

Popular Article

Impact of Livestock on Climate and its Mitigation

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Introduction

The global livestock sector serves as a fundamental pillar in the worldwide food system, playing a vital role in poverty reduction, agricultural development, and ensuring food security. According to the Food and Agriculture Organization (FAO), livestock contributes significantly, accounting for 40% of the global value of agricultural output and supporting the livelihoods and food security of nearly 1.3 billion people. In India, the livestock sector holds particular significance, providing livelihoods for approximately 20.5 million people and contributing 16% to the income of small farm households. The multifaceted role of livestock in the broader agricultural sector is underscored by its contribution to India's economy, where about two-thirds of the rural community depends upon livestock for their livelihoods. Moreover, the sector provides employment for approximately 8.8% of the country's population. Despite the declining contribution of agriculture to the country's GDP, the livestock sector's role is on the rise, contributing 4.11% to the total GDP and 25.6% to the total Agriculture GDP. However, the growth of the livestock sector is not without challenges. While gains in

productivity and production of livestock products such as milk, meat, and eggs have been substantial, the environmental impact of livestock activities cannot be ignored. Livestock through various processes including land use change, feed production, and manure management, influences climate patterns and contributes to negative environmental consequences such as land degradation, air and water pollution, and biodiversity loss.

Impact of Livestock on Climate

Livestock production is associated with significant greenhouse gas (GHG) emissions, including nitrous oxide (N₂O), carbon dioxide (CO₂), and methane (CH₄). Methane and N₂O, with their high global warming potential, contribute substantially to the environmental footprint of the animal agriculture industry. Globally, livestock is responsible for 14.5% of total annual anthropogenic GHG emissions, with cattle being the primary contributors. Emissions from the livestock sector surpass those of the entire global transportation sector. The emissions result from various sources within the livestock supply chains, including enteric fermentation, respiration, manure management, feed production, and processing. Enteric fermentation, constituting 39.1% of the sector's emissions, is the largest contributor,

followed by manure management and direct deposit at 25.9%.

- **Methane Emission:** Enteric fermentation, Poor quality feed contribute to methane emission. Methane also can be emitted from manure pits where anaerobic conditions occur. Methane is an extremely potent GHG, with a global warming potential over 25 times higher than that of CO₂ over a 100-year time frame
- **Nitrous Oxide (N₂O):** Nitrification and denitrification of animal waste (Urine, dung & manure) produces N₂O. N₂O has a global warming potential about 300 times that of CO₂ and it has over 100 years of atmospheric lifetime.
- **Carbon Dioxide:** It is a fermentation byproduct in ruminants also emitted due to Deforestation, Land degradation, Feed production and Respiration. Traps the sun's heat and produce Greenhouse effect.

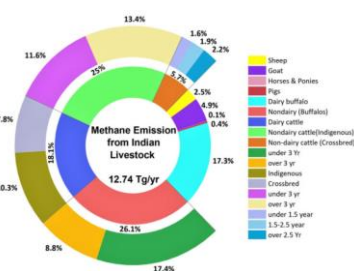


Fig.1 Livestock category-wise Methane emission from the country (2019)

Impact of Climate Change on Livestock

The consequences of climate change on livestock are diverse, affecting feed crops, water availability, animal health, and overall production. Rising temperatures, changes in precipitation patterns, and variations in atmospheric CO₂

concentration pose challenges to critical aspects of livestock production such as forage quality, water consumption, disease prevalence, and animal well-being.

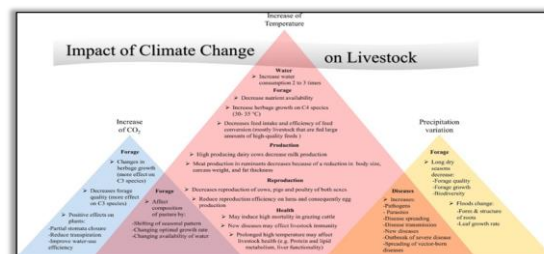


Fig.2 Impact of Climate Change on Livestock

- **Quantity and Quality of Feeds:** Climate change influences the quantity and quality of feed crops and forage, with increased atmospheric CO₂ levels affecting herbage growth. The impacts extend to C3 and C4 species differently, and extreme climate events like floods can alter root structure and overall yield. Climate change strongly influences the amount and quality of food available to rear animals, thus posing a problem to the health and productivity of animals. Increased temperature and extreme weather conditions, such as droughts and floods, reduce the availability of forage and feed crops. For instance, more carbon dioxide in the atmosphere may favorably promote plants growth in the initial stages. However, it can have the adverse side effect of making plants less nutritious, containing less protein and minerals. On the other hand, shifts in rainfall patterns can lead to alterations in growth conditions for feed crops, thus creating inequalities in available supplies and yields. These changes threaten livestock productivity, as animals may face increased heat stress and reduced feed intake, ultimately affecting their

growth, reproduction, and overall health. Studies predict that without adaptation, livestock populations could decline by 7-10% by mid-century due to these challenges, highlighting the urgent need for climate-resilient agricultural practices.

- **Availability of Water:** The livestock sector's demand for water, accounting for 8% of global human water use, may increase due to rising temperatures. Additionally, water salination, influenced by sea-level rise, poses risks to animal metabolism, fertility, and overall digestion. Climate change is expected to significantly impact the availability and quality of water supplies used for livestock production, with serious implications for animal health and performance. The livestock sector accounts for approximately 8% of global human water usage, mostly due to the high-water requirements of feed, which comprises over 90% of the total water use in many systems. Rising temperatures combined with altered precipitation patterns will likely exacerbate water scarcity, particularly in arid and semi-arid regions, where drought events may be more frequent and extreme. Additionally, the increase in sea level can lead to water salinization, thereby reducing water quality. Increased salinity can disrupt animal metabolic functions, reduce reproductive output, and negatively impact digestive efficiency and nutrient uptake. Livestock species vary in their tolerance to saline water, with poultry and dairy cattle being relatively sensitive to high salt levels in the water. Poor water quality impairs the health, growth, and productivity of livestock, making

adaptive strategies imperative to manage available water resources better and, therefore, achieve sustainability in livestock production under climate change.

- **Livestock Diseases:** Climate change, particularly temperature increases, directly and indirectly affects animal health by influencing microbial communities, spreading vector-borne diseases, and impacting host resistance. Pathogens and parasites may thrive under changing climate conditions, posing risks to livestock. The physiological characteristics of vectors such as mosquitoes and ticks, along with the development of pathogens, depend a lot on climate change. High temperature favors survival, reproduction, and feeding of vectors while at the same time speeding up the development of pathogens, which leads to rapid transmission of diseases. Changes in precipitation create new habitats, and changes in habitat may increase or decrease vector populations. Besides, higher temperatures facilitate the spread of vectors into areas that were previously not suitable for them, hence widening the diseases such as tick fever. Climate change also exerts evolutionary pressure on pathogens and vectors, perhaps leading to resistance to treatment and complicating control efforts. Heat stress can negatively affect immune functions via cell-mediated and humoral immune responses. As a result, periods of hot weather can cause livestock to be more vulnerable to diseases and raise the incidence of certain diseases (such as mastitis), leading to an increased potential of morbidity and death.

- **Heat Stress:** Elevated temperatures and humidity levels result in heat stress among livestock, affecting forage intake, milk production, feed conversion efficiency, and overall performance. Heat stress contributes to variations in behavior, metabolic functions, and mortality. With an increase in ambient temperature above the animal's thermoneutral zone-usually between 10-30°C-the animal is unable to dissipate sufficient heat, resulting in rising body temperatures. The more extreme forms of heat stress can lead to hyperthermia, with a 3-4°C elevation above normal body temperature, and result in heat stroke, organ dysfunction, and death. Heat stress led to decreased feed intake (3-5% less feed per degree rise of temperature above 30°C. Mastitis has a significant correlation with heat stress due to suppressed immunity, thermal injury of the udder and spread of pathogens in the summer. Numerous mutations may be the cause of the Bombay phenotype in Caucasians.

Mitigation Strategies

Efforts to mitigate the environmental impact of livestock production involve various strategies, including carbon sequestration, improved diets, manure management, and efficient fertilizer use. Public policy support is crucial for the effective implementation of these measures.

- **Carbon Sequestration:** Practices such as reducing deforestation rates, improving pasture management, and incorporating trees into grazing lands can contribute to carbon sequestration, thereby reducing GHG emissions.

Capturing and storage of atmospheric Carbon dioxide is called carbon sequestration.

- **Reducing deforestation rates:** Forests are the carbon sink of environment and can be conserved by establishing protected areas. Also, Reforestation and afforestation can help in forest conservation. Implementing sustainable land use practices can significantly reduce deforestation rates by use of agroforestry in croplands.
- **Pasture Management:** Rotational grazing can enhance pasture growth and carbon sequestration.
- **Grassland Management:** Grasslands maintained with healthy plant cover and diversity can enhance carbon sequestration.
- **Enteric Fermentation:** Mitigating methane emissions from enteric fermentation involves improving animal nutrition and genetics. Dietary adjustments, supplements, and the use of antimethanogens are among the strategies to reduce methane production.
- **Improving Animal Nutrition High-Quality Forages:** High-quality forages have lower fiber contents, such as cellulose and hemicellulose, and higher digestible carbohydrates, like starches and sugars. These latter substances are fermented more efficiently in the rumen, leading to less production of hydrogen (H₂), which is used by methanogenic archaea to produce methane gas (CH₄). Increased digestibility reduces rumen fermentation time and limits availability of H₂ to methanogens.

- **Grain based diet:** Grains have high starch content which ferment rapidly producing propionic acid. Propionate competes with methanogens for H_2 thereby reducing H_2 availability to methanogens.
- **Fat supplementation:** Introduction of fats, reduce methane emission without decreasing ruminal pH. Medium-chain fatty acids (FAs) are known to reduce methanogenesis by several mechanisms includes (a) reducing the proportion of energy supply from fermentable carbohydrates, (b) changing the rumen microbial population, particularly inhibiting rumen methanogens and, to a limited extent, (c) biohydrogenation of unsaturated FAs that works as an hydrogen acceptor. Fatty acids improve energy density of the diet, reducing overall feed intake and fermentation. The combined effect of above processes can lead to reductions in CH_4 production of between 3.8% and 5.4% per 1% addition in lipids (up to 6% lipid supplementation on a DM basis).
- **Improving genetics:** Genetic selection is a viable strategy for reducing greenhouse gas (GHG) emissions from livestock. Implementing mating programs within breeding initiatives is cost-effective and can lead to permanent improvements over generations, even if its immediate impact is less than nutritional changes. Methane production is a heritable trait, with heritability estimates between 0.10 and 0.40. In Spain, the dairy herd has decreased by 1% to 2% annually, allowing for a projected reduction of 4% to 6% in enteric methane emissions over ten years, equating to a decrease of over 500

tons of methane per billion liters of milk produced. Additionally, selecting for traits such as fertility, longevity, and feed efficiency is expected to further reduce methane emissions, as longer productive lifetimes decrease the need for heifers, thus lowering overall emissions. Recent studies have shown that genetic selection can lead to significant reductions in methane emissions, with estimates suggesting a potential decrease of up to 7.9% in residual methane through the integration of GHG sub indexes into breeding programs. This approach not only targets methane production directly but also enhances overall livestock efficiency and productivity.

- **Antimethanogens:** Bromo-chloro-methane (BCM), 2-bromo-ethane sulphonate (BES), and chloroform are chemical agents that can significantly reduce methane (CH_4) production by 25% to 95%, as demonstrated in in-vivo studies with sheep, goats, and cattle. However, these halogenated compounds are themselves potent greenhouse gases (GHGs), raising environmental concerns. An alternative compound, 3-nitrooxypropanol (3NP), has shown promise as a safer option with fewer health risks. It has achieved a 24% reduction in methane emissions in in-vivo trials with sheep and reductions ranging from 7% to 60% in cattle. This makes 3NP a more sustainable and less harmful solution for methane mitigation in livestock.

The use of photochemical agents such as saponins, essential oils, tannins as anti-methanogenic agent in the diet is generally safe, cheap, and easily

available from a wide range of plants and therefore, can be employed to modify rumen microbial fermentation. Tannins reduced methane release per gram of organic matter degraded with average reduction of 10–17% in methane production on the feeding of tannin rich forage was reported. Saponin has an inhibitory action on protozoa. In vitro study reported a reduction of 29% in methane production on the supplementation of 4% commercial grade saponins to wheat straw and concentrate based diet.

- **Manure Management:** Shortening storage duration, anaerobic digestion, covering storage facilities, and altering animal diets are effective ways to reduce methane emissions from manure management. Alteration of manure storage practices can reduce manure GHG emissions. These include shortened storage duration, lowered storage temperature, solid–liquid separation, and less use of water. By reducing the storage time of manure it minimizes the chances of anaerobic condition development which lead to methane production. Frequent application of manure on field cut down the emission as there is no enough time for anaerobic conditions to develop. Use of manure for production of biogas (mixture of CH₄ and CO₂). Anaerobic digestion can lead to an over 30% reduction in GHG emissions compared to traditional manure treatment. Covering of the storage pit will prevent methane escape. Nutrient management of animals can also reduce the methane emission.
- **Fertilizer Management:** Enhancing

nitrogen use efficiency, utilizing organic fertilizers, and adopting advanced agricultural practices can minimize nitrous oxide emissions from fertilizer application on animal feed crops. Fertilizer management reduces N₂O emissions by controlling the soil inorganic nitrogen and preventing accumulation. Under wet, compacted conditions, nitrate-nitrogen is more prone to leach and denitrify than ammonia-based sources like urea. Good rate, type, timing, and placement of the nitrogen fertilizers in combination with minimum tillage reduce N₂O emissions and improve the nitrogen use efficiency.

- **Shifting Human Dietary Trends:** Reducing meat consumption, particularly beef, can significantly lower GHG emissions from the livestock sector. Substituting beef with chicken or plant-based proteins can lower emissions due to the lower resource requirements and emissions associated with these alternatives. Reducing beef consumption can help improve the efficiency of land use.

Conclusion

While the livestock sector is crucial for global food security and economic development, its environmental impact, particularly in terms of GHG emissions, cannot be overlooked. Effective mitigation strategies, encompassing changes in land use, dietary practices, and technological advancements, are essential to address the sector's contribution to climate change. Simultaneously, adapting livestock production systems to the impacts of climate change is imperative for ensuring continued food security and sustainable

agricultural practices. Incorporating these mitigation and adaptation factors into livestock production systems is recommended to strike a balance between meeting the growing demand for livestock products and safeguarding the environment.