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Original Article

Greenhouse gas emissions from the barnyard: Linking animal production to global climate change

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Abstract
The livestock production sector is significantly contributing to global greenhouse gas emissions, thus playing a vital role in climate change. This review examined the major sources of greenhouse gases (GHGs) from the livestock sector basically methane (CH_4) produced from enteric fermentation, nitrous oxide (N_2O) released from chemical fertilizers and organic manure, and carbon dioxide (CO_2) released due to land use change and energy consumption with ruminants animals (cattle in particular) as the primary emitters due to their digestive processes. Literature revealed that ruminant animals produced for about 7.8 million tons of CH_4 in 2000 which might probably rise to 11.1 million tons by 2030. Agricultural land management is the major source of N_2O emissions in the Sub-Saharan Africa, causing approximately 64% of the total N_2O emissions in 2020, which is likely followed by the application of synthetic fertilizers to urban soils. The review has further examined the impact of feed production, manure management and energy consumption on the environment across the various livestock production systems. The strategies of mitigation include diet modifications, genetic improvement, effective manure handling, production of biogas, and modified practices of land management. This research will impart information on policy decisions and support the practices that will sustainably minimize the carbon footprint of livestock production sector.

INTRODUCTION

Climate Change and the Role of Agriculture

Unfortunately, an uninterrupted increase in the concentration of GHGs in the world causes the effect of greenhouse leading to the risk of global warming and changes to the climate (Gopalakrishnan *et al.,* 2019). Globally, there is an increased GHG emission by 75% in the last 30 years (Outhwaite *et al.,* 2022). Presently, carbon dioxide (CO_2) account for about 76% of the

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total GHGs, while methane (CH_4) contributes about 16%, whereas nitrous oxide (N_2O) leveled up to 6% (Crippa *et al.,* 2021). The main instrumentals to the GHGs emissions within the corridor of agriculture are energy consumption, in processing of food and operating farm inputs in addition to the agricultural land use (Chalise and Naranpanawa, 2016). Looking in to the emissions sources of GHG from agriculture like digestive fermentation form ruminants and emitted CO_2 in farm operation is crucial in developing the most proper downplay and adaptation generalship such as sustainable farming with reduced emissions of GHGs from energy use in agriculture. Several factors indicated that the levels of atmospheric GHGs, specifically CO_2 and CH_4 gases, already skyrocketed over the previous decades due to the increase in agricultural practices (such as fertilizer application), forestry practices (such as deforestation), and domestication of farm animals (Maindi *et al.,* 2020).

GHGs Emission from Animal Husbandry

There is an increase in enlightenment within the communities dealing with researches and policy-making that an increased in the production and consumption of animals products is helping to a wide range of an alarming environmental threat globally, notably being the sector's significant contribution to emissions causing climate change. Presently there is a high increase of interest in understanding the relationship of livestock rearing and the scenario of climate change and this has been encouraging a higher number of researches (Aydinalp, 2010). Consequently, this study reviewed the contribution of livestock rearing to the change of climate globally and the strategies of mitigation.

Objective

This study aimed to identify the major sources of emissions within livestock systems and evaluate potential strategies for mitigating their environmental impact. The specific objective of this review however, was to analyze the contribution of livestock production sector to global GHG emissions and its role in climate change.

Scope of the Review

The scope of the review encompasses both intensive and extensive livestock systems across different geographic regions, assessing their respective contributions to global GHG emissions. It also evaluated the strategies of mitigation directed towards decreasing the environmental footprint of animal agriculture, including dietary changes, improved manure management, technological innovations, and policy interventions. By synthesizing current scientific findings, this review seeks to inform stakeholders, including policymakers, producers, and researchers, about the environmental implications of livestock production and support efforts toward more sustainable agricultural practices.

MAJOR GHGS FROM LIVESTOCK SYSTEMS

Methane (CH_4) from enteric fermentation

Rumen fermentation mainly occurs in the digestive tract of ruminant animals under the control of rumen microorganisms by breaking the plant materials ingested by the animals to produce methane which is released through exhaling, belching, and other means. This account for the largest share of emissions from ruminants animals source (Beauchemin, 2009). Domesticated farm animals (such as cattle, swine, sheep, and goats) naturally produce CH_4 as crucial part of their digestive processes (Robinson, 2020). As these domestic animals are reared by human being as source of food and other purposes, GHG emissions from them are considered to be human-related (Smith *et al.,* 2016).

About 35 - 40% of annual methane emission was resulted from livestock production sector (Steinfeld *et al.,* 2006) due to the enteric fermentation in ruminant animals and from animal manure. The emissions of methane are influenced by a myriad of certain factors, which includes the age of the animal, body weight, quality of feed offered, digestive efficiency, and physical exercise (Paustian *et al.,* 2006; Steinfeld *et al.,* 2006). Even though, each animal normally produces relatively little amounts of methane gas (U.S. EPA, 2007b), the more than one billion (> 1 billion) ruminants reared yearly account to a noticeable methane source (FAO, 2008). Certainly, rumen fermentation produces methane emission for about approximately 86 million metric tons globally (Steinfeld *et al.,* 2006). The GHG emissions resulted from animal production sector in particular and agricultural practices in general are expected to increase as food production cost grows to keep pace with a challenge of growing world which population is expected to reach 8.3 billion by 2030 and 9.1 billion by 2050 as estimated by (UN, 2008).

In some developing countries especially in Africa, there is an observed increased in methane emission which resulted from the increased livestock production. Herrero *et al*. (2008) reported that in Africa, there was an estimation that cattle, sheep and goat produced for about 7.8 million tons of methane in 2000 which might probably rise to 11.1 million tons by 2030. As according to the report of Bruinsma (2003), if the linear correlation of methane emission and the population of livestock population persist, it could be declared that methane emission from livestock production sector may skyrocket to 60% by 2030 globally.

Nitrous oxide (N_2O) from manure and fertilizer use

Even though 70% of anthropogenic emissions of N_2O result from combined crop and livestock agriculture, domestic livestock production, including growing feed crops, accounts for about 65% of N_2O emissions globally (Steinfeld *et al.,* 2006). The report of Paustian *et al. (*2006) showed that the management of manure from farm animals accounts for about 6% of N_2O emissions from agriculture. The N_2O emissions from pig manure alone might globally account for almost half of the total GHG emissions from livestock manure (Steinfeld *et al.,* 2006).

Numerous management activities of agricultural land in Sub-Saharan Africa like synthetic or organic fertilizers application and other cropping practices, the manure management, burning of agricultural residues generate N_2O emissions (Borrelli *et al.,* 2020; Popp *et al.,* 2017). Agricultural land management is the major source of N_2O emissions in the Sub-Saharan Africa, causing approximately about 64% of the total N_2O emissions in 2020, which is likely be followed by the application of synthetic fertilizers to urban soils (lawns, golf courses) and forest lands (Adams and Acheampong, 2019).

Carbon dioxide (CO_2) from energy-use and land use change

Changes in land use and use of energy in agricultural practices have a serious influence on the carbon sequestration and GHG emissions in Sub-Saharan Africa (Mullins *et al.,* 2018). Normally, plants used to absorb atmospheric CO_2, and from many other natural ecosystems evolved over thousands of years could store enormous amounts of carbon (Outhwaite *et al.,* 2022). Abbass *et al*. (2022) and Tongwane and Moeletsi (2018) reported deforestation as the main cause of climatic change in Ethiopia, Sudan, Chad, and Niger. Close to that, high tillage practices are a local land-use technique in Mali, Guinea, and Mauritania that significantly contribute to climatic changes by regular disruption of the topsoil (Tongwane and Moeletsi, 2018). These practices increase CO_2 and CH_4 emissions by inducing the top soil organic matter decomposition and at the same time soil erosion (Ngarava *et al.,* 2023). Because of that, forest practices and woodland management have also enormously influenced the concentration of atmospheric GHGs thereby resulting in the climatic change (Robinson, 2020).

Furthermore, agricultural energy use, such as a use of tractor for land clearing, machinery for fertilizer application, and other tillage practices in some part of Southern African nations like Zambia, Zimbabwe, Namibia, and Botswana, have significantly altered the nitrogen and carbon cycles, contributing to GHG emissions and climate change (Davis-Reddy, 2018). Furthermore, in Western African countries (such as Nigeria, Ghana, Togo, Burkina Faso, and Senegal), organic farming play a vital role in contributing a significant level of GHG emissions due to a poor management strategy of crop residue as the agricultural wastes in these countries are usually burnt publicly or left for the grazing of farm animal (Ngarava *et al.,* 2023).

Sources of GHGs by production type

Ruminants

Recently, there is a global rise in public concern about dairy livestock GHG emissions and their contribution to global warming and climatic change (Vázquez-Carrillo *et al.,* 2020). A study has revealed that an increased in CH_4 gas emissions can be caused substantially by animal farming (La *et al.,* 2028). Composting manure and rumen microbial fermentation produce methane by which the animal expels from the rumen through gas eructation (Hardan *et al.,* 2022).

Yearly, ruminant animal is believed to release between 80 and 95 million tons of CH_4 gas globally (Patra, 2014). Methane (CH4) production also represents a loss of certain amount of energy available to the host ruminant, mostly accounting for about a range of 2% and 12% of the total available energy (Bekele *et al.,* 2022). Ruminants such as cattle and sheep mostly contribute to the GHG emissions in agriculture, estimating for up to 18% of the global total GHG emissions, usually in the form of rumen methane (Herrero and Thornton, 2013). Cattle are mostly considered as food-producing animals due to their higher contribution to the sector's GHG emissions, methane in particular (Aan den Toorn *et al.,* 2020). The stomach fermentation processes normally produce for about more than 90% of CH_4 gas emissions from farm animals and 40% of agricultural GHG emissions (Tubiello *et al.,* 2013).

The Intergovernmental Panel on Climate Change (IPCC) and Food and Agriculture Organization (FAO) of the United Nations (UN) has a view that, a cow that's fully developed, can emit a methane gas of up to 500 liters per day approximately accounting for 3.7% of the total GHG emissions (Tubiello *et al.,* 2013).

Non-Ruminant Animals

Globally, pigmeat approximately accounts for about 35% of the meat supply, with over 747 million tons of carbon dioxide (CO_2) emissions annually. Piggeries GHG emission is originated from animals through the exhalation of CO_2 and CH_4 enteric fermentation, and from farm manure. The amount of the CO_2 gas exhalation normally depends on the physiological status of the animal, the body weight (BW), the level of production and the feed intake of the concerned animals. The principal enteric CH_4 (E-CH_4, pig) is related to dietary fibre intake and the capacity of the pig's hindgut to fermentation. The pigmeat industry was accounted to have emitted 26.6 MMT CO_2e or 0.34% in US (US EPA Greenhouse Gas Inventory, 2015). According to the report of Ersoy and Ugurlu (2020), Turkey birds usually produce 33.85 MT of carbon dioxide equivalent (CO_2-eq), in addition to enteric fermentation and management system of manure in 2015 (IPCC, 2006).

PATHWAYS LINKING ANIMAL HUSBANDRY TO CLIMATE CHANGE

Manure Management

There is a significant contribution of manure in the emissions of CH_4 and N_2O. The decomposition of organic substances in the absence of air is normally accompanied with releases of methane gas, and the decomposition of ammonia releases nitrous oxide. Manure contained two chemical components; an organic substance and nitrogen content which are responsible for the emission of N_2O in the process of storage and processing (Grossi *et al.,* 2019). Soil emission is considered as the highest manure-related N_2O in relation to manure application (Steinfeld *et al.,* 2006). In addition to that, moisture, animal diet, temperature and waste management are considered as other factors affecting emissions from manure.

Feed Production

Feed production emits gases such as CO_2, N_2O, and CH_4. Production of feed, it's processing and transport account for about 45% of total emissions related to livestock. Of all these, nitrogen oxide derived from fertilization of feed crops and methane released from the application of manure to pasture account for about 50%, while other related land use change practices generate about 25% of the total emission (Gerber *et al.,* 2013). Carbon dioxide emission spring up from fertilizers and pesticides production for feed crops, transportation and processing of feeds, energy used in the production process, and other changes that are associated with land use.

Land Use Change

Land use change is also livestock-related indirect way of generating GHG emissions. According to the report of the Gerber *et al.* (2013), about 9.2% of the total livestock-related GHG emissions are due to land use change. Globally, land for agricultural purposes covered 38% of the total land surface, in which livestock sector covers about 2/3 of the total land (FAO, 2021). To meet the feed demand of the ever-increasing livestock sector therefore, the area under grazing is predicted to cover about 70% of the total land under agriculture (Yitbarek, 2019).

Formerly, an increased in livestock and feed production has enormously affected the land use in relation to the natural carbon cycle (Rojas-Downing *et al.,* 2017). The report of the Steinfeld *et al*. (2006) revealed that increased pasture and feed crop production are the main cause of deforestation which consequently accounts for approximately 8% of total anthropogenic CO_2 emissions.

Energy Consumption

The emissions of CO_2 come from energy consumption, majorly related to the use of fossil fuel. The emissions related to energy in livestock sector, occur throughout the supply chain ranging from fertilizer production, operating machinery, and feed and livestock transportation. Within the farm, energy from animals includes that used for heating/cooling, ventilation, illumination, and milking. Production of feed in upstream requires energy in the production process, drying, and transport of the commodity. Energy in the downstream is normally used in processing the livestock commodities, packing and in transporting the final products to retailers. The total amount of energy consumed along the supply chain of livestock accounts for about 25% of total GHG emissions in the sector (Gerber *et al.,* 2013).

MITIGATION STRATEGIES IN LIVESTOCK SYSTEM

A lessen strategies exist in nature to cushion the GHG emissions from the livestock sector. The report of Gerber *et al*. (2013) ascertain that the variability of the intensities of livestock emission ranging from the system of production, regions and the potential of mitigation relies within the gap of management techniques resulting in the lowest and highest emission intensities. They projected the possibility of reducing GHG emissions resulting from the livestock sector to the minimum of 18% provided that the producers in the system, region, and climate agreed to accept and practices the presently applied techniques by the uppermost 25% of producers with the lowest possible intensity of GHG emission and 30% if techniques will be employed by barely the top 10% (FAO, 2013).

Dietary Modifications and Feed Additives

The rapid changes in the composition of the animal diet can reduce the production of CH_4 up to at least 30% depending on the level of variation and the nature of the intervention (Benchaar *et al.,* 2001). Giving altered diets may not only increase the forage quality but also target the direct process of methanogenesis or alter the mechanism of metabolism, thereby leading to a decreased methanogenesis. A feed supplements with a promising value for reducing CH_4 and CO_2 emissions from farm animals is organic acid, which act by influencing the formation of propionic acid in the rumen (Castillo *et al.,* 2004). Propionate precursors can be added in the diet as it reduced the production of CH_4 though there is a variation in the reductive pathways of the organic acid sources (McAllister and Newbold, 2008). Some plants contain a varied number of the classes of secondary metabolites that can be used as feed additives or ingredients that can reduce the GHG emission from livestock (Salem *et al.,* 2014). The inclusion of tannins directly from plants or as plant extracts, in ruminant diets, has been showed to decrease CH_4 above 20 g/kg (Jayanegara *et al*., 2011). Petlum *et al.* (2019) reported that inclusion of *Siamese* neem suppressed CH_4 output at inclusion levels of 2, 4 or 6 mg/100 g DM, while supplementation of *Leucaena* leaves showed reductions on CH_4 production at 6 mg/100 mg DM of supplementation

Breeding and Genetic Improvement

Prioritizing on the selection of certain traits in animal that can ascertain a drastic decrease in methane gas production is the most potential way to consider. Improving livestock performance was facilitated through a high precision breeding in genetics. The changes in genetics are cumulative and permanent; it is therefore an alternative which is attractive for reducing or targeting the GHG emissions in ruminant animals (González-Recio *et al.,* 2020; Manzanilla-Pech *et al.,* 2021). A research from New Zealand revealed that breeding that targeted a reduced emission in sheep has no any impact on productivity and health (Sharon *et al.,* 2022). In Canada, marketing of dairy semen with high methane efficiency traits is common among the traders, whereas in Ireland, beef farmers are being paid to take part in genomic programmes (Nienke *et al.,* 2024).

Land Resources Management

Land use and livestock management practices are most real way of mitigation. At maximum, Thornton and Herrero (2010) opined that the mitigation potential of livestock and pasture management is projected to account for approximately 7% of the global potential of mitigation from agriculture by 2030. Possible actions include improved pastures adoption, improving ruminant diets and breeds, changing the stocking rate, and reducing the grazing intensity. Havlík *et al.* (2014) pointed that achieving a noticeable emission reduction will be through changing to livestock production that is more efficient and less land-demanding.

Enteric Fermentation

As explained earlier, the main figure of ruminant methane emissions is from enteric fermentation which can be managed through the management of diets and genetics at large. The findings of Knapp *et al*. (2014) showed that a strategic nutrition and feeding such as forage digestibility improvement can lessen enteric methane production by minimum of 2.5–15% per unit of milk produced and an increased reductions can be achieved if alternatively combine the approach of genetic and management. Antibiotics, lipids, grain, and ionophores are feed additives and supplement that have also been playing a role in decreasing the enteric methane gas emissions by altering the microbial ecology of the intestine thereby increasing carbon and nitrogen retention by the animals (Caro *et al.,* 2016).

Manure Management and Biogas Production

Making changes in the practice of storing manure such as short storage duration, reduced storage temperature and water, and solid - liquid separation can significantly reduce the amount of GHG emissions from the manure (Montes *et al.*, 2013). Normally microorganisms break down manure through anaerobic digestion in the absence of oxygen thereby producing a mixture of biogas (mainly CH_4 and CO_2) and digestate that can be captured and used as bioenergy to produce heat or electricity. Anaerobic digestion is surely a way that can lead to an over 30% reduction in GHG emissions when compared to traditional manure treatment (Battini *et al.,* 2014).

The production of biogas can be from nearly all kinds of biological materials deriving from the agricultural sectors and other various industrial and domestic organic waste streams. Biogas production and use, is normally seen as a clean and sustainable energy generation option that can certify a significant GHG savings when compared to fossil fuels (Ojeu, 2009). This positions biogas as a reliable energy resource in the energy transition to green and low carbon energy and electricity mix (Kabeyi and Oludolapo 2020).

CHALLENGES AND KNOWLEDGE GAPS

Socio-economic Barriers to Adoption

Several factors such as awareness and attitudes of the farmers play a vital role in adopting the mitigation strategies of greenhouse gas emissions. For example, study revealed that in Ireland, only 52% of the farmers population were aware of greenhouse gas emissions and only 35% out that have indicated their interest to adopt an emissions advisory tool (May, 2019). Similarly, a study from United Kingdom reported that the limited knowledge of the farmers about the relationship between the environment and the agriculture has seriously affects their desire to accept the beneficial environmental practices and innovation attitudes (Jantke *et al.*, 2020). Moreover, investigations in Germany on the knowledge and attitudes of farmers towards agricultural GHG emissions assessed that factor such as insufficient information makes farmers to shortly fail in adopting the strategies of emissions reduction despite of their knowledge of climate change and interest of adopting the sustainable practices (Jantke *et al.*, 2020).

Previous study highlighted the role of digital technology as important agricultural component for climate change mitigation especially when combined with active efforts of participation from farmers and stakeholders (Blasundram *et al.,* 2023). Another study from Ireland highlighted the conservative attitude and insufficient knowledge as the factors that negatively affect the interest of the old farmers to adopt new practices (O'Shea *et al.*, 2018). Additionally, it was recognized that the level of awareness of emissions is the non-economic key factor that is influencing the voluntary adoption rate of feasible mitigation measures (Adenaeuer *et al.*, 2020).

Trade-offs between productivity and sustainability

Addressing the impact of climate change has become as a major challenge of the current century, despite the facts that the world continues to face other pressing key issues such as reducing global poverty and economic inequalities among others. According to Taghizadeh-Hesary and Yoshino (2022), global investments in renewable energy and energy efficiency has declined by 1% in 2017 and 3% in 2018, respectively. This downward trend poses a threat to the progress made under UN Climate Change Conference (COP21) Paris agreement. Additionally, substantial cross-country evidence suggests that economic growth is typically linked to increased carbon dioxide emissions the primary anthropogenic greenhouse gas- at least up to a certain level of economic development (Jacob *et al.*, 2014).

FUTURE DIRECTION AND RESEARCH NEEDS

Innovations in low-emission livestock system

Cattle farming are now a central to climate change discourse, as livestock production is estimated to contribute between 12% and 14.5% of global greenhouse gas emissions (Gerber et al., 2013; FAO, 2023). Nevertheless, properly managed grazing ruminants have the potential to offset some of these emissions by enhancing carbon sequestration in soils and above-ground vegetation often referred to as "flux fixation" as well as through ecological restoration (Mattila et al., 2021; Manzano et al., 2023). Moreover, several strategies exist to lower the emissions intensity of ruminant farming, which is vital for realizing goals related to zero hunger, better nutrition, and sustainable agriculture (FAO, 2023).

Integration of Climate-Smart Agricultural Practices

Climate Smart Agriculture (CSA) aims to undertake the challenges in agricultural development by increasing agriculture productivity in an environment-friendly manner reducing the greenhouse gases emissions and ensuring food security. The CSA practices, therefore, can assist agriculture adapt to climate change, reducing climate change, and sustainably enhance productivity (Nagar *et al.*, 2023). It provides enablers in which specific technologies and practices can be assessed in terms of their impacts, especially relative to national development and food security in the context of the changing climate (Barasa *et al*., 2021). Climate-smart agriculture is therefore linked with many sustainable development goals as it has an extensive impact across the spectrum, which is beyond the defined scope of climate change and adaptation (Aishwarya and Kumar, 2024). This holistic strategy seeks to prevent the negative impacts of climate change, respond to their occurrences, and consequently enhance the probability of improved efficiency in agriculture (Balogun *et al*., 2024).

Role of Policy, Education and Stakeholders Engagement

Education is fundamental in mitigating climate change as it raises awareness, cultivates critical thinking, and encourage sustainable behaviors. Climate change education (CCE) is crucial for developing ethical frameworks and scientific understanding, which are crucial for preventing and adapting to climate impacts (Tripathy *et al.*, 2024). The urgency of integrating climate education across all sectors is underscored by the need for immediate action against environmental threats, advocating for a collaborative approach to empower global citizenship and address shared challenges (Riaz *et al*., 2024).

CONCLUSION

This study highlighted the influence of livestock production as a major source of greenhouse gases emissions; mainly methane and nitrogenous oxide which are released from enteric fermentation, manure management and fertilizer use. It also stressed on the environmental impacts of land use changes such as deforestation. Manure improvements, source of feeding and grazing management were recommended as greenhouse gas emissions mitigating strategies. Coordinated research efforts were advocated to reduce emissions and move towards more sustainable livestock production.

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