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Overview

Frontier technologies in livestock production and health with special reference to global warming

Global warming and rising temperatures are known to negatively affect animal fitness directly through effects on physiology, but they may also help in better production in cold environments. Understanding how species' thermal limits have evolved across the tree of life is central to predicting species' responses to climate change. To evaluate the changes and understand the mechanisms involved, an integration of physiological data into assessments of species' climatic vulnerability needs to be developed. Global warming is reshaping species distributions and altering ecological communities. Yet, we do not know what mechanisms have driven or obstructed past adaptation to temperature changes over evolutionary time scales.

The agricultural production system, both in developed and developing countries, is undergoing a transformation in which the contributions from livestock to total agricultural production are showing a significant increase, reaching almost 47% of total agricultural production contributions in the economy. This development brings several considerations and challenges that the modern livestock production system must confront. This demands innovation in approach so that the compounding influences from climate and global warming are mitigated.

The Global Animal Health Association, in its valuable report on 'Health for Animals' (2023), emphasizes that animal diseases and health challenges are constantly evolving and impact the global economy, animal and human health and present serious challenges to sustainable development. Between 2000 and 2016, the above study indicates almost 3060 animal disease outbreaks were recorded across 116 countries in the world, causing enormous losses and impacting trade as well as global food security. The report further emphasizes that during the same time, pet ownership has skyrocketed across the globe to over 50% of households. In India also, besides the large population of domestic livestock, pets need now to be counted as they have an impact on the total health and human welfare.

The accelerated application of smart, digital, and precision livestock technologies offers a historic opportunity and challenge to improve animal health and productivity of animals and to generate the rural transformation needed for achieving sustained growth and development under climate change. Many of the challenges faced by animal owners/farmers are the result of information asymmetries and deficiencies. Frontier technologies can mitigate these challenges by providing farmers with real-time solutions to their problems. Despite a long list of techniques and technologies developed, the benefits of the uptake of these technologies by animal owners/farmers remain limited. To address the existing barriers to the adoption of these technologies, it is important to invest in the adoption of the techniques in rural areas and establish a new generation of veterinary delivery system extension services.

Technology can increase animal health and production. Genetic improvement, nutritional strategies, disease management, reproductive technologies, and precision livestock farming are all effective strategies that can be used alone or combined to enhance animal productivity. As technology advances, new strategies will likely be developed, further improving animal health and production.

Genetic enhancement improves animal health and output. Since traditional methods are not always effective, genetic selection and breeding programs have been developed to enhance desirable traits in animals, such as increased milk production or disease resistance. Through selective genomic breeding, farmers can improve the genetic traits of their livestock and enhance their productivity. In addition, molecular genetics has made it possible to identify specific genes responsible for desirable traits, allowing for more targeted breeding programs. Genome editing technologies allow programmable DNA nucleases-based accurate genome alterations. Despite its many benefits, genetic improvement in livestock creates technological, ethical, and societal issues. Several technological options for gene modification to improve animal health and production are available.

In the agricultural scenario of this country, the statistical analysis very amply proves that the nutritional sustainability and total agriculture economy are greatly dependent on livestock production. The demand driven growth of livestock sector in total agriculture also presents several challenges to increase production and productivity among the livestock. Modern advances in Embryo biotechnology and IVF techniques developed and pioneered in India are playing a significant role in the improvement of our indigenous breeds. Emerging technologies, artificial intelligence/stem cell technology and new generation of vaccines are to provide greater opportunities to predict, prevent, diagnose and treat animal diseases more quickly, accurately and safely. Veterinary research is thus focused on reducing disease spread and its impact. The unique features of an animal production system that involves resources of poor landless animal owners and their low economic standing, a vast biodiverse animal population, poor nutritional status and feeding from straws, and the endemic nature of several infectious diseases make the sector more vulnerable to the effects of climate change. This implies technologies have to be evolved and delivered to the animal owners, mostly landless with poor resources, and necessarily also ensured that their produce from the livestock is handled in a biosafe system, marketed efficiently with profitable economic returns to the producer.

The health of the animals, whether livestock or pets, is linked to the well-being of the people, meaning better animal health plays an integral role in sustainability. The health of animals is of critical importance to One Health and sustainable development goals. Developing innovations that are effective across this diverse landscape is a significant challenge, which is why a policy and regulatory environment that recognizes the unique characteristics of the animal health sector is essential.

Vaccines are among the most powerful tools in the veterinary toolbox. New vaccines and delivery methods provide opportunities to prevent more diseases. Streamlining regulatory approval and assessment of biologicals and vaccines could inspire more and quicker vaccine development. There are several technologies involving innovative approaches which are reaching the market for use on animal diseases and helping protect animals, food supplies and livelihoods. RNA vaccines work by giving cells in the body a blueprint for how to fight off infectious diseases. Heat resistant vaccines in tropical countries or areas should be developed where refrigeration is not possible. Precision systems to deliver vaccines can improve vaccination rate, a procedure which has been adapted in poultry production. More effective vaccines and delivery mechanisms can help protect more animals against diseases, which means protecting the livelihoods of millions, reducing the need for antibiotics, reducing the risk of zoonotic diseases and protecting livestock from environmental calamities and disasters as also giving animals physiological and genetic capacity/capability to resist the adverse effects of climate change.

The climate tolerance of livestock could be increased by identifying and strengthening those local breeds that are already resilient. Alternatively, local genetics can be improved through cross-breeding with heat and disease-tolerant breeds. Meanwhile, advances in breeding technologies are now enabling genome modification in livestock by using gene editing tools to unlock specific traits. For example, gene editing can limit milk yield reduction during hot weather. Other horizon technologies relate to the genomic evaluation of a young animal's performance, based on tissue samples to determine whether offspring are likely to have certain characteristics such as heat tolerance. In animal breeding, the use of chips based on SNP genomic data from a large number of animals has made it possible to have an effect on an early selection of animals for breeding programs. This enables farmers to determine breeding values and strengthen climate-resilient traits among their herds. Many livestock breeds are already well adapted to harsh climatic conditions.

Ongoing research on cold and ambient plasmas or ionized gases has shown that these substances can destroy harmful pathogens without leaving residues. Antimicrobial peptides (AMPs) are broad spectrum antimicrobial molecules that are produced in almost all animals as part of the immune system. These days, AMPs have become one of the most widely researched alternatives to conventional antibiotics—treatments using nanotechnology or tiny particles for antibiotic-resistant bacteria or in development and test trials. Nanoparticles delivering antibacterial

substances such as propolis, a compound made from B to protect their hives could be added to animal feed to treat infections. Treatments that direct the immune system response could harness an animal's natural defenses against bacterial infection. Immunotherapies are used to attack certain cells or infections.

Digital technology offers an opportunity for veterinary medicine to become more efficient and precise. Automation, greater connectivity and more health data can allow earlier diagnosis and more accurate treatment. This requires infrastructure, expertise and capacity for adequate analysis. The government and the private sector have to move fast in this area, first to ensure that accurate elaborate data is generated and there is a uniform code and analytical procedures that will help in correct inferences drawn from the data generated. Software systems can harness the wealth of data provided by digital technologies to predict disease and health challenges.

Advancements in digital monitoring and surveillance are rapidly transforming the animal health landscape, bringing improvements in speed and efficiency that enable individual-level treatment. Even in groups of animals, the new technology of sensors, tags and collars can allow farmers and veterinarians. To treat individuals or groups of animals, real-time monitoring and surveillance using cameras, microphones and sensors can produce accurate and continuous data on animals' well-being, productivity and performance. Prediction technologies through software systems can harness the data provided by digital technologies to protect disease or health. Early disease detection and individual treatments can help support sustainable development and help in developing strategies for mitigation of climate change effects. The digital livestock systems could improve livestock production, reduce the livestock industry's environmental impact, save energy, and improve animal welfare.

Artificial intelligence has the ability to improve diagnostics, enabling more predictable and rapid analysis of samples. Microfluidics devices such as tiny chips can conduct analysis on extremely small volumes of fluids such as blood and biofluids and enable practitioners to bring diagnostic devices to the convenience of the user. The use of molecular diagnostics for analyzing biological markers in the genetic code are helping in veterinary medicine.

Technological innovations in Livestock nutrition have brought in the concept of probiotics and phytogenic feed additives, which alter and improve the gut microbiome. Precision feed preparation and smart livestock production and health bring in the economy and efficiency of production.

Technologies and climate adaptation solutions often relate to developing resilient feed crops and livestock breeds, pasture rehabilitation and optimizing feed and production systems. This section also presents advances in heat stress detection and management and digital technologies for livestock monitoring. The frontier technologies identified above could have a hugely positive effect on rural livelihoods, livestock economies, and the ability of the food supply chain to tackle the grand challenges of climate change.



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Overview

India is one of the world's leading countries in livestock and fisheries production, and these sectors play a vital role in the country's economy, livelihood, food and nutritional security. India is the largest producer of milk and 2nd largest producer of fish. However, per-animal productivity is very low owing to the poor genetic potential of indigenous livestock. Indian farmers face enormous challenges including lack of modern infrastructure, lack of appropriate connectivity, growing demands for animal proteins, food spoilage, and disease with rising concerns around animal health. India is also experiencing the impacts of climate change, with rising temperatures, erratic rainfall, and extreme weather events adversely affecting both the livestock and fishery sectors. Heat stress in livestock can lead to reduced productivity, increased mortality, and higher healthcare costs. In fisheries, changes in ocean temperatures and weather patterns can disrupt fish migration and breeding patterns, impacting fish populations and catch rates. In addition, the country is also facing various emerging environmental issues, such as climate change, habitat degradation, water scarcity, and pollution. These issues pose serious challenges to the sustainability of animal husbandry and fisheries practices. To address some of the above mentioned challenges, several new technologies are being developed and adapted in technologically advanced countries. In this context, some frontier technologies can play a crucial role in advancing animal and fishery sciences in India. These technologies encompass a wide range of innovations and tools that are reshaping the way for the enhancement of animal production and health, fisheries, and environmental conservation. Some of these emerging technologies are:

- 1. Precision livestock farming (PLF):** Precision livestock farming, incorporating sensors, artificial intelligence (AI), and data analytics, is already being used in the animal husbandry sector, particularly in large organized farms in technologically advanced countries. By closely monitoring animal health, behaviour, and nutrition, PLF optimizes feed utilization, reduces greenhouse gas emissions, and improves overall productivity. However, this technology is at the very initial stage of its application in some organized animal farms in India. As more than 80% of livestock sector in India is unorganized and the animals are reared in small holding agriculture system, some of these technologies do not appear to be applicable. Therefore, the real challenge is to innovate and develop technologies suitable to smallholder livestock-agriculture farming systems. The new technologies should ensure resource efficiency and minimal environmental impact.
- 2. Vertical farming for livestock feed:** Climate change-induced droughts and unpredictable weather patterns can affect traditional crop cultivation, leading to shortages of livestock feed. Vertical farming, where crops are grown in stacked layers indoors, offers a potential solution. This technology can produce high-quality, nutrient-rich animal feed using limited space, water, and energy resources. It has the potential to reduce the reliance on traditional agricultural practices, thereby mitigating climate risks.
- 3. Recirculating aquaculture systems (RAS):** RAS are becoming popular in the Indian fishery sector to mitigate water scarcity and prevent water pollution. RAS enables fish farming in controlled environments, recycling water and reducing the pressure on natural water bodies. Implementing RAS in land-locked regions ensures year-round fish production, supporting sustainable aquaculture practices. RAS allows for the production of fish in

land-based facilities, reducing pressure on natural water bodies and minimizing the risk of disease transmission to wild fish populations.

4. **Eco-friendly aquaculture techniques:** India is exploring eco-friendly aquaculture practices such as integrated multi-trophic aquaculture (IMTA) and biofloc technology. IMTA combines multiple species, with waste from one species becoming a resource for another, reducing environmental impact. Biofloc technology uses microbial communities to improve water quality and nutrient recycling in aquaculture systems.
5. **Aquaponics and integrated farming:** Aquaponics combines fish farming (aquaculture) with soilless plant cultivation (hydroponics) in a symbiotic system. Fish waste provides nutrients for plants, and the plants, in turn, purify the water for the fish. This integrated approach reduces waste, conserves water, and optimizes resource use, making it an eco-friendly and resource-efficient method for producing both animal protein and vegetables.
6. **Aquaculture automation:** In the fishery sector, aquaculture automation is gaining traction as a means to enhance efficiency and reduce environmental impacts. Robotic systems are being developed to automate fish feeding, water quality monitoring, and waste management in fish farms. By optimizing feeding schedules and monitoring environmental conditions, automation can help minimize feed wastage and reduce the risk of disease outbreaks, ultimately leading to more sustainable aquaculture practices.
7. **Biotechnology, genomic selection and gene editing technologies:** India is slowly beginning to adopt biotechnological advancements and genomic selection in livestock and fish breeding to develop breeds/varieties with high productivity, climate-resilience and disease-resistance. These technologies can help in optimizing animal production and reducing the use of resources such as feed and medication, contributing to environmental conservation. Genomic selection and gene editing techniques have immensely impacted animal and fish breeding in technologically advanced countries. By identifying desirable genetic traits and making precise modifications in the DNA, biotechnologists can develop animals and fish with improved disease resistance, enhanced growth rates, and better adaptability to changing environmental conditions. These technologies promote more efficient resource utilization and reduce the need for antibiotics and other interventions. Genomic technologies, including next-generation sequencing (NGS) platforms, have an enormous impact on the field of animal and fishery sciences. They allow for the rapid and cost-effective sequencing of genomes, enabling researchers to study genetic diversity, disease resistance, and the breeding of more resilient and productive livestock and fish species.
8. **Artificial intelligence (AI)-driven ecosystem management:** AI-driven technologies, combined with remote sensing and satellite imagery, are enabling better ecosystem management for sustainable fisheries and livestock production. These tools can monitor fishing activity, assess fish stocks, and detect illegal, unreported, and unregulated fishing practices. By promoting responsible fishing and conservation measures, these technologies contribute to preserving marine biodiversity and ecosystems.
9. **Digital agriculture and remote sensing:** Digital agriculture and remote sensing technologies offer valuable insights into crop and pasture health, enabling better livestock management and sustainable land use. These technologies help optimize resource allocation and minimize environmental damage caused by excessive land use.
10. **Sustainable feed production:** In the Indian context, frontier technologies are being employed to develop sustainable and locally sourced animal feed and fodder. Utilizing agro-industrial by-products and crop residues helps reduce feed costs, decrease waste, and lessen the environmental impact associated with feed production. Biotechnological advancements in feed and nutrition focus on optimizing feed formulations, improving nutrient absorption, and promoting animal health. Nutrigenomics, for example, studies the interaction between genes and nutrients, leading to personalized and more efficient diets for livestock and fish. Such innovations reduce feed waste and environmental impacts while ensuring optimal animal and fish growth.

- 11. Climate-smart farming:** India is promoting climate-smart farming practices in both animal and fisheries sectors. Climate-smart agriculture techniques, like agroforestry, intercropping, and rotational grazing, enhance ecosystem services and contribute to climate change mitigation and adaptation.
- 12. Blockchain traceability:** Blockchain technology is transforming supply chain management in the animal and fisheries sectors in advanced countries. By providing transparent and immutable records of product origin, handling, and distribution, blockchain enhances traceability and promotes sustainable practices. Consumers can verify the environmental credentials of products, incentivizing responsible production and reducing the risk of illegal and unsustainable fishing practices. Blockchain technology is being used to track the health and provenance of livestock. This can help in disease control and ensure the safety of animal products. However, these technologies are still not being applied in livestock and fishery sectors on a large scale in India.
- 13. Telemedicine for animals:** Though telemedicine has been around for quite some time in advanced countries, it became more sought after during the Coronavirus pandemic when the movement of people was restricted across the world. Nowadays, telemedicine platforms are becoming useful in many developing countries like India. Telemedicine enables companion animal/livestock keepers and farmers to consult with veterinarians remotely. This technology helps in quick diagnosis and timely treatment of animal health issues without visiting the veterinary clinics.
- 14. Internet of Things (IoT)-based monitoring:** IoT is another technology that has emerged in the past few years and has a profound impact on disease diagnosis both in humans as well as animals. IoT devices are being used to monitor vital signs, such as temperature and heart rate, in animals. This technology helps in early detection of health issues.
- 15. Disease Surveillance Apps:** Mobile applications are being developed to monitor and track the spread of diseases among animals. These apps provide real-time data, which can be crucial for preventing outbreaks. Regional continuous monitoring of emerging mutant pathogens in the animals and vectors enables researchers to analyse the potential risks to humans and animals from emerging mutants.
- 16. Veterinary telepathology:** Advanced imaging and telepathology systems are aiding in the rapid diagnosis of animal diseases, even in remote areas.
- 17. Animal wearables:** Wearable devices like GPS trackers and health monitors are being used to keep track of livestock and pets, ensuring their safety and health.
- 18. Vaccination management software:** Software solutions are available for efficient management of vaccination schedules and monitoring vaccine effectiveness in livestock.
- 19. Artificial Intelligence for diagnostics:** AI-driven diagnostic tools are being used to analyze medical/veterinary images and lab results, assisting veterinarians in making accurate diagnoses.

The livestock and fishery sectors in India face various challenges that hinder their growth, sustainability, and resilience. Some of the key challenges include:

 - 1. Lack of modern infrastructure and technology:** Largely, the livestock and fishery sectors in India still rely on traditional and outdated practices. The lack of modern infrastructure, including cold storage facilities, transportation networks, and processing units, hamper the efficient handling and distribution of livestock and fish products. Limited access to advanced technologies like precision farming and aquaculture automation also affects productivity and resource management.
 - 2. Small and marginal farming:** The majority of farmers and fisherfolk in India are small and marginal landholders with limited resources and access to credit. This poses challenges in adopting modern practices, investing in technology, and accessing markets.

3. **Disease outbreaks:** Livestock and fishery sectors in India are vulnerable to disease outbreaks, which can lead to significant economic losses and food safety concerns. Inadequate disease surveillance, biosecurity measures, and veterinary services can exacerbate the impact of diseases on both animals and fish populations.
4. **Water pollution and depletion:** Water pollution from industrial, agricultural, and urban sources affects both aquaculture and natural fish habitats. Polluted water bodies can lead to fish mortality and reduced fish quality. Moreover, overexploitation and mismanagement of water resources in some regions can cause depletion of fish stocks and hamper sustainable fishing practices.
5. **Inadequate market linkages:** The lack of well-organized and efficient market linkages poses a challenge for both livestock and fish producers. Farmers and fisherfolk often face difficulties in accessing markets and getting fair prices for their products. This issue is particularly acute for small-scale producers who lack bargaining power and may be forced to sell their produce at lower rates.
6. **Limited awareness of sustainable practices:** Awareness and adoption of sustainable practices are crucial for the long-term viability of the livestock and fishery sectors. Many farmers and fisherfolk may not be well-informed about climate-smart practices, resource conservation techniques, and sustainable aquaculture/farming methods.

Conclusion

In the Indian context, frontier technologies can play a vital role in enhancing the productivity and sustainability of animal and fisheries practices while addressing emerging environmental issues. From precision livestock farming to sustainable aquaculture techniques and climate-smart farming practices, these technologies can transform the agriculture, animal husbandry and fisheries sectors, making them more resilient, efficient, and eco-friendly. From genome editing to blockchain traceability and AI-driven ecosystem management, these technologies can enhance productivity, minimize environmental impacts, and contribute to the sustainability of these vital sectors. Embracing and responsibly deploying these technologies can play a pivotal role in securing a more resilient and sustainable future for animal and fisheries practices amidst the challenges posed by environmental changes. By adopting and investing in these innovative approaches, India can strike a balance between economic growth and environmental conservation, securing a sustainable future for its animal and fisheries industries.



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Overview

Leveraging frontier technologies in animal and fishery sciences to address emerging environmental challenges

Introduction

The Indian Journal of Animal Health takes great pride in presenting this special issue, which casts a spotlight on the symbiosis between frontier technologies and the dynamic realms of animal and fishery sciences. This collection of articles meticulously examines how cutting-edge technologies are harmoniously integrated into these disciplines to confront the burgeoning environmental challenges of our time. Our primary objective is to provide a comprehensive exploration of the transformative potential of frontier technologies within animal and fishery sciences, offering innovative solutions to the emergent environmental issues that confront our planet.

Key Focusing Areas:

- 1. Precision agriculture and livestock management:** Within the landscape of animal welfare, sustainability, and environmental responsibility, the application of frontier technologies in precision agriculture and livestock management heralds a paradigm shift. In this issue, we illuminate the transformative impact of technologies such as the Internet of Things (IoT), Radio-Frequency Identification (RFID), and GPS-based systems. These technologies optimize resource allocation and minimize environmental footprints, thereby playing an instrumental role in nurturing responsible agricultural practices.
- 2. Genomics and biotechnology:** The special issue provides an illuminating perspective on the ground-breaking influence of genomics and biotechnology in the realm of animal sciences. It delves deep into how these advancements are reshaping breeding programs, enhancing productivity, fortifying disease resistance, and enabling adaptability in the face of evolving environmental conditions. Furthermore, we underscore the indispensable role of genetic selection in safeguarding biodiversity and preserving species teetering on the brink of extinction.
- 3. Aquaculture innovation:** Addressing the escalating demand for seafood, this issue underscores the paramount significance of sustainable aquaculture practices. We explore how innovations like Recirculating Aquaculture Systems (RAS) and sustainable feed production are pioneering a sustainable seafood supply. Simultaneously, these innovations mitigate issues such as overfishing, habitat degradation, and water pollution, forging a path toward responsible resource management.
- 4. Remote sensing and GIS:** Our issue showcases the indispensable role played by Remote Sensing (RS) technologies and Geographic Information Systems (GIS) in monitoring and managing aquatic ecosystems. These technologies offer invaluable insights into water quality, habitat alterations, and temperature fluctuations, thereby advancing

the cause of conserving marine and freshwater environments. The advanced RS sensors and Drone technology aid in monitoring the natural resources and food production system for resource optimisation and sustainable utilisation.

5. **Ecosystem modelling and ecosystem services:** Our special issue delves into the intricate realm of advanced ecosystem modelling techniques and their application in sustainable fishery resource management. These models meticulously account for the complex interactions within ecosystems, enabling optimized harvest strategies and the safeguarding of vulnerable species, thus addressing pressing environmental challenges.
6. **Artificial Intelligence and Machine Learning:** We delve into the transformative potential of Artificial Intelligence (AI) and machine learning within the purview of animal and fishery sciences. This issue underscores their contributions to species identification, disease detection, and population monitoring, which are instrumental in fortifying conservation efforts and building resilience against the impacts of climate change on animal habitats.
7. **Conservation technologies:** The special issue aptly highlights the pivotal role played by frontier technologies in strengthening wildlife conservation efforts, especially for threatened and endangered species. It examines the innovative utilization of genetic markers, GPS tracking, and camera traps to gain profound insights into animal behaviour, migration patterns, and genetic diversity, effectively contributing to species preservation.
8. **Climate change and vulnerability assessment:** Our special issue also focuses on the aspects of climate change on natural animal and fish genetic resources and their food production system. This issue highlights the established methodologies, frameworks, concepts and advanced tools and techniques employed in the field of climate change and vulnerability assessment studies in animal and fishery sciences.
9. **Policy perspectives:** Our issue explores the policy perspectives viz., Sustainable Development Goals (SDGs), Intellectual Property Rights (IPRs), Access and benefit-sharing (ABS), International regulations and obligations, Community participation and socio-economic aspects having the potential to address the ongoing or emerging environmental challenges in the field of animal and fish sciences.

Conclusion

The special issue of the Indian Journal of Animal Health is a comprehensive exploration of the profound influence of frontier technologies on animal and fishery sciences. It underscores their transformative potential in addressing emerging environmental challenges. By presenting a compendium of cutting-edge research and illuminating case studies, we aim to provide readers with a profound understanding of how these technologies can be harnessed to advance sustainable practices, conserve biodiversity, and protect our ecosystems and wildlife in the face of evolving environmental concerns. We extend an open invitation to researchers, scientists, and practitioners to contribute to this special issue, thus becoming an integral part of this transformative journey



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Overview

Technological breakthroughs in animal and fishery sciences have been critical in resolving a slew of growing environmental challenges. As we struggle to deal with the repercussions of climate change, habitat destruction, overfishing, and pollution, emerging technologies are playing an important role in alleviating these difficulties while also improving productivity and sustainability in the animal and fisheries industries.

Precision livestock farming is one of the most disruptive technologies in animal sciences. It uses a combination of sensors, data analytics, and automation to monitor and manage the health and welfare of individual animals in real time. Farmers can utilize this technology to optimize feed utilization, reduce antibiotic use, and reduce environmental effects. Smart collars with global positioning system (GPS) and health sensors, for example, may continuously track cattle's whereabouts and vital indicators, alerting farmers to any signs of suffering or diseases. Furthermore, the use of underwater drones and cameras in aquaculture allows farmers to monitor fish behavior and health, providing optimal conditions in fish farms. These solutions not only increase animal welfare but also reduce resource waste and greenhouse gas emissions, which is in line with the growing concern about global warming.

Satellite technology has transformed how we monitor and manage our oceans in fisheries science. Overfishing is a major concern, therefore satellite-based tracking systems have proved invaluable in enforcing fishing regulations and combating illicit, unreported, and unregulated (IUU) fishing. These satellites can detect the movement of fishing boats, allowing authorities to quickly identify and intervene in suspect activity. Furthermore, the deployment of autonomous underwater vehicles (AUVs) outfitted with modern sensors enables scientists to collect data on marine ecosystems with previously unheard-of precision. These AUVs can explore the ocean's depths, detecting changes in temperature, salinity, and marine animal distribution. Such information is crucial for understanding the effects of climate change on fisheries and ecosystems, as well as making sound conservation and management decisions.

Furthermore, genetic technologies are at the forefront of efforts to conserve biodiversity and improve animal and fish population resilience. Advanced genetic engineering techniques, such as CRISPR-Cas9, have the potential to generate cattle with higher disease resistance and feed efficiency. These genetically engineered animals have the potential to not only minimize the need for antibiotics but also to assist in meeting the expanding worldwide need for animal protein while leaving a reduced environmental footprint. Genetic research in fisheries is critical for the protection of endangered species and the regeneration of damaged ecosystems. DNA analysis can detect distinct genetic markers in fish populations, assisting in the creation of policies for protecting and rebuilding depleted supplies. Furthermore, genetically guided selective breeding programs can result in the generation of fish varieties that are better suited to changing environmental conditions, such as rising water temperatures.

Emerging environmental difficulties in animal and fishery sciences are inextricably tied to the larger issues confronting our world. For example, climate change has far-reaching consequences for both terrestrial and aquatic ecosystems. Rising temperatures and shifting weather patterns can cause heat stress in livestock, impacting their health and productivity. To alleviate these impacts, innovative cooling systems like as climate-controlled barns and wearable devices that regulate body temperature are being employed. Ocean warming has the potential to disrupt fish migration patterns and affect the distribution of marine species in fisheries. In response to these issues, the

fisheries sector is exploring new fishing grounds and creating sustainable aquaculture practices.

Another urgent environmental concern is pollution, which has far-reaching ramifications for animal and fishery sciences. Manure and wastewater discharge in animal farming can affect land and water supplies. To reduce pollution and capture the energy potential of organic waste, advanced waste management technologies such as anaerobic digesters and nutrient recovery systems are being adopted. Pollution is a direct threat to aquatic ecosystems in fisheries, with chemicals and plastic trash damaging marine life. Sensor-equipped autonomous robots and drones are employed to detect and clear up pollution in water bodies. These technologies not only safeguard aquatic habitats but also contribute to the long-term viability of fisheries by guaranteeing that seafood is safe to eat.

In conclusion, frontier technologies improve sustainability, animal welfare, and productivity while also assisting in the mitigation of the effects of climate change, pollution, and overfishing. As we face tremendous environmental challenges, incorporating creative solutions in animal and fisheries sectors will be critical to creating a more sustainable and resilient future for both terrestrial and aquatic ecosystems.



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Overview

The utilization of animal resources for human benefits carries with it the consequence of exerting an impact on the environment. In recent years, there has been a growing global emphasis among researchers, entrepreneurs, and policymakers on examining the environmental implications of animal agriculture. The environmental impact of animal production is substantial, manifesting in a range of consequences that encompass both beneficial and detrimental effects. Animal agriculture has been associated with various detrimental effects, such as the emission of greenhouse gases, deforestation and land degradation, environmental contamination and pollution, as well as habitat destruction and biodiversity losses. On the other hand, animal farming presents various opportunities for environmental protection. These include nutrient recycling, enhancing land use efficiency, preserving regional landscapes and cultural heritage through the promotion of indigenous farming systems, as well as investment prospects in technology development aimed at reducing emissions, enhancing feed efficiency, and improving waste management practices.

The field of animal production and husbandry, as well as the management of animal health, has experienced a significant shift in scientific development in recent decades. The current emphasis is directed towards the advancement of precision animal production and management systems. Numerous ecologically sustainable technologies have been devised within the domain of veterinary and animal sciences, yielding noteworthy advancements in animal production and the maintenance of animal well-being. These technological advancements play a significant role in promoting sustainable practices, mitigating the environmental consequences associated with animal agriculture, and improving the overall welfare of animals. These technologies encompass various advancements in animal selection and breeding based on molecular signatures, as well as the implementation of modern vaccines and disease control strategies. Additionally, there are alternative approaches to minimize the use of antimicrobials in animal production, precision animal feeding to enhance efficiency and reduce feed wastage, methods and or strategies to decrease the carbon footprints of animal production systems, enhanced biosecurity practices, efficient water management in animal farming systems, and the integration of circular economy principles into animal production.

Additionally, it is worth mentioning that interconnected relationships exist between systems biology, animal production, and environmental protection, particularly within the realm of agriculture and livestock management. The field of systems biology is dedicated to comprehending the intricate biological processes, genetics, and interconnections inherent in livestock. The application of computational and mathematical models facilitates the understanding of these processes, consequently enhancing animal health, reproduction, and productivity. The utilization of systems biology in animal production facilitates the optimization of breeding strategies, nutrition, and disease management. The comprehension of molecular and cellular mechanisms enables the development of more effective strategies aimed at improving animal growth, health, and overall productivity. Consequently, this contributes to the reduction of the environmental impact associated with animal husbandry. The incorporation of systems biology into animal production has the potential to contribute to the advancement of sustainable agricultural practices. This process entails the reduction of the environmental impact through the optimization of feed efficiency,

waste management, and emissions control, resulting in a more environmentally sustainable and efficient agricultural system. The incorporation of systems biology into animal production is of utmost importance, as it holds the potential to enhance productivity, promote animal welfare, and mitigate the environmental impact associated with agricultural practices. The adoption of an interdisciplinary approach facilitates the development of animal farming methods that are more sustainable and environmentally conscious.

I would like to express my sincere gratitude to the official and editorial board members of the “Indian Journal of Animal Health (IJAH)” for their efforts in publishing the special issue on “*Frontiers technologies in animal and fisheries vis-à-vis emerging environmental issues*”. This particular edition has presented opportunities for researchers and academics engaged in the enhancement of animal production systems and animal health management practices, with the aim of improving efficiency and promoting environmental protection.



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Overview

According to the FAO (Food and Agriculture Organization), agriculture and related activities account for 17% of total world greenhouse gas emissions, of which 'about 40% come from livestock, 16% from mineral fertilizers, 17% from burning biomass, and 8% come from agricultural wastes. Agricultural activities that purportedly generate 'toxins' released into air include fertilizers and pesticides, animal husbandry including fisheries, agricultural waste, and salts from applied irrigation water. Agricultural solids and waste are burnt in order to clear out the area for next cultivation, but this causes release of soot, particulate matter and other toxins into the air.

Therefore, environment-friendly technologies are the need of the hour in the present day changing climatic conditions more so in the context of veterinary, animal and fishery fields and concomitant developments. Currently, technologies are getting screened by their societal benefits and also by their impact on the environment. It looks like we can no longer afford to have technologies that have environmentally adverse impacts. Already, modern technologies are dwindling our animal breeds, resulting in complications such as rising antibiotic and pesticide residues, hormonal contents, etc. Not to undermine the benefits we have accrued by these technologies; they are also leaving a lot of carbon footprints. There has to be compromise struck between benefits and carbon footprints. It is true that arable land in the country has remained almost the same for several years, but at the same time, our requirements are growing. Under these circumstances, no doubt we need to have modern technologies to meet our food demands, but certainly not at the cost of increasing carbon footprints. This issue of climate is figuring in many international fora, underlining the importance that the governments attach to this menace. Already, countries are made to commit certain cuts in footprints, and targets are provided. India has committed to the target of zero carbon emissions in another five decades. However, this is going to be a Herculean task which is achievable only through people's participation and the sincerity of bureaucrats and politicians. Artificial Intelligence and Augmented Reality are cutting-edge technologies which may transform the future of animal husbandry and fisheries sectors, including production, treatment and management aspects. Plant-based extracts in the name of vegan milk are getting popular in the West, which, being low in calories as well as reduced allergy prevalence, are gaining ground in the market. It is being argued that cow's milk has significantly higher impacts than the plant-based alternatives across all metrics. Based on a meta-analysis of food system impact studies across the supply chain which includes land use change, on-farm production, processing, transport, and packaging, animal husbandry reportedly causes around three times as much greenhouse gas emissions; uses around ten times as much land; two to twenty times as much freshwater; and creates much higher levels of eutrophication.

The food industry can be considered the fastest-growing industry in India. The Indian food processing industry accounts for 32 percent of the country's total food market, one of the largest industries in India and is ranked fifth in terms of production, consumption, export and expected growth. India ranks first in milk production, contributing 23 percent to global milk production. Milk production in the country has grown at a compound annual growth rate of about 6.2 percent to reach 209.96 million tonnes in 2020-21 from 146.31 million tonnes in 2014-15; 14.8 percent growth is expected by FY 2023 in the milk processing industry. However, even though the dairy industry has made a significant contribution to the nation's economy, it may be continuing to contribute to pollution generating an

estimate of 2.5 to 3 litres of wastewater for every litre of milk processed. Water is a critical resource in milk processing units and is used for various purposes such as cleaning, washing, disinfection, cooling and heating.

It is surprising to know that for a consumer, a decade ago and in the present times, the experience of drinking milk may remain the same, but environmentally, there is a difference. Abroad, carbon footprints per litre of milk decreased over the years; land use, feed usage, and water use have reduced per litre of milk, whereas in India, these remained the same. Cattle that produce less milk are subsequently less efficient and have a greater environmental footprint for every unit of milk they produce. About 60% of feed is utilized for milk production and 40% for body maintenance, whereas it is 80:20 for high-yielding cows. The average milk production in India is 3-4 lit per cow which comes under low yielding category, so there is low feed conversion efficiency for milk production, indicating that there is a need to introduce high yielding cows and culling the low yielding ones. There is a correlation among milk yield, no of animals and carbon footprints. There is a need to enhance the productivity of our animals, for which available modern technologies have to be enforced vigorously. Our managemental issues are so complex that any improvement is a slow process. Just like huge human population is slowing down India's achievements, same situation is there in case of livestock too; we have a huge number of low productive animals to deal with. Unless govt comes out with policies that enhances high yielders and reduces low yielders, the ambitious task of diminishing carbon footprints for milk production is a long arduous task. In this regard, for creating more awareness among professionals, students, researchers and people concerned, Indian Journal of Animal Health is bringing out a special issue focusing on "*frontiers technologies in animal and fisheries vis-à-vis emerging environmental issues*" which is more relevant in the present times than ever before.