privacy and cybersecurity arise. Ensuring secure storage and ethical data usage is essential to prevent unauthorized access and misuse of sensitive information.

Additionally, ethical debates surrounding genetic modifications and AI-driven livestock management continue to shape policy discussions in the animal health sector.

Regulatory Hurdles and Compliance Issues

The adoption of emerging technologies in veterinary medicine often requires approval from regulatory bodies, which can be a complex and time-consuming process. Variations in disease control policies across countries further complicate global efforts in disease management and biosecurity enforcement.

Telemedicine is transforming veterinary care by enabling remote consultations and diagnostic assessments.

Future Perspectives and Recommendations

Strengthening Surveillance and Early Detection

AI and big data analytics should be integrated into disease surveillance systems to enable early detection and rapid response mechanisms. IoT-based environmental monitoring can also help track climate-induced disease patterns and mitigate potential outbreaks.

Enhancing International Collaboration on TADs

TAD control measures must include cross-border data sharing, harmonized vaccination campaigns, and joint research initiatives. Governments should leverage blockchain technology for disease tracking and improve biosecurity frameworks to prevent disease spread.

Promoting Sustainable Livestock Farming

Governments and agricultural institutions must prioritize sustainable livestock farming practices that incorporate genetic modifications for disease resistance, climate-resilient breeds, and eco-friendly waste management solutions.

Conclusion

The integration of cutting-edge technology in animal health presents promising opportunities to enhance disease prevention, treatment, and biosecurity. However, challenges such as economic barriers, data security risks, and regulatory complexities must be addressed to ensure widespread adoption.

Furthermore, climate change and TADs continue to pose severe threats to global livestock industries, underscoring the need for international cooperation and technology-driven solutions. By harnessing AI, IoT, blockchain, and biotechnology, the global community can strengthen animal health systems, mitigate disease risks, and contribute to a sustainable future.

ROLE OF PRIVATE AND PUBLIC SECTORS IN IMPROVING ANIMAL HEALTH AND FARM PROFITS

In the changing market environment of livestock and their health the food products they offer, including milk, meat, eggs etc., the delivery of animal health services and the infrastructure are emerging as an important priority area for enhancing the competitiveness of livestock producers for quality and safe production. At the same time, government is continuing to explore options to expand the reach of these services and identify the gaps which would enable strengthening of infrastructure and services. It is high time that the private and public institutions are further strengthened through collaborative efforts to bring value to animal health, improve farmers income and contribute significantly to the growing Indian economy.

India continues to hold leadership position in milk, meat and egg production, ranking 1st, 2nd and 5th position respectively. India's livestock sector is a cornerstone of its agriculture and rural economy, offering greater stability and income generation than the crop sector. It is vital to nation's ambitious goal of doubling farmers income. Achieving this goal requires a concerted efforts for enhancing livestock quality products through better animal health and nutrition.

Animal health and production is poised to make a generous leap in the years to come because of the multiplicity of the related events that are taking place around the globe. Increased demand of the livestock products, ease of market accessibility, and opportunity of global trade, increased cash flow in urban & rural societies, application of science & application of new technologies in production, feeding & processing may be some of the key factors responsible for the anticipated increase in livestock production. However, over a period of time the dairying farming for which animal health is of prime importance, is getting recognized as the key sector responsible of regular income to the farmers, enriching the carbon in the soil and to support quality agriculture production. Though the size of the farm in our country is still small, yet the focus remains on productivity, traceability and sustainable production of milk with little or no damage to natural resources.

Animal Health: Reproduction & Production

Animal Health defines the economy and cost of milk production. Better health leads to more production, productivity and farm profits. In the similar way, con-

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trol or management of diseases leads to reduction in expenses, which in other words means profits. The government is now focused on animal health, production and disease control programmes. Several programme of the government which are bringing value in direction are: 1) Rashtriya Gokul Mission 2) National Livestock Management 3) Livestock Health and Disease control etc.

Some of these initiatives would help in achieving the goal of FMD Mukt Bharat by 2030. This would mean reducing the losses worth 24000 Cr, more milk production and better farmers profits.

Animal Feed & Nutrition

Feed is also the main input factor for milk and meat production from livestock constituting 60-70% of the cost of livestock products. Inadequate feed supply is coupled with the availability of low-quality fibrous feeds and fodder forming the major roughage and nutrient challenge. The cost of feed ingredients is spiraling high with each passing day. It is really beyond the means of resource of the poor animal keepers to buy good quality feeds, as they even do not get the remunerative price for their produce, making a vicious circle, which eventually results in sub-optimal performance from their animals. Though there is now improvement in usage of quality cattle feed amongst farmers, however the quality of nutrients in this feed are still is a big question.

Animal health and production is poised to make a generous leap in the years to come because of the multiplicity of the related events that are taking place around the globe.

Social Media

In our country, consumer expectations are increasingly shaped by unregulated social media narratives, particularly those questioning the consumption of milk and dairy products and their relevance to health. This hesitation has fueled either the growth of plant-based alternatives and dairy analogues or has lowered the consumption of dairy products, and may pose a significant challenge to the animal health and dairy industry at large.

Emission Management

India's huge population of ruminants which contributes to greenhouse gases emission. Reducing greenhouse gases through mitigation and adaptation continues to knock at the doors of policy planners and scientist. Emission reduction is fundamentally linked to farmer education, animal feeding and improved livestock genetics. Given India's vast cattle population, emission control must be driven by government-led policies and pragmatic programs. However, in the guise of sustainability the talks are on to an alternative to conventional dairy. If not addressed strategically, such initiatives could jeopardize India's global trade aspirations and impact the future of the animal health and dairy industry.

Biogas and Fertilizers

It is evident that no single source of en-

ergy would be capable of replacing fossil oil completely which has diverse applications. On the other hand, dependence on fossil oil would have to be reduced at a faster pace so as to stretch its use for longer period and in critical sectors till some appropriate alternative energy sources preferably renewable ones are made available. Methane gas and more popularly known as bio-gas is one such alternate sources of energy which has been identified as a useful hydro-carbon with combustible qualities as that of other hydrocarbons. Though its calorific value is not high as some products of fossil oil and other energy sources, it can meet some needs of household and farms. Apart from the gas, the organic fertilizer which is received in the form of slurry would help in adding carbon to soil, thus improving its fertility. NDDB in collaboration with leading private players and NGO have signed MOU to install more than 10000 biogas plants.

People Private Partnership

The technology is poised to revolutionize the animal health sector, where the government and the private players are participating jointly to create value for the farmers and health of the animals. Some of these areas are related to diagnosis of the disease its serrosurvillance, vaccinations and role of the society at large to get the plans executed. Department of Animal Husbandry, GOI in collaboration with World Organization on Animal Health (WOAH) had recently organized a workshop for Public-Private Collaboration. By bringing together global expertise, government initiatives, and industry innovation, the key discussions were focused on:

1. Improve animal disease management and biosecurity
2. Foster sustainable livestock farming practices
3. Strengthen One Health initiatives to safeguard public health
4. Enhance trade opportunities through compliance with international health standards

Private Sector

The private sector is equally partnering with the government to create value for

The technology is poised to revolutionize the animal health sector, where the government and the private players are participating jointly to create value for the farmers and health of the animals

themselves and the nation's economy. All this is only possible, if the animal's health is taken care. This is being done through various extension programmes for creating awareness about proper feeding, deworming, nutrition, reproduction and vaccination etc. to quote few examples; The A2 Milk in metros is available at Rs80-100/liter, the use of hydroponics fodder is catching up, the use of biogas and organic slurry is helping to improve use of clean fuel and cultivation in healthy carbon rich soil. The private sector requires level playing field, which the government should provide. Amul for that matter is now exporting its milk to US and other countries. Does this not open up the opportunities for other players??

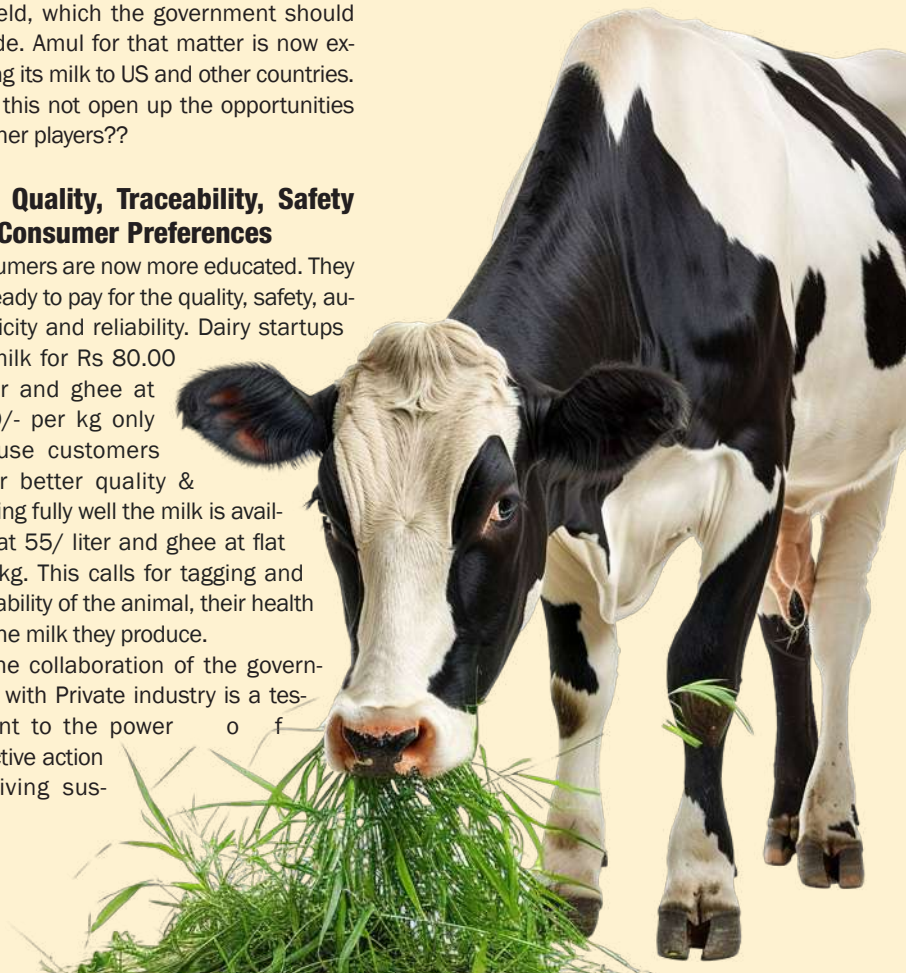
Milk Quality, Traceability, Safety and Consumer Preferences

Consumers are now more educated. They are ready to pay for the quality, safety, authenticity and reliability. Dairy startups sell milk for Rs 80.00 a liter and ghee at 2000/- per kg only because customers prefer better quality & knowing fully well the milk is available at 55/ liter and ghee at flat 650/kg. This calls for tagging and traceability of the animal, their health and the milk they produce.

The collaboration of the government with Private industry is a testament to the power of collective action in driving sustainable change.

Animal Health Sector -The Backbone of Agriculture

Livestock now controls close to 30% of the agriculture gross domestic product (GDP). The livestock sector is performing well in the manner of production, value addition, and export of dairy, fishery, wool, poultry, and other products. There is tremendous export opportunity for dairy products, employment generation and earnings potential of this industry leading to lifting of rural economy. All this means keeping animals healthy, where recently the government has earmarked the special funds for disease diagnosis, its control, vaccination with emphasis on Pashu Ayushadi, where the generic quality medicines, including ayurvedic veterinary medicines will be available to the farmers through the PM Kisan Samriddhi Kendra & Cooperative Societies. Apart from its performance, some threats also exist; we need to overcome them to grab the global market opportunities towards building Atma Nirbhar Bharat and US $ 5 Trillion economy.



ENHANCING GOAT HEALTH IN INDIA

A COMPREHENSIVE APPROACH TO DISEASE MANAGEMENT AND ECONOMIC SUSTAINABILITY

The Evolving Landscape of Goat Health Management

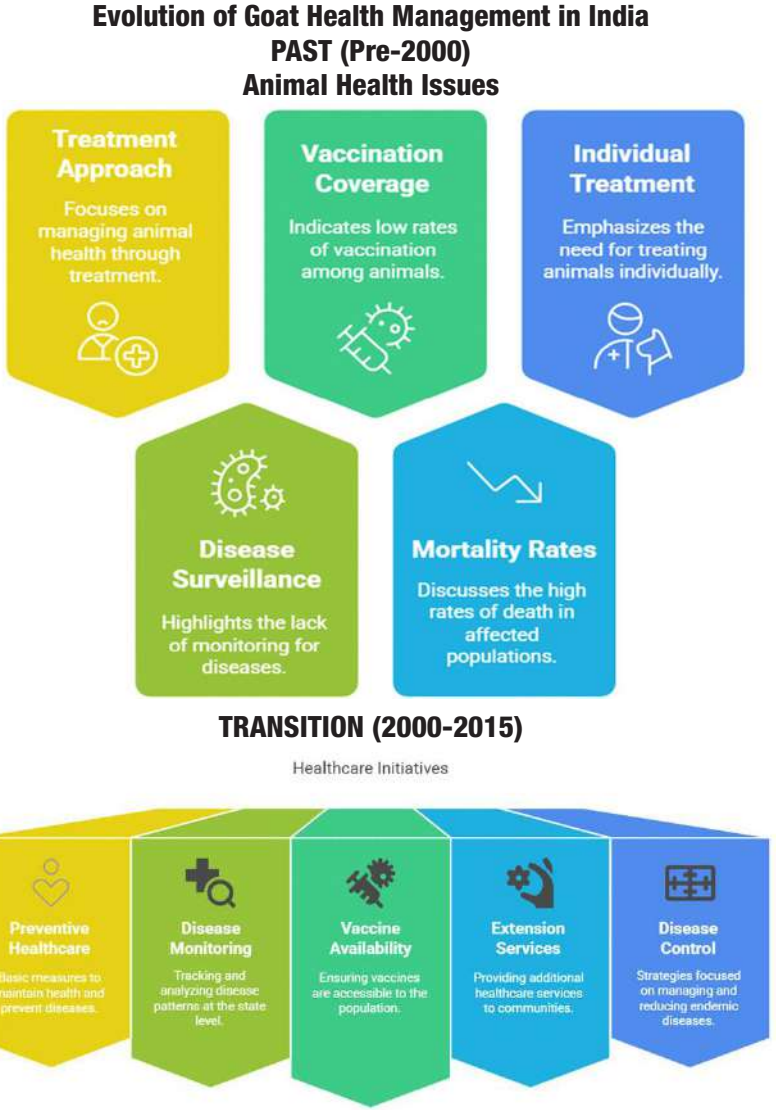
The approach to animal health in India has undergone a paradigm shift in recent years, particularly in the small ruminant sector. Where once treatment-based interventions dominated, we now see growing emphasis on preventive healthcare, biosecurity measures, and systematic disease surveillance. This evolution reflects not only scientific advancements but also a deeper understanding of the economics of animal health—prevention is invariably more cost-effective than cure.

Emerging Approaches in Disease Prevention

Modern goat health management in India is increasingly characterized by:

- **Structured Vaccination Programs**: Moving beyond ad-hoc vaccination campaigns to scheduled, comprehensive coverage under initiatives like the National Animal Disease Control Programme (NADCP).
- **Advanced Diagnostics**: Field-deployable rapid test kits and point-of-care diagnostics have revolutionized disease detection, enabling faster intervention even in remote areas.
- **Digital Disease Surveillance**: AI-powered systems now facilitate real-time disease tracking and predictive analytics for outbreak forecasting—a capability I helped pioneer during my tenure at the National Institute of Veterinary Epidemiology.

Evolution of Goat Health Management in India



About the **AUTHOR**

Dr Avinash Anand
former CEO, Uttarakhand Sheep and Wool Board and former Managing Director, Uttarakhand Sheep Goat Farmers Cooperative Federation Ltd

- **One Health Approach**: Recognition of the interconnection between animal, human, and environmental health has led to more integrated disease control strategies, particularly for zoonotic diseases like brucellosis.
- **Ethnoveterinary Applications**: Traditional knowledge systems are being scientifically validated and integrated with modern veterinary medicine, offering cost-effective alternatives for common ailments.

Major Goat Diseases: Prevalence, Impact, and Control Strategies

The disease burden in India's goat population varies significantly across geographical regions, influenced by climate, husbandry practices, and existing control measures. Based on comprehensive epidemiological studies conducted across states, we can identify patterns that should inform targeted interventions.

Peste des Petits Ruminants (PPR)

PPR remains the most economically devastating disease affecting goats in India, with annual losses estimated at Rs.1,204 crore. My analysis of national surveillance data reveals concerning state-wise prevalence patterns:

State	Prevalence (%)	Mortality Rate	Economic Impact
Bihar	33.5	High	Severe
Odisha	26.6	Moderate	Significant
West Bengal	28.9	High	Severe
Uttar Pradesh	20.6	Moderate	Moderate
Tamil Nadu	24.8	Moderate	Significant
Rajasthan	19.3	Moderate	Moderate
Maharashtra	17.5	Low	Moderate

PRESENT (2015 onwards)

The National PPR Eradication Programme launched in 2014 has made substantial progress, with mass vaccination campaigns reducing disease incidence by approximately 35% in intervention zones. However, challenges remain in achieving comprehensive coverage, particularly in migratory flocks and remote tribal areas.

Control Strategy: The path to PPR eradication requires synchronized vacci-

The National PPR Eradication Programme launched in 2014 has made substantial progress, with mass vaccination campaigns reducing disease incidence by approximately 35% in intervention zones.

State-wise Veterinary Infrastructure Assessment

State	Vet Institutions per 10,000 Goats	Mobile Vet Units	Goat-Specific Programs	Infrastructure Adequacy Rating
Gujarat	1.8	42	High	Good
Rajasthan	0.7	35	Medium	Poor
Tamil Nadu	2.3	64	High	Excellent
Bihar	0.5	18	Low	Very Poor
Maharashtra	1.4	39	Medium	Moderate
West Bengal	0.9	22	Medium	Poor
Karnataka	1.6	28	High	Good

Source: Veterinary Council of India and State Animal Husbandry Department Reports, 2023

nation campaigns covering at least 80% of the susceptible population within a short timeframe to break transmission cycles. The success of rinderpest eradication offers valuable lessons—ring vaccination strategies around outbreak zones combined with strategic immunity building in high-risk corridors.

Foot and Mouth Disease (FMD)

While traditionally considered a cattle disease, FMD significantly impacts goat productivity, with estimated annual losses of ☐1,334 crore. Unlike in cattle, FMD in goats often presents with subtle clinical signs, leading to underreporting and continued virus circulation.

Regional Patterns: FMD shows highest prevalence in dairy-intensive states like Punjab, Haryana, Gujarat, and Karnataka, where mixed livestock farming facilitates cross-species transmission.

Control Strategy: The integration of goats into the FMD Control Programme has proven challenging due to vaccination logistics and monitoring. Our pilot studies in Gujarat demonstrated that synchronized vaccination of all susceptible species in an area is essential for breaking transmission cycles. Additionally, I advocate for strain-specific vaccines tailored to regional virus variants for improved efficacy.

Brucellosis

The insidious nature of brucellosis—causing reproductive failures, abortions, and reduced milk yield—makes it particularly damaging economically while presenting a significant zoonotic risk to farmers and consumers alike.

Economic Impact: Annual losses are estimated at ☐300 crore, with Maharashtra, Punjab, Madhya Pradesh, and Uttar Pradesh reporting highest prevalence.

Control Strategy: The National Brucellosis Control Programme needs strengthening with stronger focus on small ruminants. My research supports the cost-effectiveness of vaccinating female kids between 4–8 months of age with Rev-1 vaccine, combined with test-and-segregate approaches for infected animals in organized farms.

The combined annual economic loss of over 3,200 crore from major diseases represents not just a drain on the sector but also a tremendous opportunity for value creation through preventive health measures.

Contagious Caprine Pleuropneumonia (CCPP)

CCPP causes severe pneumonia with high morbidity rates, particularly in intensive production systems. With estimated losses of ☐250 crore annually, it significantly impacts productivity in the arid and semi-arid regions of Rajasthan, Gujarat, and parts of Karnataka.

Control Strategy: Our field trials with locally produced vaccines have shown promising results, with efficacy rates exceeding 85% when administered prior to high-risk periods. Antibiotic treatment remains costly and often ineffective once clinical signs appear, emphasizing the importance of preventive vaccination.

Goat Pox

The distinctive skin lesions of goat pox not only reduce productivity but dramatically decrease market value of affected animals. With annual losses estimated at ☐150 crore, predominantly in Andhra Pradesh, Telangana, and parts of Uttar Pradesh, this disease demands attention.

Control Strategy: Live attenuated vaccines provide effective protection, and our studies show that strategic vaccination before monsoon months, when vector populations increase, can significantly reduce incidence.

Disease	Direct Mortality Cost	Production Loss	Treatment Cost	Market Value Reduction	Total Annual Impact (Rs crore)
PPR	704	380	120	-	1,204
FMD	184	650	100	400	1,334
Brucellosis	50	200	20	30	300
CCPP	120	85	45	-	250
Goat Pox	40	60	20	30	150
Total	1,098	1,375	305	460	3,238

Economic Analysis of Disease Burden

My comprehensive analysis of production data across 500 goat farms over a five-year period reveals the true economic impact of diseases beyond direct

Farm Size	Average Annual Loss Per Animal (☐)	Percentage of Income Lost	Most Common Disease Challenges
Marginal (<10 goats)	1,850	28%	PPR, External parasites, Enterotoxemia
Small (10-25 goats)	1,425	22%	PPR, FMD, Respiratory infections
Medium (26-50 goats)	1,120	16%	FMD, Brucellosis, CCPP
Large (>50 goats)	980	12%	Brucellosis, CCPP, Mastitis

Source: Comprehensive Goat Health Economic Survey (2019-2023), Indian Council of Agricultural Research

mortality:
This analysis demonstrates that production losses often exceed direct mortality costs, highlighting the importance of subclinical disease management and productivity enhancement strategies alongside mortality reduction efforts.

Economic Impact by Farm Size

Our studies reveal significant variations in disease impact based on farm size, with smaller holdings often suffering disproportionately:

Cost-Benefit Analysis of Disease Prevention

The financial returns on disease prevention investments vary by intervention type:

Intervention	Cost Per Animal (☐)	Benefit-Cost Ratio	Payback Period
PPR Vaccination	18-25	1:14.5	3 months
Deworming (bi-annual)	45-60	1:8.2	4 months
Mineral supplementation	120-150	1:5.7	6 months
FMD Vaccination	22-30	1:9.8	5 months
Brucellosis Vaccination	35-45	1:7.3	8 months

Source: National Institute of Animal Health Economics, 2022

Policy Recommendations for Sustainable Disease Management

Drawing on three decades of experience implementing livestock health programs across India, the following evidence-based policy interventions are proposed:

Restructuring Veterinary Service Delivery

The current veterinary infrastructure—designed primarily for cattle—inadequately serves small ruminant keepers. I propose:

- **Community Animal Health Workers (CAHWs)**: Training and certifying local para-veterinary workers from goat-keeping communities, with particular focus on women CAHWs to improve access for female farmers.
- **Mobile Veterinary Units (MVUs)**: Expanding the MVU network with small-ruminant-specific equipment and diagnostics to reach remote communities.
- **Public-Private Partnerships**: Engaging private veterinary practitioners through service contracts in underserved areas, a model that proved highly effective in our Karnataka pilot program.

Technology-Driven Disease Surveillance

Experiences in developing the National Animal Disease Reporting System highlighted the importance of:

- **Digital Identification Systems**: Implementing cost-effective identification methods (ear tags with QR codes) linked to health records and vaccination history.
- **Participatory Disease Surveillance**: Training farmers to recognize and report disease signs through simple mobile applications, creating an early warning network.
- **GIS Mapping of Disease Outbreaks**: Utilizing spatial analysis to identify disease hotspots and transmission corridors, particularly for seasonal migratory routes.

Economic Incentives for Disease Control

Sustainable disease management requires economic alignment:

- **Insurance Linked to Preventive Care**: Premium discounts for farmers maintaining vaccination schedules, a model that increased vaccination compliance by 65% in our Maharashtra pilot.
- **Market Premiums for Disease-Free Flocks**: Developing certification programs for disease-screened animals, creating price incentives for health management.
- **Cost-Sharing Mechanisms**: Graduated subsidy programs where government support is highest for essential vaccines (PPR, FMD) and complemented by farmer contributions for others.

Research Priorities for Enhanced Disease Control

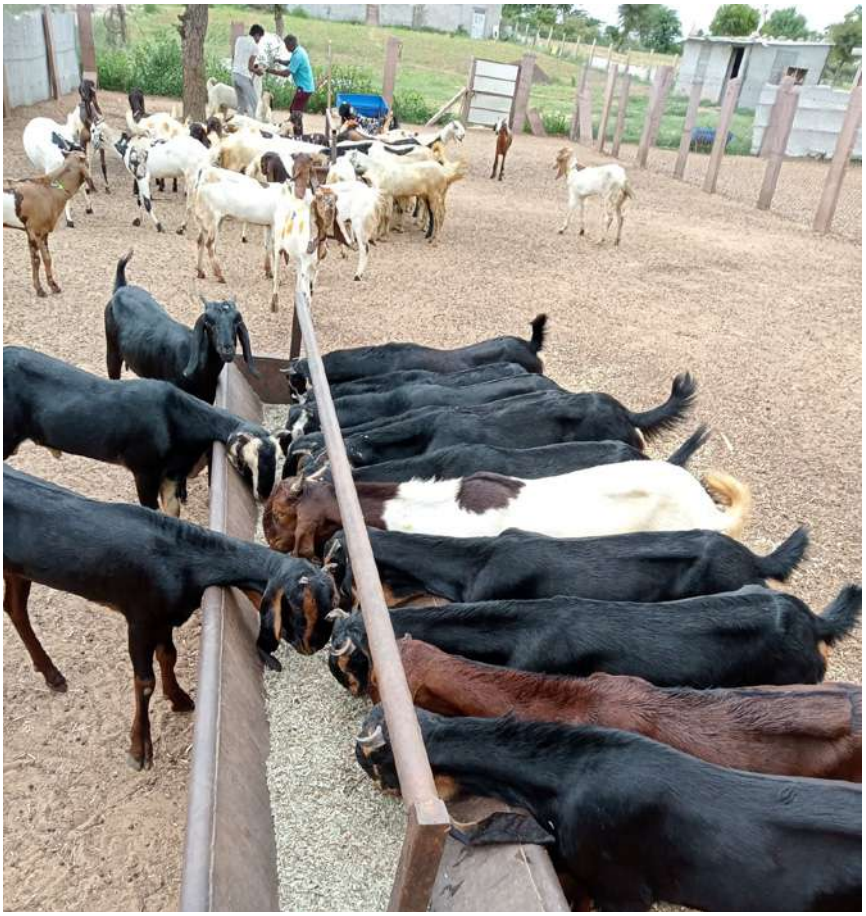
Based on identified knowledge gaps, focused research on followings are recommended :

- **Thermostable Vaccines**: Developing heat-resistant vaccine formulations to overcome cold chain challenges in remote areas.
- **Multivalent Vaccines**: Creating combination vaccines to reduce handling stress and improve coverage.
- **Genetic Resistance**: Identifying and conserving indigenous breeds with natural disease resistance traits.
- **Low-Cost Diagnostics**: Developing affordable pen-side tests for major diseases to enable field-level screening.

Case Study: Successful Disease Management in Tamil Nadu

The integrated small ruminant health program implemented in Tamil Nadu between 2018-2022 offers valuable lessons for nationwide application. This program combined:

- **Synchronized vaccination campaigns** covering 85% of the goat population against PPR and goat pox
- **Trained farmer groups** responsible for basic health monitoring and reporting
- **Digital health tracking** through a mobile application
- **Value-addition initiatives** for disease-free certified products



- **Tamil Nadu Small Ruminant Health Program Results**

The program demonstrates that coordinated, multi-dimensional approaches yield significantly better outcomes than isolated interventions. Key success factors included:

The Path Forward

The health of India's goat population is inextricably linked to the economic resilience of some of our most vulnerable rural communities. My three decades in livestock administration have convinced me that enhancing goat health is not merely a veterinary challenge but a pivotal development opportunity that can transform rural livelihoods.

The combined annual economic loss of over ☐3,200 crore from major diseases represents not just a drain on the sector but also a tremendous opportunity for value creation through preventive health measures. For every rupee invested in comprehensive disease control, our economic analyses show returns of ☐7-9 in preventing losses and productivity gains.

Vision for India's Goat Health 2030

As India aims to double farmer incomes and enhance rural prosperity, strategic investments in goat health infrastructure, surveillance systems, and targeted research will yield disproportionate returns. The future of India's goat sector lies not just in expanding numbers but in realizing the productive potential of healthier animals—a goal that is eminently achievable with coordinated action across public, private, and community stakeholders.

The humble goat—often called the "poor man's cow"—may well be the powerful engine that drives rural prosperity in the coming decades, provided we invest adequately in keeping these valuable animals healthy and productive.

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by Haris Khan

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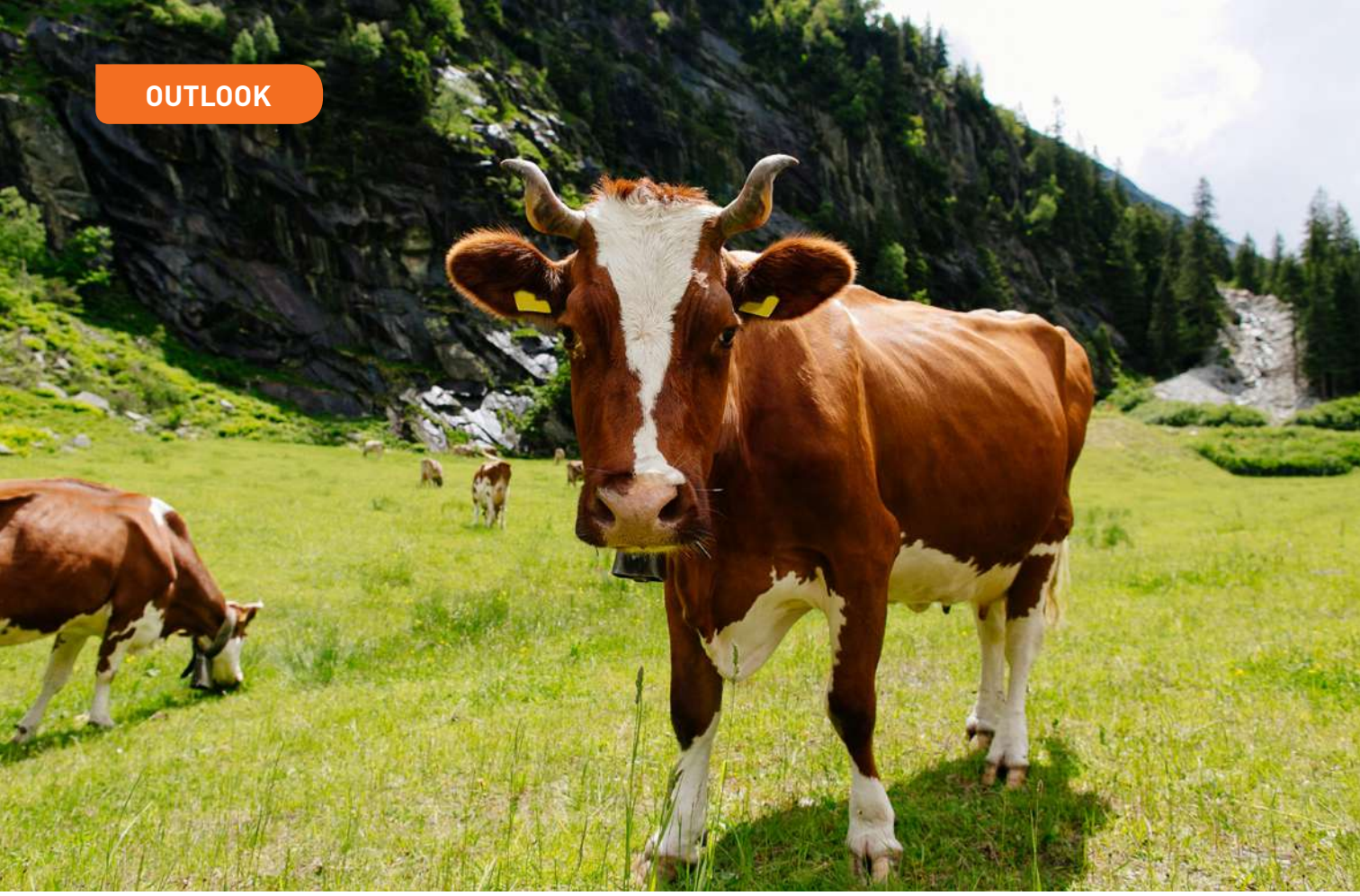

Evolving Animal Health Landscape in India

Livestock sector plays a significant role in India's rural economy. With over 70% of livestock owned by small and marginal farmers, healthy animals directly impact their livelihoods, food security, and income stability. India has the world's largest livestock population, with 537 million animals contributing 4.35% to the national GDP and 25.6% to the agricultural GDP.

Poor animal health leads to reduced productivity, affecting milk, meat, and egg yields. India, the world's largest milk producer faces annual losses of over ☐28,000 crore due to livestock diseases. Foot-and-mouth disease (FMD), brucellosis, and mastitis are common health threats, impacting productivity and trade. Investing in veterinary services, vaccination programs, and disease control improves productivity, enhances rural incomes, and supports food security. A robust animal healthcare framework is essential for inclusive economic growth, poverty reduction, and sustainable livestock development in India.

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Market Scenario

The Indian animal health market is estimated to be worth over USD 2.5 billion, with consistent growth projected in the coming years. The industry encompasses animal pharmaceuticals, vaccines, feed additives, and veterinary services, all of which contribute to the well-being of livestock, poultry, aquaculture, and companion animals.

India's animal health market is expanding rapidly, driven by increasing livestock production, rising awareness of animal healthcare, and government support. The market can be categorized into three primary segments: **animal pharmaceuticals, vaccines, and feed additives**.

Animal Pharmaceuticals commands roughly 55-60% of market share and it includes antibiotics, anti-parasitic drugs, anti-inflammatory medicines, and reproductive health products. With the increasing incidence of diseases like foot-and-mouth disease (FMD), mastitis, and brucellosis, the demand for effective veterinary medicines is rising. Leading companies such as Zydus Animal Health, Indian Immunologicals Ltd., and Virbac India hold significant shares in this segment.

Vaccines, comprising 20-25% of market share play a crucial role in disease prevention and are gaining traction due to government initiatives such as the **National Animal Disease Control Programme (NADCP)**, which aims to eradicate FMD and brucellosis. India is one of the largest producers of animal vaccines, with major players like Hester Biosciences and Indian Immunologicals Ltd. leading the sector. The increasing focus on disease prevention rather than treatment is expected to drive growth in this segment.

Feed Additives with15-20% of market share includes vitamins, amino acids, minerals, and probiotics that enhance livestock nutrition and productivity. With the rising demand for high-quality dairy and meat products, the segment is experiencing steady growth. Companies like Cargill India, Trouw Nutrition, and Avitech Nutrition are key players. The poultry industry is a major consumer, followed by dairy and aquaculture sectors.

Ensuring optimal animal health is essential for improving productivity, preventing disease outbreaks, and sustaining rural livelihoods.

The Indian animal health industry is poised for significant expansion, with a projected **CAGR of 8-10%** in the coming years, making it a vital component of the country's agricultural economy.

India's Potential in the Animal Health Industry

India holds immense potential in the animal health sector largely because of a growing livestock industry. India is the world's largest producer of milk and the second-largest producer of poultry and fish. The increasing demand for animal protein, particularly in urban and semi-urban areas, has spurred the need for effective veterinary healthcare solutions.

The Indian government has been actively promoting animal healthcare through initiatives such as National Animal Disease Control Programme (NADCP) for eradicating Foot and Mouth Disease (FMD) and Brucellosis, Livestock Health and Disease Control Programme (LHDCP) to enhance veterinary services across the country and Dairy Development Schemes to boost milk production and ensure cattle health.

Indian pharmaceutical and biotech companies are investing heavily in R&D to develop innovative vaccines and medicines tailored to the country's specific animal health needs. With strong manufacturing capabilities and cost advantages, India is emerging as an export hub for veterinary pharmaceuticals and vaccines, catering to markets in Asia, Africa, and Latin America.

Challenges of the Livestock Health Sector in India

Ensuring optimal animal health is essen-

tial for improving productivity, preventing disease outbreaks, and sustaining rural livelihoods. There are some key challenges that has prevented India's animal health sector from attaining its true potential.

Livestock in India is highly susceptible to diseases such as Foot-and-Mouth Disease (FMD), Brucellosis, Mastitis, and Peste des Petits Ruminants (PPR). With over 537 million livestock animals, India faces a shortage of veterinary professionals and infrastructure. The country has approximately one veterinarian for every 5,000 animals, far below the recommended ratio. Many rural areas lack veterinary clinics, diagnostic labs, and emergency care services, leading to delayed treatment and higher mortality rates.

Although India produces a significant share of veterinary vaccines, quality control and timely availability remain concerns. Many small-scale farmers struggle to access affordable, high-quality medicines, leading to improper or delayed treatment. Additionally, counterfeit drugs in the market pose serious risks to animal health.

The overuse and misuse of antibiotics in livestock have led to rising cases of antimicrobial resistance (AMR), posing risks to both animal and human health. A lack of stringent regulations and awareness among farmers results in excessive antibiotic use, especially in poultry and dairy farming. AMR is a growing global concern, and India needs stricter policies to combat it.

The Indian animal health industry is poised for significant expansion, driven by the rising demand for livestock, government support, and technological innovations.

Malnutrition significantly affects livestock health, productivity, and fertility. Many smallholders rely on low-quality feed and fodder, leading to nutrient deficiencies. The availability of high-quality feed additives and mineral supplements remains limited, affecting growth rates and milk yield.

Extreme weather conditions, droughts, and floods are affecting livestock health by reducing feed availability and increasing disease outbreaks. Additionally, zoonotic diseases like avian influenza, Nipah, and bovine tuberculosis threaten both animals and humans.

To address these challenges, India needs strengthened veterinary infrastructure with more rural clinics and mobile veterinary units; Stricter regulations on antibiotics to prevent AMR; Better disease surveillance and vaccination programs for effective disease control; Investment in research and innovation for improved feed and medicines and Awareness programs for farmers to promote preventive healthcare and best livestock management practices.

A holistic approach to livestock healthcare can enhance productivity, boost rural incomes, and ensure food security in India.

Future is Very Bright

The animal health industry in India is expected to grow at a CAGR of 8-10% over the next five years. Technological advancements such as precision medicine, digital health solutions, and AI-driven diagnostics will revolutionize veterinary care in India. Telemedicine platforms for pet and livestock care are gaining traction, making healthcare services more accessible.

Preventive healthcare, including vaccination programs, deworming, and nutritional supplements, will gain prominence, reducing disease outbreaks and enhancing livestock productivity. Strengthening regulatory frameworks and quality assurance in veterinary pharmaceuticals will be crucial to ensuring global competitiveness. The Indian government is likely to introduce more stringent guidelines for antibiotic use in livestock to address concerns over antimicrobial resistance (AMR).

With favourable investment policies, India is witnessing increased foreign direct investment in the veterinary sector. Multinational corporations continue to expand their presence through joint ventures and acquisitions.

The Indian animal health industry is poised for significant expansion, driven by the rising demand for livestock, government support, and technological innovations. While challenges such as disease outbreaks and antibiotic resistance persist, the industry's proactive approach to research, investment, and regulatory improvements bodes well for sustained growth. With India's strong manufacturing capabilities and increasing global presence, the country is well on its way to becoming a major player in the global animal health sector. The coming decade will witness transformative changes that will not only enhance animal welfare but also contribute to the economic development of India's agricultural and pharmaceutical industries.

EMPOWERING SMALLHOLDER FARMERS IN BIHAR: A SUSTAINABLE APPROACH TO ANIMAL HEALTH

The livestock sector is one of the major and important contributors to the rural economy in India, so is in Bihar. Unfortunately, this sector is prone to economic losses due to disease outbreaks, morbidity and mortality because of lack of proper veterinary service provision in the villages, unavailability of fodder, infrastructural constraint, and lack of knowledge of farmers about appropriate husbandry practices. Thus, Passing Gifts Private Limited (PGPL), a subsidiary of Heifer International had initiated innovative approaches and models like grooming a pool of Community Agro-vet Entrepreneurs (CAVEs) aka Pashu Sakhi, Goat Enterprise development, Pass on Gift (POG) Model, Farmers' Field School (FFS) on Animal husbandry Practices for improving livestock health and economic stability of smallholder farmers under the Bihar Sustainable Livelihood Development (BSLD) project, which covers more than 71,000 smallholder women farmers in six districts of Bihar namely Darbhanga, Madhubani, Muzaffarpur, Samastipur, Sitamarhi, and Vaishali.

The project follows a two-pronged strategy:

1. **Enhancing Resiliency:** Building social cohesion, providing skill development, and implementing climate risk management strategies.
2. **Strengthening Social Enterprises:** Creating farmer-led agribusinesses, improving access to financial services, and promoting women's leadership in agricultural activities.

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Key Interventions Driving Change in Animal health and welfare

1) Community Agro-Vet Entrepreneurs (CAVEs) Model

Lack of available and affordable veterinary care has been a major challenge for Bihar's goat farmers. PGPL introduced Community Agro-Vet Entrepreneurs (CAVEs) development model—local proactive women farmers trained on primary animal healthcare practices to render low-cost veterinary services such as periodic vaccinations, deworming, and essential first-aid treatments at the farmers' doorsteps in the remote rural villages. This innovative decentralized model has significantly reduced the goat mortality rates, improved animal health, welfare & productivity, which have boosted local economies.

2) Infrastructure Development for animal health and welfare

For smallholder farmers, access to the right infrastructure can mean the difference between survival and prosperity. Recognizing this, the BSLD project has supported farmers for constructing well-ventilated goat shelters resulting in better animal welfare, reduced disease risks and mortality. Farmers have received high-quality breeding bucks to enhance herd productivity, along with azolla tanks for cost-effective nutritious feed for improved animal health.

3) Farmers Field School (FFS) Model

Knowledge is key to sustainability. PGPL ensures farmers receive hands-on training in improved livestock management techniques. Through farmers field school and other training, they learn about improved animal husbandry practices including biosecurity measures, balanced nutrition, and early disease detection. These practices have improved goat health, survival rates and empowered farmers to manage their herds more efficiently.

Lack of available and affordable veterinary care has been a major challenge for Bihar's goat farmers.

4) Mission 1000 Acres: Ending Fodder Scarcity

Fodder shortages significantly impact goat health and productivity in Bihar. PGPL's Mission of 1000 Acres fodder cultivation initiative promotes large-scale fodder cultivation in the area. This has reduced reliance on costly external feed and ensured a steady supply of high-quality nutrition for livestock.

5) From Debt to Growth: The Goat Enterprise Development

Financial limitations often prevent small farmers from expanding their goat herds. The Goat enterprise, a community-driven financing model, provides low-cost loans for self-help group (SHG)

- Goat mortality rates dropped from 53% in FY'21 to 30% in FY'24.
- Average household herd size increased from 1.67 goats in FY'21 to 2.89 goats in FY'24.
- Annual household incomes surged by 81% compared to FY'21 status, reaching INR 131,465 in FY'24.

members to purchase quality goats, construction of shelters, and insurance of goats. Loan repayments are reinvested to support new beneficiaries, creating a cycle of financial empowerment. With this support, farmers have been able to scale their operations, increase productivity, and secure long-term economic resilience.

6) Developing Social Capital and the Pass-On Model

A core principle of PGPL's approach is social capital development, derived from Heifer's 12 Cornerstones for Just and Sustainable Development. The Pass-On Model ensures that beneficiaries pass on livestock, training, or financial assistance to others, creating a self-sustaining cycle of development. This model fosters trust, cooperation, and shared responsibility, strengthening rural communities.

Transforming Livelihoods: The Measurable Impact of Livestock Interventions

In rural communities, where livestock is a cornerstone of economic stability, our strategic interventions have brought about remarkable improvements in animal health and farmer incomes. One of the most striking successes has been the reduction in goat mortality rates, which have dropped from a staggering 53% in FY'21 to 30% in FY'24. This dramatic improvement reflects the effectiveness of enhanced veterinary care and disease prevention measures.

Smallholder farmers are not only rearing healthy herds but also increased their herd size from the average household herd size of 1.67 goats in FY'21 to 2.89 goats in FY'24. This increase is a crucial step toward building resilience and ensuring long-term economic sustainability for rural families.

The financial impact of these efforts is equally compelling. Annual household incomes have surged to INR 131,465 in FY'24, marking an 81% increase from FY'21—a testament to how improved livestock management has directly translated into economic empowerment. Additionally, vaccination rate has risen, with 58% of farmers now vaccinating their livestock, while 86% administer regular deworming, preventing infections and ensuring healthier animals.

The CAVE model remains instrumental for women's economic empowerment, for instance, women who once had limited income opportunities, now thrive as skilled veterinary service providers.

The CAVE model remains instrumental for women's economic empowerment, for instance, women who once had limited income opportunities, now thrive as skilled veterinary service providers. Trailblazers like Usha Devi, Minu Kumari, Gunja Das, and Sudha Devi earn between INR 11,000 and INR 30,000 per month. And the average annual income per CAVE has increased from INR 11,832 in FY'21 to INR 54,663 in FY'24, reaching INR 68,174 in Q1 FY'25. Additionally, the number of families a CAVE benefiting has grown from 33 per month in FY'24 to 38 per month in Q1 FY'25, while the number of animals treated has increased from 74 to 80 per month led to healthy animals.

Sustaining Long-Term Change

Farmers now recognize livestock as a sustainable asset rather than supplementary income. Farmer Producer Organizations (FPOs) have been integrated into the model, ensuring fair pricing and better market access. Besides, farmers' livestock insurance adoption is growing.

The Way Forward

Looking ahead, PGPL aims to scale up its interventions with a focus on:

- Expanding the CAVE network to reach more villages for ensuring improved animals health and welfare as well as increased income of CAVEs.
- Strengthening livestock insurance adoption to ensure broader financial protection for farmers.
- Enhancing market linkages by deepening engagement with FPOs and improving access to organized markets.
- Promoting sustainable feeding practices for better livestock nutrition.

The BSLD Project has demonstrated that innovative approaches and models improve animal health and welfare while ensuring sustainable income for the households and women's economic empowerment.

EMPOWERING FARMERS THROUGH TECHNOLOGY:

LUVAS FMD E-LOSS CALCULATOR©

Naresh Kumar Kakker: Consultant Faculty and Professor, Veterinary Microbiology (Retired)
Swati Dahiya: Scientist, Veterinary Microbiology
Neelam Rani: Veterinary Surgeon, Department of Animal Husbandry and Dairying, Haryana, Panchkula
Anshul Lather: Assistant, Professor, Veterinary Microbiology
Naresh Jindal: Vice-Chancellor, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar...Photograph is of Naresh Kindal

In the ever-evolving world of agriculture, farmers face numerous challenges that affect productivity and profitability. Among these, animal diseases pose a significant threat, impacting livestock health and economic stability. Foot-and-mouth disease (FMD) is a highly contagious viral infection affecting cloven-hoofed animals, including cattle, buffalo, sheep, goats, and pigs. The FMD has a profound economic impact worldwide due to its effects on livestock health, trade, and farm productivity. The direct costs of lost productivity, trade restrictions, disease control, and long-term financial instability severely burden farmers and the agricultural industry. Effective disease prevention, rapid response, and vaccination programs are crucial for minimizing economic damage caused by FMD and similar transboundary animal diseases.

LUVAS FMD E-LOSS CALCULATOR©: A Game-Changer for Farmers

To mitigate these economic losses, scientists at Lala Lajpat Rai University of Veterinary and Animal Sciences (LUVAS), Hisar, have developed a ground-breaking tool: the **LUVAS FMD E-Loss Calculator©**. This innovative Android-based mobile and tablet application enables farmers to accurately calculate the economic impact of FMD and make informed decisions regarding vaccination and animal management.

The app covers five cloven-hoofed species (cattle, buffalo, sheep, goat, and pig) and calculates direct economic losses due to FMD outbreaks under four major categories:

- Reduction in milk production
- Reduction in draft capability
- Mortality of animals
- Treatment costs of affected animals

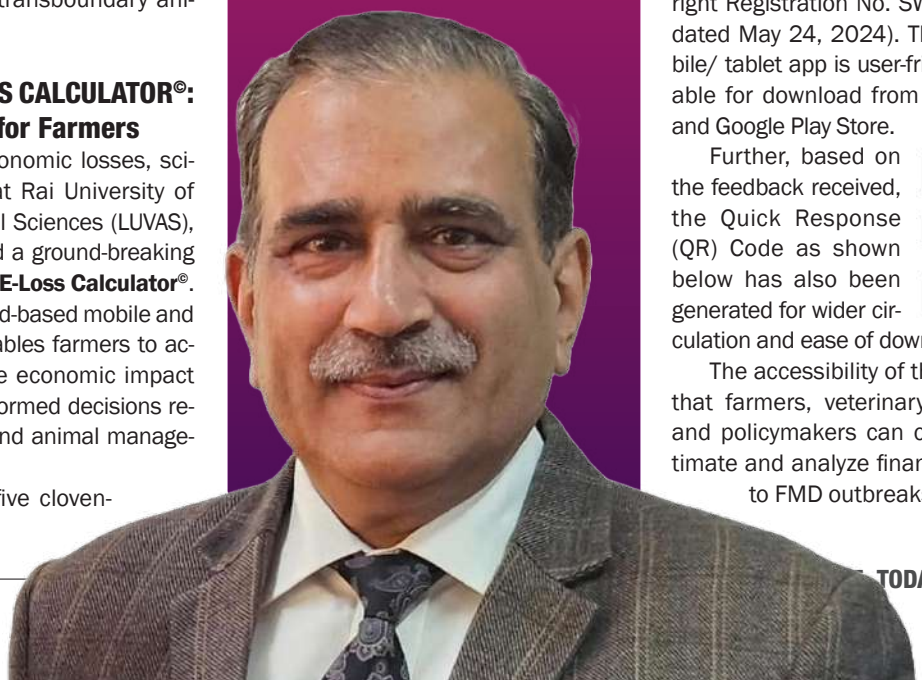
Although initially designed for FMD, the app can be adapted to assess economic losses from other livestock diseases using the same parameters. The ability to quantify the economic losses is instrumental in guiding policymakers, veterinarians, and farmers toward more effective disease control strategies.

Registration and Availability

The LUVAS FMD E-LOSS CALCULATOR© has been registered with the Registrar, Intellectual Property, Govt. of India (Copyright Registration No. SW-18808/2024, dated May 24, 2024). This android mobile/ tablet app is user-friendly and available for download from LUVAS website and Google Play Store.

Further, based on the feedback received, the Quick Response (QR) Code as shown below has also been generated for wider circulation and ease of downloading:

The accessibility of this tool ensures that farmers, veterinary professionals, and policymakers can conveniently estimate and analyze financial losses due to FMD outbreaks. With an easy-



to-navigate interface, even those with minimal technical experience can utilize the calculator effectively.

Economic Analysis in Animal Disease Management

Animal diseases, including viral, bacterial, fungal, and parasitic infections, cause severe economic losses in agriculture. These losses can manifest in direct losses as under:

1. **Reduction in Milk Production:** Diseases reduce milk yield, affecting farm profitability. Farmers who rely on dairy production suffer significant income losses due to decreased milk output during and after an FMD outbreak.
2. **Reduction in Draught Capability:** Sick draught animals cannot perform agricultural tasks, leading to economic losses. Many small-scale farmers in developing countries depend on bullocks and buffaloes for ploughing, making this a critical factor in economic loss.
3. **Mortality of Animals:** The death of animals results in financial losses from lost productivity and costly replacements. In severe outbreaks, livestock farmers may experience herd depletion, requiring substantial reinvestment.
4. **Treatment Costs:** Managing infected animals involves significant veterinary expenses, further straining farm resources. Timely and effective medical intervention is essential to control the disease and prevent further losses.

Downloaded View of "LUVAS FMD E-LOSS CALCULATOR©"mobile App.

The LUVAS FMD E-LOSS CALCULATOR© represents a significant advancement in livestock management, providing farmers with a reliable tool for assessing economic losses and implementing preventive strategies.

Functionality of the App

The **LUVAS FMD E-LOSS CALCULATOR©** provides an intuitive platform for economic loss calculation:

- **Data Entry:** Users input data on affected animals by species and age group, reduction in milk yield, draft capability loss, and treatment costs.
- **Cost Estimation:** The app calculates total economic losses based on entered data, offering real-time analysis.
- **Comparative Analysis:** Farmers can compare potential losses with the cost of preventive measures like vaccination and bio security improvements.
- **Decision Support:** The tool aids in financial planning by helping farmers assess the economic feasibility of various disease prevention strategies.

Example for Calculation of Direct Economic Losses due to FMD

For a farmer with three milch cattle, one bullock, two heifers, and two male calves: If all animals contract FMD due to lack of vaccination, the economic losses would be calculated based on the input provided in the App. The milch animal will show a reduction in milk yield (about eight litres per day; Rs. 50/- per litre) for six days; the bullock will be unable to work for six days (about eight hours per day; Rs. 150/- per hour). Further, the cost of treatment for adults, heifers and calves comes out to be Rs. 2500/-, Rs. 1500/- and Rs. 1000/-, respectively. Of these animals, one female heifer and one male calf (standard market value Rs. 20,000/- and Rs. 5,000/-, respectively) die of FMD.

- Milk production loss: Rs. 7,200/- (3 animals x 8 litres x 6 days x Rs. 50/-)

- Draught capability loss: Rs. 7,200/- (1 animal x 8 hours x 6 days x Rs. 150/-)
- Mortality loss: Rs. 25,000/- (1 heifer x Rs. 20,000 + 1 calf x Rs. 5,000/-)
- Treatment costs: Rs. 15,000/- (4 adults x Rs. 2,500/- + 2 heifers x Rs. 1,500 + 2 calves x Rs. 1000/-)
- **Grand Total Economic Loss: Rs. 7,200 +7,200 +25,000 +15000= Rs. 54,400/-**

This calculation underscores the financial burden that FMD imposes on farmers and highlights the economic benefits of preventive vaccination.

Importance of Vaccination in Disease Prevention

Vaccination is a critical strategy for preventing the spread of animal diseases and mitigating economic losses. Timely vaccination programs reduce disease incidence, lower treatment costs, and enhance farm productivity. Effective vaccination strategies lead to improved milk, meat, and wool yields, thereby boosting revenue and profitability for farmers.

Governments and veterinary organizations should work together to promote mass vaccination campaigns and ensure adequate coverage to reduce the prevalence of FMD. In addition to vaccination, improved bio security measures, early disease detection, and farmer education are crucial components of a comprehensive disease management plan.

Future Prospects

The LUVAS FMD E-LOSS CALCULATOR© shall serve as an invaluable tool for farmers, policymakers, and veterinary professionals. The app highlights the financial risks associated with inadequate vaccination and enables data-driven decision-making for disease prevention and management. The app can also be utilized for farmer's training programs, offering a practical demonstration of economic losses due to animal diseases.

Future enhancements to the application may include:

- **Expansion to Other Diseases:** The calculator can be adapted to estimate losses from other livestock diseases such as mastitis, brucellosis, bluetongue, lumpy skin disease, hemorrhagic septicaemia, haemoprotozoan and parasitic diseases.
- **Cloud-Based Data Storage:** Integration with cloud computing can allow users to store and access their loss estimation data over time for better record-keeping.
- **Multilingual Support:** To cater to a broader range of farmers, multilingual options can be incorporated to improve usability in diverse linguistic regions.
- **Integration with Government Schemes:** The tool can be linked with veterinary health programs to provide recommendations for financial aid and insurance claims.

The LUVAS FMD E-LOSS CALCULATOR© represents a significant advancement in livestock management, providing farmers with a reliable tool for assessing economic losses and implementing preventive strategies. By leveraging technology and scientific expertise, LUVAS is committed to revolutionizing veterinary research and strengthening the livestock sector against emerging challenges.

The impact of this tool extends beyond individual farms; it has the potential to shape national disease control policies, guide investment in veterinary infrastructure, and ultimately enhance the economic sustainability of the livestock industry. The LUVAS team remains dedicated to continuous innovation in animal health management, ensuring that the benefits of scientific research translate into tangible improvements for farmers.

Acknowledgements : *The authors acknowledge the Department of Animal Husbandry and Dairying, Ministry of Fisheries and Animal Husbandry, Govt. of India; Indian Council of Agricultural Research-National Institute of Foot-and-Mouth Disease, Bhubaneswar, Odisha; Department of Animal Husbandry and Dairying, Govt. of Haryana; and Lala Lajpat Rai University of Veterinary and Animal Sciences (LUVAS), Hisar, for their support in developing this application. Special thanks to Mr. Aashish Nagpal, Staff, and Mrs. Swasti Kakker, Senior Software Engineer, LinkedIn, Bengaluru for their technical contributions in app development.*

DIGITAL SOLUTIONS FOR ENHANCING CATTLE HEALTH

Dairy farming in India is a vital economic activity, supporting millions of smallholder farmers who depend on cattle for their livelihoods. The sector plays a significant role in national milk production, making India the largest producer of milk globally. However, Indian dairy farmers face persistent challenges related to cattle health, including disease outbreaks, inefficient nutrition management, and reproductive inefficiencies. These issues impact not only farm productivity but also milk quality and overall profitability. Limited access to veterinary care, traditional feeding practices, and a lack of real-time health monitoring further aggravate these problems. Addressing these issues requires scalable, data-driven solutions that provide farmers and dairy extension teams with actionable insights for effective cattle health management.

Stellapps Technologies Private Limited, headquartered in Bangalore, is leading the Indian dairy ecosystem through digital innovation. By integrating AI-driven analytics, IoT-enabled monitoring, and mobile-based advisory services, Stellapps bridges the gap between traditional dairy practices and modern precision farming techniques. These solutions help farmers and dairy extension teams detect diseases early, optimize cattle nutrition, and improve reproductive performance. As a result, farms achieve higher milk yields, lower veterinary costs, and reduced methane emissions per liter of milk.

Maintaining an optimal Body Condition Score (BCS) is essential for dairy cattle, as both underweight and overweight animals are prone to metabolic disorders and reproductive challenges.

Stellapps digital tools for enhancing cattle health include mooON, a patented herd management platform that facilitates the management of cattle, farms, and extension teams, and smartFarms, an application that enhances transparency and empowers dairy farmers by

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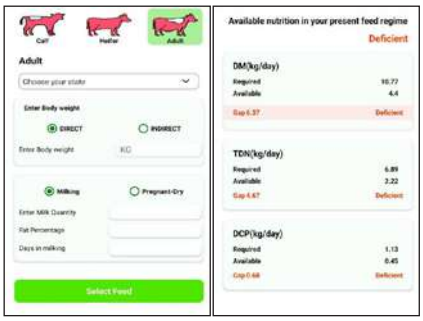


Feed Calculator

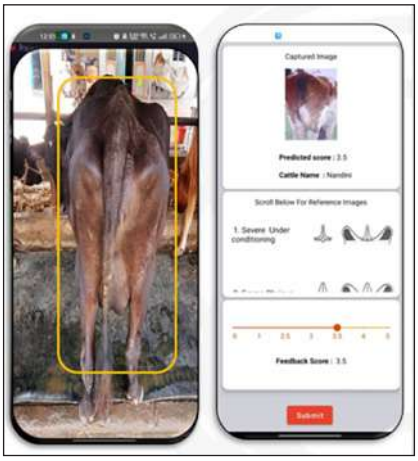
By integrating digital solutions with traditional dairy farming practices and leveraging the support of the dairy extension team, Indian farmers can achieve higher efficiency, greater profitability, and contribute to a more sustainable future for the dairy industry.

fostering a more collaborative and accountable milk supply chain. mooON's contribution to productivity improvement and methane emission mitigation was recognized as a case study by the United Nations Environment Programme (UNEP) report at COP29. Additionally, AI-powered modules such as the Feed Calculator and mooBCS are integrated into both mooON and smartFarms, further supporting data-driven decision-making for improved cattle management.

Optimizing Nutrition for Better Cattle Health

Nutrition is a crucial factor in maintaining cattle health and ensuring optimal milk production. Poor feeding practices often lead to metabolic disorders such as ketosis, acidosis, milk fever etc., which can severely affect productivity. Many Indian dairy farmers rely on locally available feed ingredients that lack a balanced nutrient profile. Stellapps Feed Calculator addresses this issue by helping dairy extension teams and farmers formulate cost-effective, hyper-localised and nutritionally balanced diets based on the animal's age, lactation stage, body weight etc. By providing scientifically backed feeding recommendations, the tool helps prevent nutritional deficiencies and enhances overall cattle health and milk yield.

Maintaining an optimal Body Condition Score (BCS) is essential for dairy cattle, as both underweight and overweight animals are prone to metabolic disorders and reproductive challenges. Stellapps mooBCS tool helps dairy extension teams and farmers assess BCS by capturing a photograph of the cattle from the rear. The tool then provides tailored nutrition recommendations through the feed calculator to help achieve the ideal BCS. Effective BCS management enhances immunity, minimizes metabolic disorders, and boosts reproductive efficiency, ultimately leading to healthier animals and improved productivity.

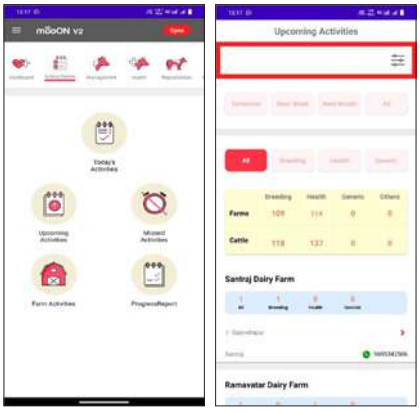


mooBCS

Preventive Healthcare for Disease Control

Preventive healthcare is essential to minimizing disease risks and maintaining a healthy herd. In rural India, access to veterinary services is often limited. Stellapps mooON platform automates vaccination and deworming schedules, ensuring that dairy extension teams and farmers receive timely alerts for essential preventive healthcare measures. By keeping cattle on a proper vaccination and deworming schedule, the risk of infectious diseases and parasitic infestations is significantly reduced. (refer image 3: Task management)

Digital health records maintained by Stellapps solutions allow dairy extension teams and farmers to track disease history, treatments, and vaccination schedules. Access to such data enables better decision-making regarding treatment and culling, reducing overall healthcare costs and improving herd management.



Task Management module

Enhancing Reproductive Efficiency and Fertility Management

Reproductive inefficiencies result in economic losses for dairy farmers, with challenges such as missed heat detection and repeat breeding affecting productivity. Stellapps mooON platform tracks artificial insemination records and pregnancy diagnoses, identifying cows that fail to conceive. Early detection of repeat breeders allows dairy extension teams to provide timely interventions, improving conception rates and reducing calving intervals.

Real-Time Monitoring and Health Alerts

Monitoring cattle activity helps detect heat signs and potential health issues. Stellapps actiTrak solution provides real-time tracking of cattle movement, identifying heat, lameness, and behavioral changes. This helps farmers and extension teams improve artificial insemination success rates and detect illnesses

early, reducing treatment costs and preventing productivity losses.

Milk composition is a crucial indicator of an animal's health. mooON captures and helps detect abnormalities in Fat and SNF (Solids Not Fat) levels, aiding in the early identification of mastitis and other metabolic disorders. Farmers and dairy extension teams can use these insights to take preventive measures, ensuring better milk quality and reducing antibiotic dependency.

Sustainable Dairy Farming and Methane Emission Reduction

Sustainable dairy farming is essential for reducing environmental impact. Methane emissions from cattle contribute significantly to greenhouse gases. Stellapps digital solutions improve nutrition, optimize feed efficiency, and enhance cattle health, reducing methane emissions per liter of milk produced. Healthier cattle produce more milk with less feed, contributing to sustainable dairy farming.

Inbreeding affects herd productivity and health. Stellapps mooON platform tracks artificial insemination semen details, helping farmers and extension teams monitor genetic lineage and prevent inbreeding. This improves herd genetics, fertility rates, and overall productivity.

Image 4: actiTrak

Enhancing Access to Healthcare Products and Services

The SmartFarms app leverages digital technology to improve cattle health by providing farmers with expert advisory services on animal nutrition, breeding, and disease control. Its milk quality monitoring feature ensures that farmers can track and maintain industry standards, promoting better cattle well-being. Additionally, the app facilitates access to financial products such as cattle loans and insurance, enabling farmers to invest in proper veterinary care and nutrition. By connecting farmers with high-quality dairy feed, supplements, and essential farm equipment, SmartFarms ensures that livestock receive the best possible care. Through these integrated solutions, the app serves as a comprehensive digital platform for enhancing cattle health and overall farm productivity.

Leading the Dairy Ecosystem Through Digital Innovation

Stellapps digital solutions leverage AI, IoT, and data analytics to provide real-time insights for improved herd management. From optimizing nutrition to tracking disease history, detecting fertility issues, and reducing carbon emissions, these innovations contribute significantly to sustainable and profitable dairy farming. By integrating digital solutions with traditional dairy farming practices and leveraging the support of the dairy extension team, Indian farmers can achieve higher efficiency, greater profitability, and contribute to a more sustainable future for the dairy industry.

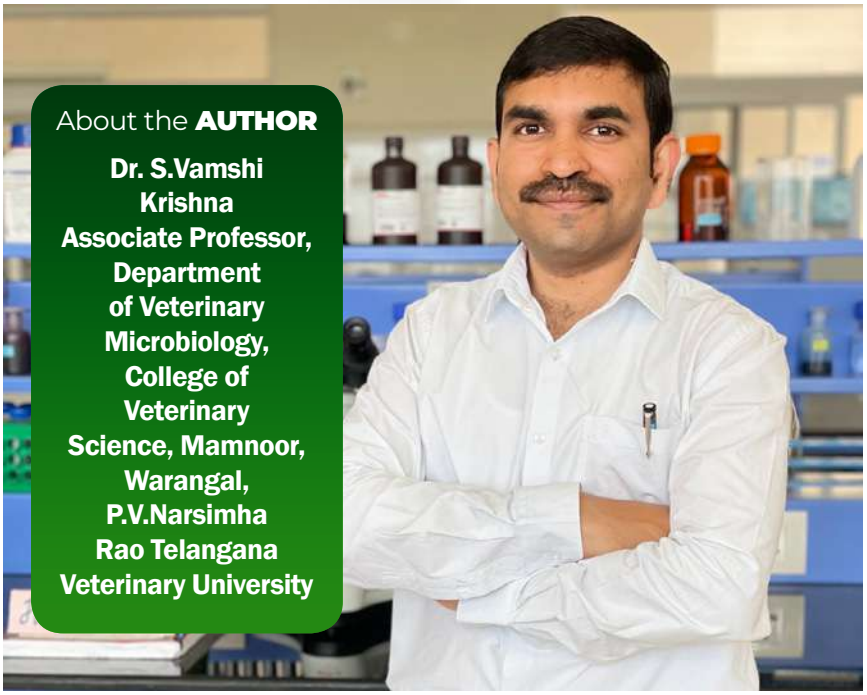
RESEARCH AND DEVELOPMENT IN THE ANIMAL HEALTH SECTOR IN INDIA:

PROGRESS, CHALLENGES, AND FUTURE PROSPECTS

India has one of the largest livestock populations in the world, contributing significantly to the agricultural economy. The animal husbandry sector is not only crucial for food security but also for employment and rural livelihoods. Given the importance of livestock in the economy, research and development (R&D) in animal health has gained substantial attention in the recent years. The growth in livestock sector in the country and the need for sustainable agriculture and animal husbandry is fostering R&D in the animal health sector. Advances in veterinary medicine, disease diagnosis, control, genetics, biotechnology and development of new generation vaccines have contributed in fostering animal health, improving productivity, and sustainability in the sector. However, several challenges remain, requiring continuous innovation and effective policies implementation.

Country's efforts in veterinary research date back to the early 20th century when premier institutions such as the ICAR-Indian Veterinary Research Institute (IVRI) were established. Later, R&D in the sector has expanded with the establishment of several research institutions, agricultural and veterinary universities, public-private partnerships and private-sector collaborations. These institutions have played a pivotal role in driving and nurturing R&D in animal health sector.

The emphasis of these establishments and initiatives has been on developing veterinary vaccines, improved diagnostic tools, mechanisms for disease surveillance and monitoring, and improved livestock management practices such as precision livestock farming (PLF). The government has also initiated various schemes and policies to encourage private-sector participation and technological advancements. The inclusion of



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biotechnology and artificial intelligence in veterinary sciences has further enhanced the scope of research in animal health.

Key Areas of R&D in Animal Health Sector

Disease diagnosis, prevention and control

One of the key focus areas has been the development of innovative and effective diagnostic techniques for early detection of livestock diseases. Traditional methods are being supplemented with cutting edge technologies such as lateral flow assays (LFA), PCR-based rapid diagnostic tests, biosensors and CRISPR based diagnostics enabling rapid and accurate disease detection in relatively short period of time. Rapid and early diagnosis of livestock diseases paves the way for effective control and prevention of several diseases in livestock and birds. India has made remarkable progress in combating major livestock diseases such as foot-and-mouth disease (FMD), brucellosis, and avian influenza. Research in this area has led to the development of effective vaccines and diagnostic techniques.

The government's National Animal Disease Control Programme (NADCP) is a major initiative aimed at eradicating diseases like FMD and brucellosis through vaccination and surveillance. Additionally, in rural areas effective implementation of mobile veterinary services and telemedicine applications have been developed to provide timely diagnosis and treatment to livestock.

Precision livestock farming (PLF)

The concept of precision livestock farming (PLF) has gained a momentum in India, during the last few years. Advances in artificial intelligence and information technology enabled to continuously monitor and manage livestock in real-time, studying the individual animal behaviour thus improving animal health, welfare and productivity and making the animal management easy. The PLF in future may meet the expectation of establishment of large dairy farms in the country.

Advances in artificial intelligence and information technology enabled to continuously monitor and manage livestock in real-time, studying the individual animal behaviour thus improving animal health, welfare and productivity and making the animal management easy.

Advances in Biotechnology

Biotechnology has opened new avenues for improving animal health and productivity. Research in molecular biology and genetic engineering has contributed to formulate better breeding programs and development of disease-resistant livestock. Techniques such as Cloning, genome editing (such as CRISPR), and artificial insemination with superior germplasm techniques have enhanced the quality and resilience of indigenous breeds. With the rise of genomic selection, farmers are now able to choose livestock with superior genetic traits, yielding higher milk yield, improved meat quality, and enhanced disease resistance. One more application is advancement in stem cell research, which paved the way for regenerative medicine in veterinary science, offering new treatments for injuries and genetic disorders in animals.

Development of Veterinary Pharmaceuticals

The veterinary pharmaceutical sector has witnessed rapid growth, driven by the increasing demand for antibiotics, vaccines, and feed supplements. In the recent years, Indian companies, aligning with global pharmaceutical giants, are investing in R&D for development of new drugs and alternatives to antibiotics, probiotics, prebiotics and synbiotics to combat and contain antimicrobial resistance (AMR)for sustainable production. Several herbal and plant-based veterinary medicines have been discovered with promising effect in improving animal health and production. Research into Ayurveda, homoeopathy and traditional medicine for treating livestock ailments has opened new frontiers in sustainable veterinary healthcare. Moreover, the production of medicines similar to already approved drugs has significantly reduced the cost of veterinary treatments.

Livestock Nutrition and Feed Technology

One more important and major area for research is vested on animal nutrition. The last decade witnessed on optimizing feed composition, improving digestion, and enhancing immunity through dietary supplements and formulation of immunoboosters. The use of probiotics, prebiotics, and nutrigenomics is being explored to boost productivity in dairy and poultry farming.

Nutrigenomics, which studies the interaction between diet and genes, has enabled the development of customized feeding programs that enhance livestock performance. Additionally, alternative protein sources such as insect-based and algae-based feeds are being investigated to provide sustainable nutrition solutions. The impact of climate change on feed availability has also prompted researchers to explore drought-resistant fodder crops.

Need for One Health Approach

The One Health initiative, recognized globally as the interconnection between human, animal, and environmental health, is gaining momentum in India. Research on several zoonotic diseases like brucellosis, leptospirosis, rabies, tuberculosis, and Nipah virus is crucial for preventing outbreaks that could affect both animals and humans.

The COVID-19 pandemic has highlighted the importance of disease surveillance at the animal-human interface. Hence, collaborative efforts between veterinarians, medical professionals, and environmental scientists are now being prioritized to mitigate the risks of future pandemics. India has been investing in integrated disease surveillance programs to track and control zoonotic threats effectively in the near future.

Challenges in R&D in Animal Health Sector

Despite significant progress, several challenges persist in animal health research and development in India:

- **Insufficient Funding:** Public and private investment in veterinary R&D is relatively low compared to human healthcare. Additional financial support is necessary to enhance research capabilities in government and private sector.
- **Lack of Infrastructure:** Many research institutions and veterinary hospitals face a shortage of advanced laboratories and diagnostic equipment. This limits the ability to conduct large-scale studies and trials.
- **Emerging Diseases:** Climate change and globalization have led to the emergence of new infectious diseases, requiring constant surveillance, vigilance and research.
- **Antimicrobial Resistance (AMR):** The excessive use of antibiotics in livestock poses a major threat to both animal and human health. Research into alternative treatments such as phage therapy, herbal medicines and alternatives to antibiotics is still in its early stages.
- **Limited Private Sector Participation:** While some multinational companies invest in veterinary R&D, more incentives are needed to encourage domestic players. Regulatory bottlenecks and long approval processes also hinder innovation.
- **Farmer Awareness and Adoption:** Many new technologies developed are not widely adopted due to a lack of awareness among farmers. Training programs and extension services need to be strengthened for effective adoption and utilization in the field.

With the right policies, effective policy enforcement, attracting investments, and technological interventions, India can position itself as a global leader in veterinary research, ensuring a healthier and more productive livestock sector.

Future Prospects and Recommendations

To strengthen research and development in animal health sector, India needs a multi-pronged approach:

- **Increased Funding and Policy Support:** The government should allocate more resources to veterinary research institutions and in establishment of infrastructure in government institutions.
- **Strengthening Public-Private Partnerships:** Collaboration between academic institutions, research organizations, and pharmaceutical companies can accelerate innovations in research and development.
- **Advanced Technologies in Veterinary Science:** Investments in artificial intelligence (AI), big data analytics, and precision livestock farming can revolutionize disease management and productivity.
- **Capacity Building and Training:** Enhancing veterinary education and training programs will ensure a skilled workforce for future advancements.
- **Strengthening Regulatory Frameworks:** Effective policies and regulations are needed to control the indiscriminate use of antibiotics, ensuring vaccine quality, and facilitate the approval of new drugs.
- **Sustainable and Eco-friendly Practices:** The integration of eco-friendly farming methods, improved waste management, and organic feed alternatives will contribute to a sustainable livestock sector.
- **Encouraging Indigenous Research:** More focus should be given to utilizing India's diverse biodiversity to develop locally adapted veterinary solutions.

Animal health sector in India is witnessing significant research and development activities aligning with global trends in technology adoption and sustainable livestock practices. However, to achieve sustainable growth in livestock sector, there is a need for continued investment and focus on addressing country-specific challenges to ensure sustainable growth in livestock sector. With the right policies, effective policy enforcement, attracting investments, and technological interventions, India can position itself as a global leader in veterinary research, ensuring a healthier and more productive livestock sector. By embracing modern technologies, fostering innovation, and prioritizing sustainability, animal health sector in India can contribute significantly to food security, rural development, and economic prosperity.

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ACCELERATING WOMEN'S LEADERSHIP: ENTREPRENEURS DRIVING CHANGE

Agriculture Today Group in collaboration with Passing Gifts, a subsidiary of Heifer International organised an interactive webinar on "Accelerating Women's Leadership: Entrepreneurs Driving Change" on 3rd March 2025. This is the second time that the ATG and passing Gifts are coming together to celebrate Women's Day. This year's theme was about breaking barriers, amplifying voices, and driving real, lasting change in the world of entrepreneurship and leadership. The meeting saw an outstanding line-up of speakers who shared their experiences and insights with each other.

Anjana Nair, Group Editor, Agriculture Today welcomed everyone and pointed out that women across the globe are not only starting businesses but reshaping industries, innovating solutions, and creating opportunities for others. She then introduced the first speaker **Sonmani Chowdhury, Program Director of Bihar Sustainable Livelihood Development Projec**t.

Sonmani shared her experiences in the field of rural women entrepreneurship and discussed the importance of government initiatives aimed at economically empowering women. She discussed the challenges faced by the agriculture sector in India, which contributes significantly to the rural economy but is growing vulnerable to weather-related variabilities. She highlighted the need for more entrepreneurs to boost employment in both rural and urban India. Sonmani also shared the progress of the Bihar Sustainable Livelihood Development Project, which supports smallholder families in agriculture, horticulture, goat, and poultry value chains. She emphasized on the importance of Community Agrovet Entrepreneurs (Cave) in advising farmers and connecting them to farmer producer companies and markets. Sonmani also noted the success of women-owned and managed enterprises in rural India, which are crucial in addressing declining female labour force participation.

Mira Devi – CAVE, Mushkan SHG, Baingra village, Muzaffarpur, Bihar shared her experiences and strategies for diversifying income sources through training, setting up vet medicine shops, and growing Napier.

Dr. Nutan Kaushik, Director General, Amity University shared her experiences as a woman in a male-dominated academic field, emphasizing the importance of support from family and the need to

prove oneself more than men. She highlighted her international exposure and the importance of continuous learning and improvement. Dr. Nutan also discussed her work with rural women, training them in food processing and entrepreneurship, and promoting sustainable agriculture and biopesticides. Nutan also emphasized on the importance of family support for women in achieving their career goals, noting that those with family backing have more opportunities for exploration. She also mentioned that many women are delaying marriage due to lack of support from their families.

Smt. Anjali Mahanta, a progressive poultry farmer, Maa Laxmi SHG, Pipilia village, Keonjhar, Odisha, shared her business journey and the significant impact of modern techniques in her operations. She also highlighted the challenges faced in disease management and market access.

Renuka, **co-founder and CEO of Bioprime**, discussed her company's efforts in increasing women's representation in research and development, and the importance of changing societal perceptions to encourage more women to pursue careers in science and technology. She stressed the need for equal opportunities and the importance of challenging social conditioning to promote gender equality.

Smt. Kummari Kalyani, Nagalingeswara Farmer Interest Group, Anantapur, Andhra Pradesh shared her experiences and discussed various topics including entrepreneurship and marketing.

Ms. Komal Shah, Director, SML Limited, discussed the significant impact of climate change on human health, particularly affecting women and children. She highlighted that in India, a large percentage of women suffer from anaemia, leading to a significant GDP loss due to micronutrient deficiencies. Komal emphasized the need to improve soil health to enhance the nutritional quality of food, which in turn would benefit farmers and consumers. She expressed admiration for women-led teams in the agriculture sector and encouraged more women to take active roles in solution development.

Ms. Dipanwita Chakrabarty, a social and environmental impact expert, shared her experiences in nurturing the rural woman ecosystem in the corporate world. She discussed the importance of a multi-pronged approach to address the complexities of rural development. She highlighted the need for tailored leadership development programs focusing on critical skills like decision-making, problem-solving, negotiation, and financial literacy. She also emphasized the role of sponsorship from organizations and the community, as well as the need for role models and visibility. Additionally, she stressed the importance of providing entrepreneurial and business incubation support to create sustainable models, and discussed the need for digital inclusion to bridge the rural digital divide. Dipanwita discussed the importance of breaking cultural norms and emphasized the need for individuals to take control of change within themselves and champion each other.

Sheikh Razia, founder of Bastar Food Firm, who through recorded message shared her view point. Her initiative, Bastar Foods and Consultancy Services (BFFCS), launched in 2018, focused on improving food technologies and empowering rural women in tribal regions across Chhattisgarh and neighbouring states.

Women Entrepreneurs in Agriculture and Animal Husbandry

Megha Desai, Senior Coordinator - Self Employed Women's Association (SEWA) - the single largest Central Trade union registered with a membership of over 3.2 million poor, self-employed women workers from the informal economy across 18 states in India, spoke about the importance of organized strength in agriculture and animal husbandry. She emphasized the potential of family farming as a non-lucrative, collective enterprise that can contribute to the building of nurturing economies. Megha also highlighted the need for natural pesticides, fertilizer technology, and insurance for women entrepreneurs, as well as the importance of data-based decision making for farmers. Bhavnaben, also associated with SEWA discussed her farming routines and her achievements.

Rina Soni, Executive Director, Passing Gifts, expressed her gratitude to the panellists and praised the work of each panellists in the area of women empowerment.

The webinar was a fruitful exercise that discussed various topics related to women's empowerment and entrepreneurship, including government initiatives aimed at economically empowering women, challenges faced by the agriculture sector in India, and the importance of community agrovet entrepreneurs in rural India. The speakers shared their experiences and strategies for diversifying income sources, promoting sustainable agriculture and biopesticides, and increasing women's representation in research and development. The meeting also emphasized the need for a multi-pronged approach to address rural development complexities, and the importance of breaking cultural norms and challenging social conditioning to promote gender equality. The panellists also divulged their future programmes

- Sewa to continue promoting climate-resilient technologies and data-based decision making for farmers.
- Bioprime to maintain efforts in having 70% women-led R&D and grooming women for leadership positions.
- SML Limited to continue work on improving soil health and nutritional quality of food to address micronutrient deficiencies.
- Dr. Nutan Kaushik to continue training rural women in food processing and sericulture.
- Meera Devi to expand her community agrovet entrepreneur (CAVE) services.
- Anjali Mahanta to maintain biosecurity measures and modern techniques in her poultry farming.
- Kumari Kalyani to continue diversifying her income sources through poultry and other enterprises.
- Passing Gifts to continue supporting and showcasing women entrepreneurs in agriculture.
- Agriculture Today to feature more stories of women entrepreneurs in agriculture in upcoming editions.

AI : FOR A SMARTER, SUSTAINABLE FUTURE

Indian agriculture forms the basis of the Indian economy, enabling the employment of more than 50 percent of the population. Even with this significant source of employment, this important sector is facing multiple systemic problems. A major problem is its water issue. Over 80 percent of the country's water resources are allocated to agriculture, and yet the careless farming practices and irrigation methods employed only serve to worsen the water crisis. In many areas, the combination of overexploited groundwater resources and modern farming techniques has caused a further aggravation of the already critical water situation.

Moreover, Indian agriculture is significantly behind the world in crop yield, which is mainly attributed to poor cultivation practices and lack of pest control. A single pest or pathogen can result in an annual crop yield decrease of 20-40%. The agriculture sector is also at increasing risk of climate change, suffering from the consequences of drought, high tides, floods, and irregular rainfall, which makes farming and harvesting more difficult. To alleviate and tackle these issues, AI seeks to completely redefine the agricultural landscape of India.

AI's Impact in Transforming the Indian Agricultural Industry

There are endless ways in which AI has the ability to tackle the challenges. One of the best ways that it can work is through increased data collection and analysis. From sowing the seeds and irrigation to harvesting, precision agriculture utilises AI to optimise all aspects of farming. AI-powered farming incorporates real-time data regarding soil conditions, weather predictions, and crop yields by utilising analytics, sensors, and remote sensing. Farmers simply process the information at hand, and AI helps them make efficient, agriculture-enhancing decisions. It really is as simple as that!

Programs like DigiAgriDiv will provide farmers nationwide with AI tools that increase productivity, improve transparency, and simplify operations.

AI in agricultural technology comes in many forms, one of which is precision irrigation. Farmers can amplify productivity and scale water resources with advanced AI irrigation systems. This optimises the predicted irrigation needs, and control of the watering system is automatic based on current climatic conditions. This is very helpful for Indian farmers in regions with limited water, as it gives crops the exact amount of water they need to grow well, without wasting any.

AI is also playing a vital role in reshaping pest and disease management. Traditionally, Indian approaches to pest management are rather labour-intensive and largely rely on chemical pesticides, which typically have negative consequences on the environment. More environmentally friendly solutions can come from newly developed technologies such as predictive modelling, artificial intelligence, and machine learning. While artificial intelligence can identify pests and diseases early on so farmers may respond before it is too late and on the other hand, machine learning can forecast the probability of pest outbreaks. This reduces pesticide spraying, eliminates undesired pesticide remnants, and saves money as well.

AI & Biologicals

In recent years, the entire agriculture industry has shifted more towards using biopesticides, biofertilizers, and biostimulants, along with other bioproducts. These biological products are non-toxic to humans and the environment and are obtained from organic matter, thus aiding in strengthening agroecosystems. They have significant importance in the management of soil nutrient cycles, integrated

pest management (IPM), and sustainable crop production.

Modern artificial intelligence (AI) techniques in India are improving farming practices in the region. Farmers can now use AI to analyse the optimal timing of applying biopesticides and biofertilizers.

Furthermore, AI makes certain that biofertilizers are provided at the right time which increases soil productivity. This specificity in agricultural processes helps prevent soil salinisation and eutrophication overuse issues, aids sustainable agriculture, and enhances the diversity of the soil microbiome. With the help of AI, it is possible to estimate the soil characteristics as well as how the nutrients will be released, which enables the application of biofertilizers in a more efficient manner. AI can also facilitate the development of new biostimulants.

The Path Forward

As artificial intelligence continues to grow, it is becoming more connected to Indian agriculture. Programs like DigiAgriDiv will provide farmers nationwide with AI tools that increase productivity, improve transparency, and simplify operations. Additionally, the new generation of Indian farmers is becoming more skilled in tech, and that is a piece of good news, as it will help create a bright future for agriculture in the country.

Yet, some of the challenges still cast a long shadow, and the biggest issues are hefty upfront costs and a lack of educational backgrounds among farmers. For AI to truly take root and thrive, it's essential to close the digital gap, make advanced technologies more affordable, and ensure that educational resources reach farmers, especially those in rural areas.

All in all, it can be said that we are witnessing a new dawn in Indian agriculture, where sustainability and high-tech efficiency are almost like two peas in a pod. By blending biological methods with artificial intelligence, farmers all over India can enhance their harvests while being kind to Mother Earth. AI brings a treasure trove of solutions to the urgent challenges facing the industry, including pinpoint irrigation, prompt pest management, and reliable weather predictions. With AI stepping into the field, the agricultural landscape in India is on the brink of a remarkable metamorphosis that caters to both today's demands and tomorrow's aspirations.

With the help of AI, it is possible to estimate the soil characteristics as well as how the nutrients will be released, which enables the application of biofertilizers in a more efficient manner.

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ROLE OF BASMATI RICE IN INCREASING INDIA'S AGRICULTURAL EXPORT

The Indian government's hyperactivity in amplifying the country's exports to reduce trade deficits has been commendable. The emphasis on enhancing trade has been extended to several sectors, especially agricultural products. The Ministry of Commerce and the Union Budget have also highlighted this notion, as the country aims to increase its agricultural exports to $100 billion by 2028.

This comprehensive effort is being spearheaded by both the authorities and the private sector and is backed by policies, Free Trade Agreements (FTAs) and other aspects. For instance, the Union Budget 2025 allocated INR 63,500 Crore for the PM Kisan scheme, along with emphasising the Prime Minister Dhan-Dhanya Krishi Yojana, High yielding seeds mission and others. These schemes and missions are expected to positively impact the cultivation and export of Basmati rice across international

In the last few fiscal years, the popularity of Indian Basmati has recorded a stark rise across key international markets, especially in Europe and the Middle East.

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markets, contributing towards increasing India's agricultural exports towards north of $100 billion by 2028.

As one of the highlights of India's agricultural commodities, Basmati rice has been able to garner continuous growth in exports in the last few fiscal years. The Indian government has also been forthcoming in supporting the trade with meaningful policies and reforms — positioning it favourably to drive the country's agricultural exports. As things stand, export houses remain optimistic about the proactive role of Basmati rice in contributing to the country's overall agricultural export in the coming years, and the introduction of ongoing FTA talks with key nations is expected to drive this comprehensive effort.

Growing Popularity & Exports

In the last few fiscal years, the popularity of Indian Basmati has recorded a stark rise across key international markets, especially in Europe and the Middle East. This growing popularity has been identified by Indian export houses, as they have also increased the overall exports to these key regions. For instance, India exported 46 lakh tonnes of Basmati in FY 23, an increase from the 39 lakh tonnes in the previous fiscal year. The comprehensive paradigm shift in Basmati exports has been forward-looking, providing the industry with scalability aspects, and also contributing towards Prime Minister Narendra Modi's vision of making India the world's food basket. This uniquely positions Basmati rice as one of the most effective constituents of Indian agricultural exports, contributing towards reaching the predetermined target of $100 billion by 2028.

The Basmati export sector has been subject to significant support from the Indian government, both actively and passively.

Furthermore, research & innovations led by government agencies like APEDA and the private sector to boost the cultivation of Basmati rice in India by educating and supporting farmers, creating new cultivation practices and others are having a significant impact. Furthermore, the support extended towards increasing overall crop productivity will help the cultivation of Basmati in India, allowing exporters to drive scalability efforts in key international markets.

Favourable Policy Backing

The Basmati export sector has been subject to significant support from the Indian government, both actively and passively. For example, PLI schemes were introduced by the authorities in the Union Budget 2024, which looked to address the lack of containers for export purposes through manufacturing domestically. Furthermore, the government's proactive steps to curb the floor price of Basmati rice, and exempt it from export bans that have been imposed on other agricultural commodities like Wheat have helped to sustain the growth momentum of the sector. In both Union Budgets in 2024 and 2025, special emphasis was extended towards grassroots stakeholders like farmers, empowering them with practical steps like credit lines and various schemes that have been considered key to raising the production and exports to key international markets.

Furthermore, the Ministry of Commerce's focus on increasing the overall export metrics by the end of this decade coincides and aligns with India's long-term vision to transform its vast agriculture sector. As things stand, the Government of India is actively in discussions with several nations like the United Kingdom to establish Free Trade Agreements (FTAs), that will be critical towards increasing exports to several key international markets. While India remains the world's largest rice exporter at its present capacity, the sustenance of reformatory policies and arrangements with countries will directly translate into Basmati rice's popularity growth, and rising exports could be matched by export houses on a demand basis.

Future Outlook

As of now, Basmati rice remains one of the highlights of India's agricultural commodities and sustained policy backing and private sector participation will further boost its popularity across the world. This will help Basmati rice become the highlight of India's agricultural exports, positioning it at the forefront of the country's agricultural export revolution. However, a comprehensive effort from all levels of stakeholders must be sustained in the coming years, considering the increasing popularity of Basmati rice in the international markets.

HOW AGRIBUSINESSES CAN NAVIGATE CLIMATE, CYBER, AND MARKET RISKS WITH REINSURANCE

Today, modern-day agribusinesses are exposed to growing threats posed by climate change, cyber-attacks, and volatile markets. Weather-related extremes, cyber exposures, and unstable commodity prices can jeopardize operations and financial solidity. To counter such risks, reinsurance is a key component in enabling primary insurers to manage and spread losses, so agribusinesses will be able to withstand them.

Reinsurers transfer risks globally, enabling insurers to provide comprehensive coverage and foster innovation.

Climate Change and Reinsurance

Climate change is having a profound effect on food production worldwide by lowering crop yields, impacting livestock health, and interfering with supply chains. Increased temperatures, extreme weather, and pest outbreaks altogether pose significant financial threats. Reinsurance products like parametric insurance, which pays out when certain weather conditions reach a certain level, assist agribusinesses in recovering. Yield protection policies and catastrophe (CAT) reinsurance have also stepped up to protect against economic losses due to climate-related events. For instance, when a drought lowers rainfall below a certain threshold, a farm may be compensated to balance economic losses.

Insurance Against Cyber Attacks

As digital technologies are more widely used in agribusiness, the latter is more exposed to cyber attacks like ransomware attacks, data theft, and manipulations of IoT systems. Cyber reinsurance supports insurers by covering financial losses from these threats. It ensures protection against major cyber disruptions, including hacks that compromise food processing operations or smart irrigation systems that, if manipulated, could lead to crop failure.

Insuring against Market Risks

Market risks are yet another uncertainty agribusinesses must deal with. Price swings in commodities, trade barriers, and supply chain disruption can have a material effect on profitability. Reinsurance products such as Revenue-Based Reinsurance insure loss due to low yields or declining prices. Trade Credit & Political Risk Reinsurance enables companies to recover from trade barriers or payment losses arising from non-payment in cross-border transactions. Supply Chain Disruption Coverage provides financial security in the event of unforeseen breakdowns, e.g., a delayed fertilizer shipment impacting crop output. In addition, FX Risk Transfer protects agribusinesses against currency devaluation affecting export earnings. For example, if there is sudden currency devaluation for a rice exporter, reinsurance can cushion the financial effect.

Through reinsurance, agribusinesses can successfully manage such uncertainties, improve financial security, and achieve long-term sustainability. Reinsurers transfer risks globally, enabling insurers to provide comprehensive coverage and foster innovation. Through a robust reinsurance strategy, agribusinesses can improve resilience against climate challenges, cyber risks, and market volatility, thereby contributing to global food security.

About the **AUTHOR**

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AI-POWERED DRONES CULTIVATING THE FUTURE OF AGRICULTURE

The agricultural landscape is undergoing a dramatic transformation, driven by the integration of cutting-edge technologies. The convergence of artificial intelligence (AI) and drone technology is reshaping the future of farming, offering solutions to the increasing demands on global food production. This evolution is being propelled by industry innovation and increasingly supported by forward-thinking government policies. and now garnering attention from high-profile personalities, including several prominent actors like Shri Amitabh Bacchan Ji.

Traditional farming practices often grapple with inefficiencies, resource wastage, farmer's health, and environmental concerns. AI-powered drones offer a compelling solution, empowering farmers with data-driven insights and precise tools to optimise every aspect of their operations. The integration of AI with drone technology is ushering in an era of precision agriculture, marked by

Smart Crop Monitoring: Drones equipped with advanced multispectral and hyperspectral sensors capture detailed imagery of fields, providing a comprehensive view of crop health. AI algorithms analyze this data, detecting subtle anomalies indicative of stress, disease, or nutrient deficiencies, often before they become visible to the naked eye. This early detection enables targeted interventions, minimizing losses and maximizing yields

Targeted Application of Inputs: Instead of spraying entire fields, drones equipped with AI-powered mapping and control systems can precisely apply pesticides, herbicides, and fertilisers only where needed. This significantly reduces chemical usage, minimising environmental impact and promoting sustainable farming practices.

Data-Driven Decision Making: The vast amounts of data collected by drones, including crop health, weather patterns, and soil conditions, are analysed by sophisticated AI algorithms to provide farmers with actionable insights. This empowers them to make informed decisions about irrigation scheduling, nutrient management, yield prediction, and resource allocation.

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The transformative impact of AI-powered drones resonates across the entire agricultural value chain by optimising resource utilisation and minimising losses, these technologies contribute to significant gains in agricultural output, driving increased efficiency and productivity. These technologies promote environmental sustainability through reduced chemical usage and precise irrigation management, minimising environmental impact and fostering responsible farming practices. Democratising access to advanced technology and data-driven insights, AI-powered drones contribute to economic empowerment, enabling farmers to improve their livelihoods and stimulate economic growth within their communities.

The industry is actively contributing to the adoption of precision agriculture globally and remains committed to developing innovative solutions and collaborating with partners to further advance the application of AI and drones in agriculture.

AI-powered drones are not just a futuristic concept but are a present-day reality transforming the agricultural sector. By harnessing the power of data and technology and supportive government policies, we are paving the way for a more efficient, sustainable, and prosperous future for agriculture worldwide. The combined efforts of the industry and governments are driving this revolution, ensuring that the future of farming is one of innovation, sustainability, and accessibility.

CREDIT RISK IN INDIAN AGRICULTURE: THE URGENT NEED FOR COLLABORATIVE SOLUTIONS

Agriculture is a cornerstone of India's economy, providing livelihoods for millions. Despite employing 46% of the workforce, the sector contributes only 18% to the GDP, highlighting the gap between agriculture's potential and its current impact. A major factor hindering agricultural growth is the escalating credit risk, which is not just a financial issue but one that directly affects farmers' livelihoods and the nation's stability.

The government recognizes agriculture as a key driver of India's development. Finance Minister Nirmala Sitharaman, in the Union Budget 2025-26, announced the PM Dhan-Dhaanya Krishi Yojana, targeting districts with low productivity and below-average credit access. Such initiatives are a step in the right direction, but we need more concrete solutions to secure agriculture's future.

The Complexities of Credit Risk in Agriculture

Credit risk in agriculture stems from factors beyond the control of farmers—unpredictable weather, market price fluctuations, and other external variables. This makes farmers highly vulnerable, especially since 85% of them work on marginal landholdings, leaving them more susceptible to failure.

Understanding these risks is the first step toward creating solutions that will stabilize and revitalize agriculture. Farmers require innovative credit models that account for their unique challenges.

Reforming Financial Institutions – what will it require?

Addressing agricultural credit risk is not the responsibility of a single entity; it requires collaboration among governments, financial institutions, technology providers, and farmers.

Financial institutions, essential to economic health, have struggled to meet the needs of the agricultural sector. High default rates, the lack of enforceable collateral, and the inherent unpredictability of farming make lending to agriculture challenging. As a result, many farmers are excluded from formal credit systems, forced instead to rely on informal lenders with high-interest rates, trapping them in a cycle of debt.

It's clear that the current approach is unsustainable. Financial institutions must embrace innovative practices and reform credit systems to be more inclusive, flexible, and resilient.

Empowering Farmers: Overcoming Barriers with Technology

A sizeable number of farmers are still excluded from institutional credit, as reported by the Reserve Bank of India. Banks often fail to meet their Priority Sector Lending targets and resort to buying agri-portfolios from other institutions, further

complicating the issue.

The answer lies in enhancing financial literacy, improving access to credit, and fostering farmer cooperatives. Technological innovation can bridge many of these gaps. Tools like satellite technology for weather predictions, real-time market prices, and advancements in cold storage can tackle inefficiencies and reduce the influence of middlemen.

Crop insurance, for example, has immense potential. By expanding coverage and integrating predictive analytics, farmers can better withstand disasters. The AgTech industry has already begun offering AI solutions for weather forecasting, pest detection, and yield optimization. However, wider adoption is limited. To scale AI, India needs vernacular platforms, affordable solutions, and government-backed advisory services.

While robotics adoption faces challenges due to high costs and India's abundant rural labour force, automation tools like seeders and sprayers are becoming more common. To foster robotics use, India must focus on affordable solutions for small farms, establish AgTech hubs, and encourage public-private partnerships.

Collaborative Solutions for a Sustainable Future

Addressing agricultural credit risk is not the responsibility of a single entity; it requires collaboration among governments, financial institutions, technology providers, and farmers. The path forward lies in partnership and innovation. Momentum is building, as reflected in the agricultural credit flow, which reached ☐18.6 lakh crore in FY 2022-23—highlighting the transformative potential of resource mobilization.

Breaking the Cycle and Unlocking Potential

The challenges of credit access and rising input costs also present an opportunity to reimagine support systems and unlock agriculture's unrealized potential. Through modern technology, innovative credit models, and institutional support, India can transform the agricultural sector and improve farmers' livelihoods.

The future of Indian agriculture is bright. With the right strategies, we can create a robust agricultural ecosystem that empowers farmers, strengthens communities, and drives national growth.

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The challenges of credit access and rising input costs also present an opportunity to reimagine support systems and unlock agriculture's unrealized potential.

India must focus on AI in Agriculture. While AI is being used for weather forecasting and yield optimization, its adoption remains limited. India must develop vernacular platforms, affordable AI solutions, and AI-driven advisory services. Also, scaling micro-irrigation, investing in climate-resilient seeds, and leveraging AI for localized climate advisory systems has the potential to help farmers adapt to climate change.

By embracing innovation and fostering public-private collaborations, India can lead the way in sustainable, technologically advanced farming.

WATER SCARCITY AND ALTERNATIVE SOURCES IN MEGACITIES

A rapid urbanization trend has been seen over the globe. The global population living in cities has been increased from 0.8 billion (29.6%) to 4.4 billion (56.2%) and is projected to reach around 6.7 billion (68.4%) by 2050. Urbanization, population growth and socio-economic development would increase urban industrial and domestic water demand by 50–80% over the next three decades. In parallel, climate change will adversely affect the spatio-temporal distribution of water in the coming decades. In general, water scarcity is going to be one of the biggest challenges in the future, particularly in urban areas.

In 2016, 933 million (32.5%) urban population was living in water scare regions in the world. Globally 573 million (20%) and 359 million (12.5%) people were facing seasonal and perennial water scarcity, respectively. Out of the world's 30 megacities (population >10 million) and 526 large cities (population >1 million), 9 (30%) and 193 (36.7%) were located in water scarce regions, respectively. Nearly half of the world's large cities (292) are projected to be located on water-scarce regions by 2050. And, 10 new megacities will fall under the water-scarce regions by the time. India (222 million) and China (159 million) had the highest urban population facing the water scarcity. India's population growth in water scarce regions was projected to increase at much higher rate than other countries, increasing from 222 million people to approximately 550 million people by 2050.

However, urban water scarcity has typically been addressed by engineering and technology interventions. For example, reservoirs are commonly used to store excess rainfall and continuously supply water to cities to avoid the shortage of water during dry seasons**.** Desalination plants

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are increasingly being popular in coastal areas to combat water scarcity. For cities where locally, available water resources are insufficient to meet the water demand, state-of-the-art engineering measures such as inter-basin water transfer are being introduced to solve the crises. Though, investment in water conservation, distribution and storage structures is an expensive affair; requires substantial human, material and energy resources which is further limited by topography and geographic conditions of the site; and may have very significant environmental impacts. Hence, there is an urgent need for comprehensive understanding of water scarcity as a whole and the potential solutions of the present and future water crises in sustainable manner for the livable urban futures.

Multi-Faceted Approach

Raising awareness and educating citizens about responsible water usage is a fundamental strategy in combatting this crisis. Responsible water use entails a mindful and sustainable approach to managing water resources. It encompasses valuing water's finite nature, minimizing waste, and optimizing consumption practices to mitigate the impacts of water scarcity. This culture goes beyond individual actions; it involves collective efforts that resonate across households, communities, and institutions. By promoting awareness, implementing innovative technologies, enacting effective policies, and fostering a culture of responsible consumption, megacities can pave the way towards a sustainable and resilient urban future. As we tread this path, we lay the foundation for a harmonious coexistence between human societies and the vital ecosystems upon which they depend.

Thus, growing population of megacities poses a formidable challenge to maintaining a reliable water supply. However, with innovative strategies, comprehensive infrastructure development, and a collective commitment to sustainable practices, we can navigate these challenges. Ensuring adequate water supply in megacities requires a holistic approach that integrates resource management, technology, policy reform, and citizen engagement. By taking these steps, we can not only secure water for our urban populations but also create resilient, livable, and thriving megacities for generations to come. Challenges have already knocked our door, there is an urgent need to act as soon as possible before they become sever and here are some solutions we have proposed for the sustainable future of water resources in the mega cities.

Deteriorating infrastructure, inefficient distribution networks, and loss due to leakages collectively contribute to inadequate water supply.

Improving Water Infrastructure: A Path to Sustainability

The rapid expansion of megacities places immense strain on existing water resources and systems. Deteriorating infrastructure, inefficient distribution networks, and loss due to leakages collectively contribute to inadequate water supply. By improving water infrastructure, cities can simultaneously address water scarcity, reduce wastage, and ensure equitable access for all residents. The following measures can be implemented to improve water infrastructure:

(a) Leak Detection and Repair: Advanced technologies such as sensors and data analytics can help in identifying leaks in water distribution networks promptly. And thereafter, timely repairs can prevent water losses and optimizes supply.

(b) Smart Metering and Monitoring: Installing smart meters provide real-time insights about water consumption patterns. This empowers individuals and businesses to monitor their usage and make informed decisions.

(c) Demand Management: Implementing demand-based water supply systems ensures that water is supplied according to actual needs, which ultimately reduces excess water consumption.

Smart Water Saving Techniques

In this era of innovation, smart water saving techniques have emerged as beacons of hope, offering pragmatic solutions to conserve water while catering to the needs of thriving urban populations. However, there are tremendous possibilities and limitless scope in developing the smart water saving techniques in the modern age, some of them are already in the vogue:

(a) Faucet Aerators:
The unassuming faucet aerator, fitted with tiny air vents, mixes air with water to reduce flow without compromising pressure. This small addition can lead to significant water savings every time a tap is turned on.

(b) Full Loads Only:
Run washing machines and dishwashers only when they're loaded to full capacity. This reduces the number of cycles and maximizes water efficiency.

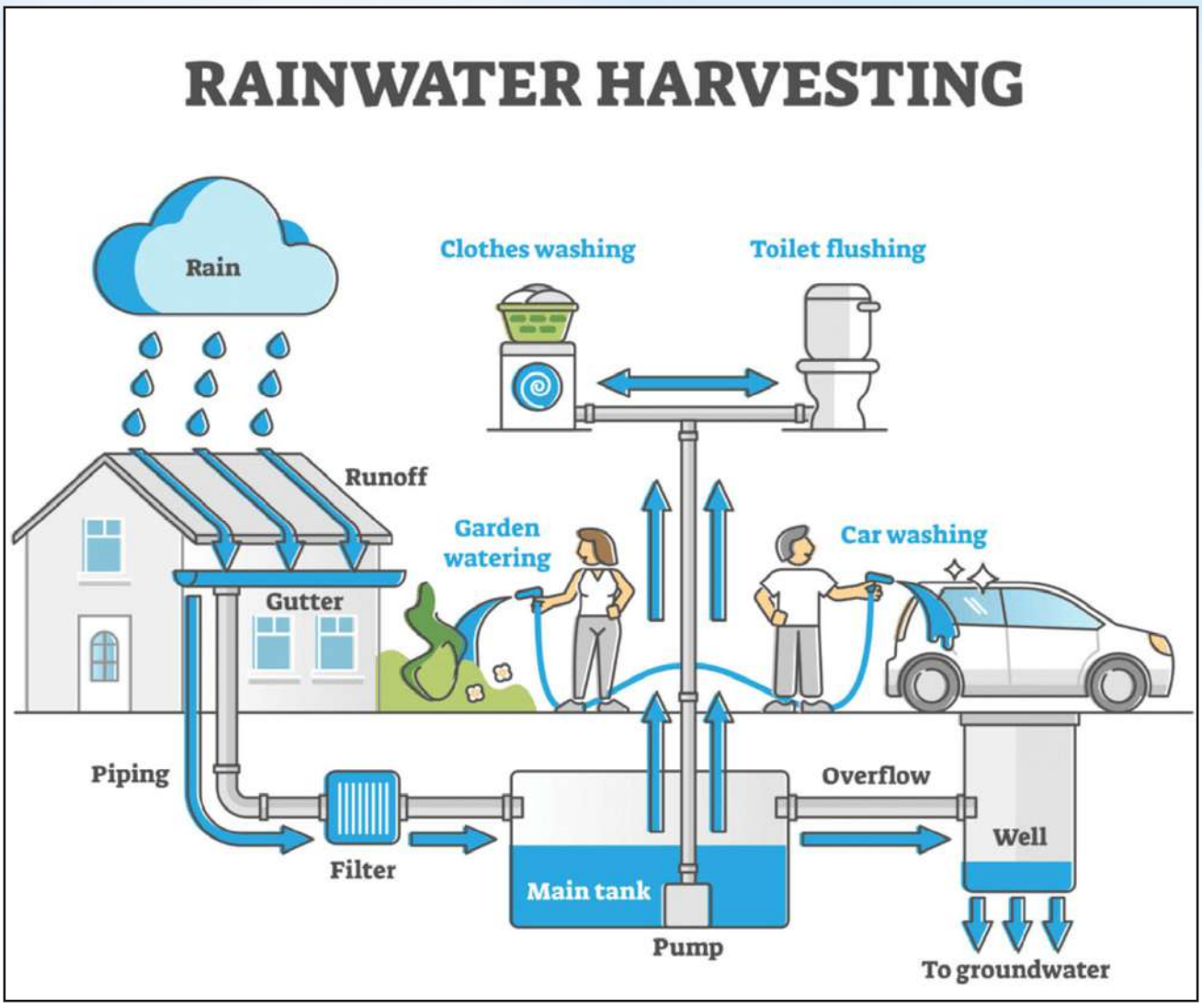
(c) Efficient Gardening Practices:
Water plants during cooler parts of the day to minimize evaporation. Mulching can help retain soil moisture, reducing the need for frequent watering.

(d) Dual-Flush Toilets:
If toilet isn't equipped with a dual-flush system, consider placing a water-filled bottle in the tank to reduce the amount of water used per flush.

(e) Mobile Apps for Behaviour Change:
User-friendly mobile applications offer real-time water consumption data and tips for efficient use. They empower citizens to make mindful choices about their water usage.

Desalination of Water

In the age of increasing water scarcity, the quest to meet growing global water demand has led to innovative solutions, where desalination emerging as a prom-



ising contender particularly in coastal regions. Desalination process, which involves converting seawater into freshwater, offers a potential lifeline for regions grappling with water shortages.

The Desalination Process:

Desalination is the process of removing salt and other impurities from seawater or brackish water, rendering it suitable for irrigation, household and industrial use and with advanced treatment for human consumption. While several methods exist, the two primary techniques are thermal desalination and reverse osmosis are more popular among others.

(a) Thermal Desalination:

Thermal desalination is a time-tested process that utilizes the principles of heat and phase change to transform saline water into fresh, potable water. This method has historically played a significant role in addressing water scarcity, particularly in regions where other freshwater sources are limited. Understanding the mechanics of thermal desalination sheds light on its inner workings and its applicability in meeting sustainable water demand.

(b) Reverse Osmosis (RO) desalination

Reverse osmosis (RO) desalination stands as a hallmark of modern engineering prowess, revolutionizing the way we combat water scarcity. This innovative process employs the principle of selective permeation to separate salts and impurities from seawater, creating a freshwater source that meets the demands of growing populations.

Rain Water Harvesting (RWH) system

Rainwater harvesting is a sustainable practice that involves collecting, storing, and using rainwater for various purposes, such as irrigation, domestic use, gardening and groundwater recharge. In mega cities, where rapid urbanization and population growth strain water resources, rainwater harvesting can offer several benefits and arise as prodigious solution of water scarcity problems.

Here's how rainwater harvesting can be change the fate of mega cities:

(a) Reduced Pressure on Water Supply

Mega cities often face challenges in meeting the water demands of their large populations. By harvesting rainwater, the demand on traditional water sources, such as rivers and groundwater, can be reduced, thereby easing the strain on existing water supply systems.

(b) Mitigation of Urban Flooding

Urbanization often leads to increased surface runoff due to paved surfaces that prevent water from infiltrating into the ground. This usually results in flooding during heavy rainfall. Rainwater harvesting systems, like rooftop rainwater collection systems, can intercept, collect, store and divert rainwater, reducing the volume of runoff and lowering the risk of flooding.

(c) Groundwater Recharge

As urban areas expand, natural areas that once absorbed rainwater are replaced by impervious surfaces. This reduces the recharge of groundwater, leading to its depletion. Rainwater harvesting can help in replenishment of the groundwater depletion by allowing water to percolate into the soil instead of being lost as runoff.

(d) Supplementing Water Supply

Harvested rainwater can be treated and used for non-potable purposes, such as flushing toilets, watering plants, washing and cleaning. This reduces the demand for treated drinking water for activities that actually don't require it, conserving the city's water resources.

(e) Drought Resilience

Rainwater harvesting provides an alternative water source during drought periods when traditional sources might be scarce. RWH enhances the city's resilience to water shortages and ensures a more reliable supply of water.

(f) Localized Benefits

Rainwater harvesting encourages a decentralized approach to water conservation and management. Individual buildings can install RWH systems, reducing the burden on centralized water infrastructure and promoting self-sufficient mega-cities.

(g) Green Infrastructure

By treating and reusing wastewater, communities can significantly reduce their dependence on freshwater sources, thus mitigating water scarcity issues.

RWH systems can be integrated into green roofs, permeable pavements, and other sustainable urban design elements. These practices can contribute to the overall sustainability and aesthetics of the cities.

(h) Regulation and Policy Support

Local governments can play a crucial role in promoting rainwater harvesting by introducing regulations, incentives, and subsidies for implementing these systems. They can also entail RWH unit as part of building codes.

(i) Challenges to Consider

While rainwater harvesting has numerous benefits, its successful implementation in mega cities may require addressing challenges such as initial infrastructure costs, timely repair & maintenance, water quality concerns, and ensuring that the harvested water doesn't become a breeding ground for disease vectors.

Recycling and Reusing of Waste Water

Wastewater, often dismissed as a waste product, contains a significant amount of recoverable resources. Through advanced treatment processes, wastewater can be purified to a level that makes it suitable for a wide range of non-potable uses including irrigation of crops, industrial processes, landscape irrigation, and even replenishing groundwater depletion. By treating and reusing wastewater, communities can significantly reduce their dependence on freshwater sources, thus mitigating water scarcity issues.

Culture of Responsible Water Use

Cultivating a culture of responsible water use involves changing the way people perceive, value, and utilize water. This cultural shift is fundamental for mega cities to overcome water scarcity challenges and promote long-term sustainability. Here's how such a culture can make a difference:

(a) Education and Awareness

Raising awareness about the importance of water conservation and management is a key first step. Public education campaigns, workshops, and school programs can inform citizens about water scarcity, its causes, and the actions they can take to contribute to the solution.

(b) Behavioural Change

Encouraging small so far impactful changes in day-today behavior can collectively lead to a significant water savings. Simple actions like fixing leaks, using water-efficient smart appliances, and turning off taps while brushing teeth can add up to substantial reductions in water consumption.

(c) Integrated Water Management

A culture of responsible water use encourages communities to implement holistic water management strategies such as rainwater harvesting, wastewater recycling and using it for variety of non-potable uses, and the use of drought-resistant plants in landscaping.

(d) Innovative Technologies

Technology can play a pivotal role in cultivating the culture of responsible water use. Smart meters, IoT-based leak detection system in water distribution network, and user-friendly mobile applications that provide water usage insights empower individuals to monitor, control and take judicial actions against their water consumption.

(e) Community Engagement

Involving citizens in decision-making processes related to water conservation and management fosters a sense of ownership and accountability. Participatory approaches ensure that solutions are tailored to the needs and preferences of the community.

SWEET BASIL SEEDS
NUTRITIONAL AND HEALTH BENEFITS

Sweet basil seeds are commonly known as sabja or kamakasturi seeds that come from the sweet basil plant (*Ocimum basilicum*), an annual culinary herb belongs to the Lamiaceae family. Sweet basil is widely cultivated across the India particularly among regions of Andhra Pradesh, Telangana, Karnataka, Madhya Pradesh, Maharashtra, Jammu, Assam, West Bengal, Bihar and Uttar Pradesh. In Karnataka, it is extensively grown in Ballari, Chamarajanagar, Kolar, Davanagare, Mysore, Shivamogga, Gulbarga, Udupi and Dakshina Kannada districts essentially for the purpose of aromatic leaves and edible seeds.

In Traditional Medicines

The herb has been used in traditional medicines (Unani, Ayurveda and Siddha) from the ancient times due to its expectorant, flatulence reliving, antidiabetic, anti-inflammatory, antiaging, antipyretic, diuretic, antiviral and antimicrobial properties. Sweet basil leaves are used either fresh or dried to add a distinctive flavour and aroma to the foods. They are also utilised in the manufacture of beverages, liqueurs, vinegars, teas and essential oils. Sweet basil seeds are aromatic, black in colour, small in size, ellipsoid in shape with dimensions ranged between 2.31-3.11 mm length, 1.30-1.82 mm width, 0.99-1.34 mm thickness. They produce considerable amount of mucilage when soaked in water that remains tightly bound to the seed core.

The sweet basil seeds are excellent source of dietary fiber (48.5 g/100 g), protein (8.6 g/100 g) and energy (328 Kcal/100 g).

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Deteriorating Lifestyle

The prevalence of lifestyle diseases in India has increased dramatically over the last few decades. A study conducted by Indian Council of Medical Research (ICMR) revealed that the national prevalence of diabetes is 11.4%, prediabetes is 15.3%, hypertension is 35.5%, generalized obesity is 28.6%, abdominal obesity is 39.5%, hypercholesterolemia is 24% and high low-density lipoprotein (LDL) cholesterol is 20.9%. Further, the past decades portrayed an increase in life expectancy as well as public's concern of leading a healthy life. The connection between diet and health is well established long ago with certain foods possessing nutraceutical components (dietary fiber, protein, vitamins, minerals, antioxidants) exhibiting additional health benefits compared to others.

Seeds- Nutritionally Content

The sweet basil seeds are excellent source of dietary fiber (48.5 g/100 g), protein (8.6 g/100 g) and energy (328 Kcal/100 g). The high dietary fiber intake is beneficial in reducing the risk of prevailing lifestyle diseases such as constipation, obesity, cardiovascular problems, diabetes, gastrointestinal disorders and cancers. The regular consumption of sweet basil seeds is associated with improved satiety and better management of body weight, blood glucose and cholesterol levels. The seeds are also good source of omega-3 fatty acid (α-linolenic acid) that has been associated with reduced cholesterol level, arterial plaque buildup, inflammatory biomarkers, blood pressure and preventing heart diseases.

The sweet basil seeds are rich source of calcium (568 mg/100 g) compared to chia seeds (463 mg/100 g), ragi (364 mg/100 g), almonds (228 mg/100 g) and milk (121 mg/100 g). They are good source of magnesium (261 mg/100 g) like amaranth seeds (270 mg/100 g), soybean (259 mg/100 g) and cowpeas (213 mg/100 g). Further, they are good source of potassium (594 mg/100 g) like chia seeds (407 mg/100 g) and banana (358 mg/100g). The consumption of foods rich in calcium, magnesium and potassium is beneficial in reducing the risk of brain stroke, hypertension, osteoporosis, cardiovascular diseases, muscular diseases and type 2 diabetes.

Sweet basil seeds also possess good amount of microminerals such as zinc (7.0 mg/100 g), copper (1.9 mg/100 g) and manganese (1.9 mg/100 g) essential for proper functioning of immune system. The zinc content in sweet basil seeds is comparable to pumpkin seeds (6.6 mg/100 g), cashew (5.3 mg/100 g) and flax seeds (4.9 mg/100 g). The copper content in sweet basil seeds is much higher than the chia seeds (0.9 mg/100 g). Thus, sweet basil seeds offer better health benefits than the chia seeds. Further, sweet basil seeds are also potential source of antioxidants such as phenols (210 mg gallic acid equivalent/100 g) and flavonoids (144 mg quercetin equivalent/100 g). The dietary antioxidants play a vital role in preventing the inflammation driven diseases (cardiovascular diseases, cancers, neurodegenerative diseases) by scavenging free radicals and attenuating the oxidative damage. Thus, sweet basil seeds are being considered as 'super seeds' of 21st century.

A Culinary Delight

Now-a-days sweet basil seeds are gaining popularity as a healthy kitchen staple across the globe. They are often used to enrich fruit drinks, lassi, sharbat, lemonades, smoothies, frozen desserts and soups. They provide cooling effect and protect the body from heat stroke. This makes them a popular addition to drinks during hot weather to prevent dehydration and fatigue. A typical serving is about 1 to 2 tablespoons of dry seeds added to 200 to 250 mL of drink. Hot drinks hydrates the seeds in one minute, drinks at room temperature takes 3 to 5 minutes and cold drinks takes about 20 minutes. The seeds are also added as whole or milled to the bakery products as a source of dietary fiber.

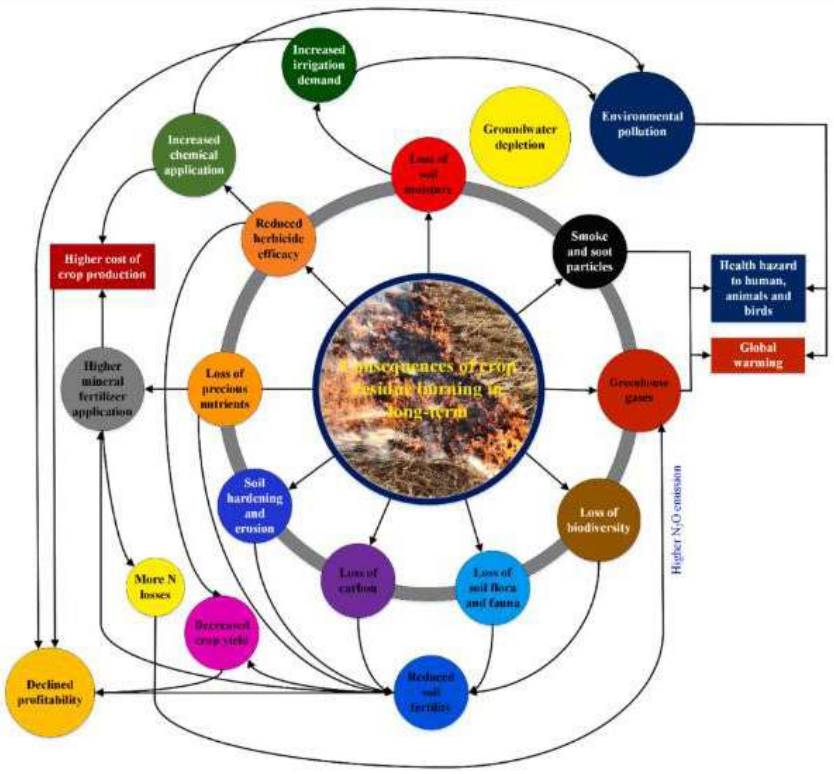
The copper content in sweet basil seeds is much higher than the chia seeds (0.9 mg/100 g). Thus, sweet basil seeds offer better health benefits than the chia seeds.

Gradual addition of seeds to the diets of people with low fibre intake to is advisable to avoid bloating, discomfort and the digestive system to adjust. Dry seeds should be cleaned and stored at room temperature in an airtight container ideally in a cool, dark place.

RESIDUE-TO-ENERGY: HARNESSING AGRICULTURAL WASTE FOR ENVIRONMENTAL SUSTAINABILITY

Rice is farmed in diverse growing places during different seasons from around 50° N to 35° S, and from below sea level to over 2000 metres height, with a mean temperature range of 17° to 33° C, rainfall 0 to 5100 mm, and sun radiation 300 to 600 calories/cm ^{2} /day. It is the world's most significant food crop, growing in 112 nations on every continent and feeding more than half of the world's population by delivering 35 to 60% of their daily calories. Fibre, protein, vitamin B, iron, and manganese are all present in reasonable levels. As a result, rice is a significant component of the Government of India's Food Security Mission, as it helps to combat malnutrition in the country.

Rice farmers, on the other hand, confront significant problems such as low income, deterioration of natural resource bases, and climate change-related amplification of both biotic and abiotic pressures, all of which take all of science's ingenuity to overcome. After



Consequences of crop residue burning on crop productivity, profitability and natural resource (Source: Kumar et al., 2023)

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Generation of cereal crop residues is highest in the states of Uttar Pradesh (72 Mt) followed by Punjab (45.6 Mt), West Bengal (37.3 Mt), Andhra Pradesh (33 Mt) and Haryana (24.7 Mt).

Crop residue generation in different states of India

State	Cereals	Fibre	Oilseed	Sugarcane	Total
UP	72.02	0.04	2.49	41.13	115.68
WB	37.26	24.43	0.95	0.62	63.26
AP	33.07	16.07	2.5	5.8	57.44
PB	45.58	9.32	0.08	1.76	56.74
MH	8.75	19.51	0.57	22.87	51.7
GJ	8.18	28.62	5.06	5.85	47.71
HR	24.73	7.58	2.15	1.93	36.39
MH	22.19	2.96	9.26	0.15	34.56

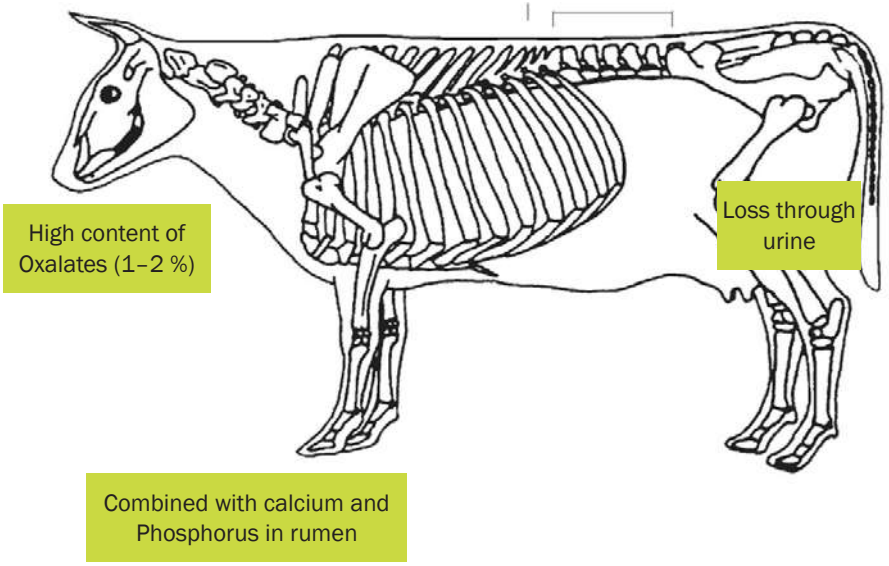
harvesting or processing the economic components of cultivated crops, such as leaves, stalks, and roots, crop residue is the residual plant material or biomass. Proper management techniques, such as incorporation or mulching, mitigate environmental impacts like greenhouse gas emissions and soil degradation are important after rice harvesting and processing. India produces an estimated 178 Mt of surplus crop residues annually, of which 87 Mt are burned. Implementing effective residue management practices contributes to sustainable rice production and environmental preservation.

Why Residue Management?

"Crop residues should be seen not as wastes but as providers of essential environmental services, assuring the perpetuation of productive agro ecosystems".

India produces an estimated 178 Mt of surplus crop residues annually, of which 87 Mt are burned.

Crop residue and its management challenges have significantly increased since high yielding varieties of crops were used in modern crop production. Crop residue burning has become a common practice, particularly in developing nations like India, due to factors such as the critical window period between two crops, which is crucial for wheat sowing after rice and sugarcane harvest, and the unsuitability of certain crop residues for animal feed.



Mechanization has increased, with the use of combine harvesters increasing from 2000 in 1986 to 10000 in 2010. Due to a lack of traditionally competing uses for crop residues such as animal feed, fodder, fuel, roof thatching, packaging and composting.

Generation of cereal crop residues is highest in the states of Uttar Pradesh (72 Mt) followed by Punjab (45.6 Mt), West Bengal (37.3 Mt), Andhra Pradesh (33 Mt) and Haryana (24.7 Mt).

Impact of rice residue burning on Animal Health

Despite certain advantages like as insect control and removing heaps prior to wheat planting, burning resulted in huge losses of N (up to 80%), P (25%), K (21%), and S (4-60%), as well as air pollution (@ CO2 13 t ha-1) depleting soils of organic matter (SOM). The high lignin and silica content of ruminate, the slow and limited ruminal breakdown of carbohydrates, and the low nitrogen and phosphorus concentration limit ruminate feeding. Rice straw has a low rate of disappearance and passage in the rumen due to its weak fermentation, resulting in reduced feed intake. Lignin cannot be broken down in the rumen due to a lack of ligninase, resulting in reduced feed consumption. Silica decreases the palatability and degradability of rice straw in the rumen due to its direct action in reducing ruminal microbial colonisation.

How to manage Rice residue?

On farm residue management

Residue retention: A conservative technique to managing crop residue in-situ that saves energy and the environment is to leave the residue on the soil surface. Recent advancements in agricultural technology enable the direct sowing of crops in soil conditions coated with residue by widening the tiny openings for the insertion of seeds and fertilizer, while maintaining the integrity of the remaining soil surface. Crop tolerance against terminal heat stress is increased, soil erosion is decreased, and soil carbon is sequestered when crop residue is kept on the soil's surface.

Residue Incorporation: The residue of

various cereal and pulses crops can either be mixed with soil using active i.e. PTO (power take-off) driven implements or buried into soil using passive type implements. However, each implement provides different soil pulverization, stubble cutting, and crop residue burial efficiency with their relative advantages and disadvantages

Straw mulched-Zero Tillage: Used for seeding the crops in an untilled field with/without anchored residue.

Happy seeder: It can be used for seeding the crops in untilled field with anchored and loose residue.

Strengthen industrial Utilization

Rakes and balers for residue removal: Balers play a pivotal role in stubble compression, acting as hydraulic presses to compact crop residues into dense, manageable packages. These compressed stubbles are securely bound using twine, wire, or strapping.

Use of rice straw as animal feed with proper treatment

Industrial Utilization Options

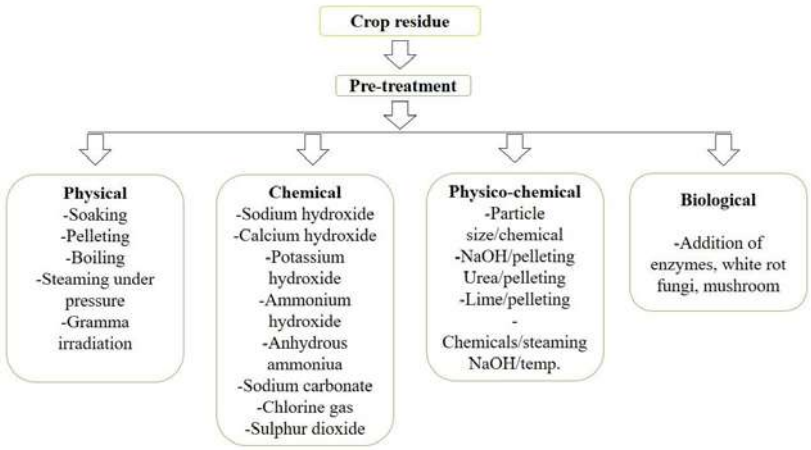
Power generation from straw

A 12 MW rice-straw power plant typically needs 120,000 tonnes of stubble, which can be collected from about 15,000 farmers. Power industry pay Rs 900 a tonne for non-basmati rice straw and Rs 1,500 for basmati rice straw

Straw as a raw material for ethanol production: As such as crop residue can serve as second generation feedstock for the production of various fuels. . In production of liquid fuel through pyrolysis, dried and pretreated biomass is exposed to high temperature (300–600 ◦C) in the absence of oxygen, which decomposes it into solid (charcoal, biochar), liquid (pyrolysis oil) and gaseous (H2, CO, CH4, CxHy, CO2 and N) components.

Value addition: Plant biomass is composed of cellulose, hemicellulose, lignin, lipids, proteins, starch, carbon, water, hydrocarbon and other compounds such as nitrogen, phosphorus, potassium, sulphur, etc., depending upon plant species and growing conditions. Rice residue, a lignocellulosic biomass, contains about 38% cellulose, 25% hemicellulose and 12% lignin

Use of rice straw as animal feed with proper treatment



Straw for paper/ board making : Similarly, in addition to paper industry, sugarcane bagasse is conventionally used in sugar mills for providing the fuel to boilers where its hemicellulose and lignin components are underutilized due to their limited contribution in total heating value

a. Straw as a packing material
b. Straw for mushroom cultivation

It is recommended that governments employ a blend of punitive and compensatory strategies to discourage farmers from incinerating crop residue. Crop residue has the ability to partially replace traditional feedstock in the processes of composting, growing mushrooms, and using biogas in rural regions. This is the current position. There is surplus agricultural residue (about 180 Mt) available in India that can be used as feedstock for second generation biofuels. For example, it has the capacity to produce 60 billion litres of bioethanol per year. Before being applied to gasification and thermal power plants, low heating value components with value additions must be extracted from crop residue. This will allow by products from one business to be systematically used as feedstock in other industries. Moreover, additional by products produced during the manufacture of biofuel, such as biochar, biomass ash, and biogas slurry, have excellent uses in the construction industry as a partial replacement for Portland cement and as a way to improve soil quality. Crop residue has enormous potential for use in the paper industry, the synthesis of multifunctional carbon materials, and cutting-edge sectors including pharmaceuticals and cosmeceuticals in addition to the biofuel program.

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