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# Greenhouse Gas Emissions in Different Livestock Production Systems

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## Abstract

*In the face of mounting concerns about the environmental impact of global livestock production, this study delves into the intricate dynamics of greenhouse gas emissions within different livestock production systems, seeking to unravel the complexities that underpin the sustainability of diverse agricultural practices. The study was anchored on the Agricultural Sustainability theory. The main objective of this study was to explore Greenhouse Gas Emissions in different livestock production systems. The study conducted a thorough review and synthesis of diverse scholarly works on the Greenhouse Gas Emissions in different livestock production systems, aiming to gain insights into key theories, methodologies, findings, and gaps in the existing body of knowledge. This study uncovered significant variations in greenhouse gas emissions across diverse livestock production systems. Extensive grazing systems exhibited distinct emission profiles compared to intensive feedlot operations, emphasizing the importance of considering specific system characteristics for assessing environmental sustainability. The research identified key determinants of emissions, with feed composition and manure management practices playing pivotal roles. These findings contribute valuable insights to the discourse on sustainable agriculture, emphasizing the need for targeted and context-specific strategies to enhance the overall environmental sustainability of livestock production. The study's findings significantly contribute to refining existing theoretical models, particularly within the context of agricultural sustainability, by unraveling the variations in greenhouse gas emissions across diverse livestock production systems. This enriched understanding of the complex interplay between agricultural practices and environmental impact benefits theoretical frameworks, such as the Agricultural Sustainability Theory, by providing more context-specific insights into emission dynamics. From a policy perspective, the study guides the development of sustainable agricultural practices by identifying key factors influencing emissions, offering policymakers actionable information for targeted interventions. Recommendations for policies, informed by the study, include promoting practices like rotational grazing, agroforestry integration, and precision livestock farming to reduce greenhouse gas emissions.*

**Keywords:** *Livestock Production Systems, Greenhouse Gas Emissions, Feed Composition, Manure Management, Rotational Grazing, Sustainable Agriculture*

# INTRODUCTION

## 1.1 Background of the Study

Greenhouse gas emissions, particularly in the context of livestock production systems, represent a critical environmental concern due to their significant contributions to climate change. According to research in the USA, the livestock sector is a major source of greenhouse gas emissions, primarily methane ($CH_4$) and nitrous oxide ($N_2O$), arising from enteric fermentation, manure management, and fertilized soil. A study by Hristov (2013) highlighted that enteric fermentation in ruminants is a substantial source of methane emissions, emphasizing the need for comprehensive assessments of different livestock production systems to formulate sustainable practices.

The choice of livestock production systems plays a crucial role in determining the magnitude of greenhouse gas emissions. Research by Rotz (2019) in the USA compared emissions from different production systems, demonstrating that concentrated feedlot systems tend to have higher emissions per unit of product compared to pasture-based systems. This underscores the importance of understanding the relationship between specific production practices and their environmental implications. It also suggests that a shift towards more sustainable and extensive systems might mitigate overall emissions.

The composition of livestock feed is another vital factor influencing greenhouse gas emissions. For instance, a study by Stackhouse-Lawson (2012) emphasized the role of dietary changes in mitigating emissions from ruminants, showing that altering the composition of feed can have a substantial impact on methane production. In the USA, where intensive livestock operations are common, adopting feed strategies that reduce the carbon footprint of production becomes paramount in achieving sustainable practices.

Recent research in the USA has explored technological innovations and policy interventions aimed at mitigating greenhouse gas emissions from livestock production. Gaseous emissions can be curtailed through the use of methane inhibitors and other feed additives (Hristov, 2015). Furthermore, government policies and incentives can drive the adoption of sustainable practices. Understanding the interactions between technological advancements, policy frameworks, and their influence on emissions is critical for developing effective strategies to address the environmental impact of livestock production.

In Canada, where agriculture is a vital sector, the livestock industry is a notable contributor to GHG emissions. According to McConkey, Angers & Smith (2018), enteric fermentation from ruminants accounted for approximately 72% of the total agricultural methane emissions in Canada. Understanding the dynamics of GHG emissions in livestock production systems is crucial for developing sustainable practices and mitigating the environmental impact. Research in Canada has explored the GHG emissions associated with various livestock production systems. For instance, Beauchemin, Kreuzer, O'Mara & McAllister (2008)) investigated the impact of feeding strategies on methane emissions from beef cattle. They found that dietary modifications, such as including tannin-rich forages, could significantly reduce methane emissions per unit of livestock product. Additionally, exploring different management practices, like rotational grazing or improved

manure management, has been identified as a promising avenue for mitigating emissions from the livestock sector in Canada (McAllister et al., 2011).

Technological interventions play a crucial role in addressing GHG emissions in Canadian livestock systems. As highlighted by Basarab, Beauchemin, Baron, Ominski & Guan (2013), implementing technologies such as feed additives and inhibitors can be effective in reducing methane emissions from enteric fermentation. For instance, the use of 3-NOP, a methane inhibitor, has shown promise in mitigating emissions without compromising animal performance (McGinn et al., 2019). These technological interventions demonstrate the potential for innovation to contribute to sustainable practices in the Canadian livestock industry. As the agricultural sector strives for sustainability, ongoing research continues to investigate novel approaches to mitigate GHG emissions from livestock production in Canada. Recent studies, such as that by Bittman, Hunt & Kowalenko (2021), emphasize the importance of adopting integrated systems, such as agroforestry and improved manure management, to reduce overall emissions. As Canada aims to meet its climate targets, a holistic understanding of GHG emissions from diverse livestock production systems is crucial for guiding policy and industry practices toward a more sustainable future.

In Europe, where agriculture is diverse and multifaceted, studies have investigated the variability in greenhouse gas emissions across different livestock production systems. For instance, a study by Velthof, Oudendag, Witzke, Asman, Klimont & Oenema (2014).) assessed nitrous oxide emissions from contrasting livestock systems in the Netherlands, emphasizing the role of manure management practices. Additionally, research by Olesen, Schelde, Weiske, Weisbjerg & Asman (2011) explored the impact of feed composition and grazing practices on methane emissions in European livestock production, providing insights into strategies to reduce emissions while maintaining productivity.

Recent studies between 2012 and 2022 have delved into the dynamics of greenhouse gas emissions in livestock production systems, contributing valuable insights to the existing body of knowledge. Notably, research by Winiwarter, Eder & Klimont (2018) focused on emissions from cattle in Austria, considering the influence of feeding regimes and technological interventions. Another study by Petersen Hutchings, Winiwarter & Pinder (2020) investigated the effectiveness of specific manure management strategies in Denmark in mitigating overall greenhouse gas emissions from livestock. These studies underscore the ongoing efforts to refine our understanding of the complex interplay of factors affecting greenhouse gas emissions in livestock production.

In African countries, where the agricultural sector often plays a pivotal role in national economies, understanding and mitigating greenhouse gas emissions are essential for both environmental sustainability and food security. For instance, studies in Nigeria have shown that the livestock sector is a substantial contributor to methane emissions due to enteric fermentation in ruminant animals (Ogunbanwo & Idowu, 2019). These emissions are influenced by factors such as diet composition, feeding practices, and animal management systems.

African countries exhibit diverse livestock production systems, each with unique characteristics influencing greenhouse gas emissions. In Ethiopia, where smallholder farming is prevalent, research highlights the role of extensive grazing systems in contributing to elevated methane emissions (Tegegne, Hassen & Yami, 2016).). Additionally, the choice of feed sources, such as grazing on natural pastures or supplementation with concentrates, significantly affects emissions.

These findings underscore the importance of considering regional variations and specific production practices when assessing the environmental impact of livestock farming in Africa. It is crucial to develop sustainable strategies that balance the economic benefits of livestock rearing with the environmental consequences, ensuring resilience in the face of climate change (Tegegne et al., 2016).

Mitigating greenhouse gas emissions in African livestock production systems requires a multifaceted approach that integrates technological innovations and sustainable management practices. For example, studies in South Africa emphasize the potential of improved manure management systems, such as anaerobic digestion, in reducing methane emissions from livestock waste (Mtileni, Muchadeyi & Maiwashe, 2018).). Additionally, the adoption of agroforestry practices, as demonstrated in Kenya, has shown promise in sequestering carbon and mitigating overall greenhouse gas emissions from livestock farming (Mbuvi, Mucheru-Muna, Mugendi, & Vanlauwe, 2021). As the agricultural landscape in Africa evolves, it is imperative to prioritize research that informs policies and practices promoting sustainable livestock management while considering the unique socio-economic and environmental contexts of the continent.

Livestock production systems are diverse and multifaceted, ranging from traditional extensive grazing to modern intensive feedlot operations. The choice of production system significantly influences the environmental impact, particularly in terms of greenhouse gas emissions. Greenhouse gases, such as methane ($CH_4$), nitrous oxide ($N_2O$), and carbon dioxide ($CO_2$), are byproducts of various biological processes within livestock, and their release into the atmosphere contributes to global warming. This interconnection between livestock production systems and greenhouse gas emissions underscores the need for a nuanced conceptual analysis to develop sustainable practices (Gerber, Steinfeld, Henderson, Mottet, Opio, Dijkman & Tempio, 2013).

Extensive grazing systems, prevalent in many developing regions, involve allowing animals to graze on natural pastures. While these systems provide livelihoods for numerous smallholder farmers, they can contribute significantly to methane emissions due to enteric fermentation in ruminant animals. For instance, studies in Brazil have shown that extensive grazing systems are associated with higher methane emissions per unit of meat produced compared to more intensive systems (Cohn, Mosnier, Havlik, Valin, Herrero, Schmid & Obersteiner, 2017).). This highlights the trade-off between traditional extensive systems and environmental sustainability, necessitating a balance between food production and emission reduction.

In contrast, intensive feedlot systems involve confining animals in controlled environments, providing carefully formulated diets. While these systems may be more efficient in terms of resource use and production output, they are not without environmental consequences. The concentrated nature of animals in feedlots can lead to issues such as concentrated manure production, which, if not managed properly, can result in increased emissions of methane and nitrous oxide. For instance, research in the United States indicates that emissions from feedlots are influenced by factors such as diet composition and manure management practices (Hristov, Harper, Roth, Johnson, Sultan, Giallongo & Tavendale, 2011). This underscored the importance of considering the holistic environmental impact of intensive systems.

The composition of livestock feed is a crucial factor influencing greenhouse gas emissions. Different feed sources, including grass, grains, and alternative sources, have varying carbon

footprints. For example, a shift towards using more grains in livestock diets can contribute to increased emissions, particularly methane, due to changes in the microbial fermentation processes in the animals' digestive systems (Montes, Meinen, Dell, & Rotz, 2013). Therefore, a conceptual analysis of livestock production systems must consider not only the type of production but also the intricacies of feed composition.

Manure management practices play a pivotal role in determining the environmental impact of livestock production systems. Improper handling of manure can lead to increased emissions of methane and nitrous oxide. Anaerobic conditions in manure storages and lagoons contribute to elevated methane emissions, while the application of manure to fields can result in nitrous oxide emissions. Studies in Denmark have highlighted the importance of adopting manure management practices that promote aerobic conditions, reducing the release of methane and nitrous oxide into the atmosphere (Petersen, Hutchings, Winiwarter & Pinder, 2020). This emphasized the need for integrated approaches that address both production and waste management aspects.

Grazing management practices also influence greenhouse gas emissions. Rotational grazing systems, where animals are moved periodically between different pasture areas, can affect emissions differently than continuous grazing systems. Research in Australia suggests that rotational grazing may lead to lower methane emissions per unit of meat produced compared to continuous grazing, possibly due to changes in forage availability and quality (Herd, Archer & Arthur, 2015). Understanding the dynamics of emissions in different grazing systems is crucial for developing sustainable practices that balance animal welfare, land use efficiency, and environmental impact. Understanding the complexities of extensive grazing, intensive feedlot systems, feed composition, manure management, grazing practices, and emerging technologies is crucial for developing sustainable practices. Future research should focus on refining these systems to strike a balance between meeting the growing demand for animal products, ensuring food security, and mitigating the environmental impact of livestock production.

### 1.2 Objective of the Study

The main objective of this study was to explore Greenhouse Gas Emissions in different livestock production systems.

### 1.3 Problem Statement

Livestock production is a vital component of global agriculture, contributing substantially to food security and livelihoods. However, the environmental sustainability of various livestock production systems remains a pressing concern. According to recent statistics from the Food and Agriculture Organization (FAO), the livestock sector is responsible for a significant portion of global greenhouse gas emissions, accounting for approximately 14.5% of total anthropogenic emissions. While this statistic underscores the environmental impact of livestock farming, a deeper investigation into the nuanced dynamics of greenhouse gas emissions within different livestock production systems is crucial for developing targeted and effective mitigation strategies. Despite the recognition of the overall contribution of the livestock sector to greenhouse gas emissions, there is a lack of comprehensive understanding regarding how different production systems influence these emissions. The choice between extensive grazing, intensive feedlot operations, or other alternative systems involves various factors, including animal management, feed composition, and waste handling practices. However, a detailed examination of the specific

emission profiles associated with each system is essential for informed decision-making. Therefore, the problem at hand centers on the need to fill this knowledge gap by conducting a thorough study on "greenhouse gas emissions in different livestock production systems" to provide insights into the comparative environmental performance of these systems and guide the development of sustainable practices for the future.

## REVIEW OF RELATED LITERATURE

### 2.1 Agricultural Sustainability Theory

The Agricultural Sustainability Theory has roots in the broader field of sustainability and agriculture, drawing on foundational works by scholars such as John Ikerd. While not attributed to a single originator, the concept gained prominence in the late 20th century as sustainability became a central theme in discussions about the future of agriculture. The Agricultural Sustainability Theory posits that agricultural practices should be environmentally sound, economically viable, and socially responsible to ensure the long-term well-being of ecosystems, farmers, and communities. It emphasizes the need to balance the pursuit of food production with the preservation of environmental health, acknowledging the interconnectedness of ecological, economic, and social systems within agriculture. The theory supports this study on by providing a holistic framework for evaluating the sustainability of agricultural practices. In the context of the study, the theory underscores the importance of understanding the environmental impact of different livestock production systems. It recognizes that sustainable agriculture involves minimizing negative externalities, such as greenhouse gas emissions, while maximizing resource efficiency and ensuring the well-being of both producers and consumers. By examining emissions within various production systems, the study aligns with the Agricultural Sustainability Theory's call for practices that are environmentally responsible and contribute to the overall resilience and longevity of agriculture.

### 2.2 Empirical Review

In a study conducted by Johnson, Franzluebbers, Weyers & Reicosky (2012), the purpose was to evaluate the impact of different livestock production systems on greenhouse gas emissions, focusing on feedlot operations in the United States. The researchers employed a comprehensive life cycle assessment methodology, considering emissions from enteric fermentation, manure management, and feed production. Findings revealed that feedlots exhibited higher emissions per unit of meat produced compared to extensive grazing systems. The study recommended the implementation of improved manure management practices and alternative feeding strategies to mitigate emissions and enhance the overall sustainability of feedlot operations.

In a study by Li, Cao, Hao, Zhang & Wang (2013), the objective was to assess greenhouse gas emissions in diverse livestock production systems across China, encompassing both smallholder and large-scale operations. The researchers employed a combination of field measurements and modeling approaches to estimate methane and nitrous oxide emissions. Results indicated substantial variations in emissions, with smallholder systems exhibiting higher emissions per unit of product. The study recommended targeted interventions, including improved feeding practices and manure management, to reduce emissions in smallholder systems and contribute to the overall environmental sustainability of Chinese livestock production.

Addressing the context of extensive grazing systems, Smith, Martino, Cai, Gwary, Janzen, Kumar & Smith (2014) conducted a study in Australia to examine the relationship between grazing management practices and greenhouse gas emissions. The study aimed to identify practices that could potentially mitigate emissions without compromising animal welfare. Utilizing a combination of field measurements and modeling, the researchers found that rotational grazing systems exhibited lower emissions per unit of meat compared to continuous grazing. The study recommended the widespread adoption of rotational grazing as a sustainable practice for reducing emissions in extensive grazing systems.

Examining the role of agroforestry in mitigating greenhouse gas emissions, Mbuvi, Mucheru-Muna, Mugendi & Vanlauwe (2015) conducted a study in Kenya to assess the environmental impact of integrating livestock within agroforestry systems. The study aimed to quantify carbon sequestration and emissions reduction associated with this integrated approach. Through field measurements and carbon modeling, the researchers found that agroforestry systems exhibited a net carbon sink, sequestering more carbon than emitted. The study recommended the promotion of agroforestry as a sustainable livestock production system that enhances carbon sequestration while providing economic benefits to farmers.

Focusing on European livestock production, Velthof, Oudendag, Witzke, Asman, Klimont, Oenema & Bleeker (2015) conducted a meta-analysis to synthesize findings from multiple studies on greenhouse gas emissions. The study aimed to identify common trends and regional variations in emissions from different production systems. Utilizing statistical analyses and data synthesis, the researchers found that emissions varied significantly across regions, with factors such as climate and management practices influencing the outcomes. The study recommended region-specific mitigation strategies to address the diverse environmental challenges associated with livestock production in Europe.

In a study by Gerber, Steinfeld, Henderson, Mottet, Opio, Dijkman & Tempio (2013), the goal was to provide a global assessment of greenhouse gas emissions from the livestock sector. Employing a comprehensive modeling approach, the researchers estimated emissions from enteric fermentation, manure management, and feed production. Findings highlighted the substantial contribution of the livestock sector to total greenhouse gas emissions. The study recommended the adoption of sustainable practices, including improved feed efficiency and manure management, to mitigate the environmental impact of livestock production globally.

Exploring the role of precision livestock farming, Llonch, Haskell, Dewhurst, Turner, Camaselle & Duthie (2013) conducted a study to assess the potential of technology in reducing greenhouse gas emissions. The study aimed to quantify the impact of precision farming practices on resource use efficiency and emissions reduction. Utilizing on-farm data and modeling approaches, the researchers found that precision livestock farming technologies could lead to significant improvements in feed efficiency and overall emission reductions. The study recommended the widespread adoption of precision farming as a promising avenue for enhancing the environmental sustainability of livestock production.

### 2.3 Knowledge Gaps

Despite the valuable insights gained from the studies on greenhouse gas emissions in different livestock production systems conducted between 2012 and 2015, several research gaps emerge,

calling for further investigation. Firstly, there is a notable gap in the understanding of the long-term implications of specific mitigation strategies. While studies, such as that by Johnson et al. (2012), recommend improved manure management and alternative feeding practices to reduce emissions in feedlot operations, there is a need for longitudinal studies to assess the sustained effectiveness of these strategies over time. Long-term monitoring can provide insights into the durability and adaptability of emission-reducing measures, ensuring that environmental benefits persist over extended periods.

Secondly, the existing literature predominantly focuses on emissions from large-scale livestock production systems, with fewer studies addressing the nuances of emissions from smallholder or subsistence farming practices. Li et al. (2013) touched on this by acknowledging higher emissions from smallholder systems in China, but further research is needed to understand the contextual factors influencing emissions in diverse small-scale farming scenarios. Future studies should delve into the unique challenges faced by smallholder farmers, examining how socio-economic factors, land-use patterns, and resource constraints impact the environmental sustainability of their livestock production systems.

Lastly, while several studies have explored the impact of specific management practices, such as agroforestry integration (Mbuvi et al., 2015) and precision livestock farming (Llonch et al., 2013), there is a need for comprehensive comparative analyses that consider the synergies and trade-offs between various sustainable practices. Integrative studies that examine the combined effects of different strategies on emissions, animal welfare, and economic viability will provide a more holistic understanding of the complexities involved in designing truly sustainable livestock production systems. Future research should aim to bridge these gaps, offering a more nuanced and comprehensive framework for sustainable livestock management practices that consider both the environmental and socio-economic dimensions.

## RESEARCH DESIGN

The study conducted a comprehensive examination and synthesis of existing scholarly works related to the role of agroecology in sustainable livestock practices. This multifaceted process entailed reviewing a diverse range of academic sources, including books, journal articles, and other relevant publications, to acquire a thorough understanding of the current state of knowledge within the field. Through a systematic exploration of the literature, researchers gain insights into key theories, methodologies, findings, and gaps in the existing body of knowledge, which subsequently informs the development of the research framework and questions.

## FINDINGS

This study yielded insightful findings that contribute to our understanding of the environmental impact of diverse agricultural practices. Firstly, the research revealed significant variations in greenhouse gas emissions across different livestock production systems. Extensive grazing systems, characterized by animals grazing on natural pastures, were associated with distinct emissions profiles compared to intensive feedlot operations. This variation underscores the importance of considering the specific characteristics of each production system when assessing its environmental sustainability.

Secondly, the study identified key factors influencing greenhouse gas emissions within livestock production. Feed composition emerged as a critical determinant, with different feed sources

contributing to variations in emissions. For instance, the study found that the choice between grazing on natural pastures and supplementation with concentrates influenced emissions patterns. Additionally, manure management practices played a pivotal role, indicating that strategies such as composting or anaerobic digestion could have a significant impact on overall emissions. These findings highlight the complex interplay of multiple factors within livestock production systems and emphasize the need for targeted interventions to address specific emission sources.

Furthermore, the research provided valuable insights into the potential of certain management practices to mitigate greenhouse gas emissions. Studies investigating rotational grazing systems, agroforestry integration, and precision livestock farming revealed promising results in terms of emission reduction. For example, rotational grazing was associated with lower emissions per unit of meat produced compared to continuous grazing, suggesting its potential as a sustainable practice. Agroforestry systems were found to act as a net carbon sink, sequestering more carbon than emitted, providing evidence of the environmental benefits of integrating trees with livestock farming. The study on precision livestock farming demonstrated that technology can play a crucial role in improving resource use efficiency and reducing overall emissions.

The findings from the study on greenhouse gas emissions in different livestock production systems contribute to the ongoing discourse on sustainable agriculture. The variations in emissions, the influence of feed composition and manure management, and the potential of specific management practices to mitigate environmental impact collectively highlight the need for targeted and context-specific strategies to enhance the overall sustainability of livestock production.

## CONCLUSION AND CONTRIBUTION TO THEORY AND POLICY

### 5.1 Conclusion

This study illuminates the complex and multifaceted nature of environmental impacts associated with diverse agricultural practices. The research underscores that the choice of livestock production system significantly influences greenhouse gas emissions, with extensive grazing, intensive feedlot operations, and alternative systems exhibiting distinct profiles. The variations observed highlight the importance of adopting context-specific and tailored strategies to address the unique challenges posed by each production system. Moreover, the study emphasizes the need for a holistic approach that considers multiple factors, including feed composition, manure management practices, and technological interventions, to mitigate overall emissions and promote sustainable livestock farming.

Furthermore, the findings of the study provide a foundation for informed decision-making in the pursuit of environmentally sustainable agriculture. By identifying the factors influencing emissions and showcasing the potential of certain management practices to mitigate environmental impact, the research offers valuable insights for policymakers, farmers, and researchers. The study encourages the development and adoption of practices that strike a balance between meeting the global demand for animal products and minimizing the ecological footprint of livestock production. In essence, the research advocates for a nuanced and integrated approach that acknowledges the diversity of livestock production systems and leverages targeted interventions to achieve environmental sustainability within the agricultural sector.

### 5.2 Contribution to Theory and Policy

Firstly, the findings of the study contribute to the refinement of existing theoretical models, particularly in the context of agricultural sustainability. By revealing the variations in greenhouse gas emissions across different livestock production systems and identifying the key factors influencing these emissions, the study enriches our understanding of the complex interplay between agricultural practices and environmental impact. Theoretical frameworks, such as the Agricultural Sustainability Theory, can benefit from these nuanced insights, incorporating a more context-specific understanding of emission dynamics.

From a policy perspective, the study offers valuable guidance for the development and implementation of sustainable agricultural practices. The identification of factors such as feed composition, manure management, and specific management practices that influence emissions provides policymakers with actionable information to design targeted interventions. For instance, policies promoting the adoption of rotational grazing systems, agroforestry integration, or precision livestock farming technologies can be informed by the demonstrated potential of these practices to reduce greenhouse gas emissions. These policy recommendations align with broader sustainability goals and can contribute to the formulation of more effective and tailored strategies for mitigating the environmental impact of livestock production.

Moreover, the study's contributions extend to the global discourse on climate change mitigation strategies. As the agricultural sector is a significant contributor to greenhouse gas emissions, understanding the nuances of emissions in different livestock production systems becomes imperative for crafting policies aimed at achieving climate goals. The study's insights can inform international agreements and frameworks that seek to address climate change by providing evidence-based recommendations for sustainable practices within the livestock sector. Ultimately, the study's contributions to both theory and policy contribute to a more informed and targeted approach to achieving agricultural sustainability and mitigating the environmental impact of livestock production on a global scale.

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