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Conceptual Paper

Achieving Net Zero in Global Dairy

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Abstract

Problem statement - Methane emission from livestock

Agriculture is the largest single source of global anthropogenic methane (CH_4) emissions, with ruminants the dominant contributor. The rearing of animals for domestic consumption and export invariably led to the production of methane as a product of digestion.

Livestock CH_4 emissions are projected to grow another 30% by 2050 under current policies, yet few countries have set targets or are implementing policies to reduce emissions in absolute terms. This review examines the significant role of methane emissions in the livestock industry, with a focus on cattle and their impact on climate change. It highlights the importance of accurate measurement and management techniques for methane, a potent greenhouse gas accounting for 14-16% of global emissions.

The study evaluates both conventional and AI-driven methods for detecting methane emissions from livestock, particularly emphasizing cattle contributions. This review covers livestock methane emissions, the potential of AI technology, data collection issues, methane's significance in carbon credit schemes, and current research and innovation. The review emphasizes the critical role of accurate measurement and estimation methods for effective climate change mitigation and reducing methane emissions from livestock operations.

Overall, it provides a comprehensive overview of methane emissions in the livestock industry by synthesizing existing research and literature, aiming to improve knowledge and methods for mitigating climate change. Livestock-generated methane, especially from cattle, is highlighted as a crucial factor in climate change, and the review underscores the importance of integrating precise measurement and estimation techniques for effective mitigation.

Keywords: $CH4$ Emissions; Methane; Climate Change

Introduction

Agriculture, including associated emissions from deforestations, accounts for about 21% of total annual anthropogenic greenhouse gas emissions when emissions are weighted using the global warming potential with a time horizon of 100 years.

The vital solution to stopping the warming trend is achieving net "zero emission "of long-lived climate pollutants (LLCPs), primarily carbon dioxide(CO_2) and to a lesser degree nitrous dioxide (CO_2) and to a lesser degree nitrous oxide (N_2O). However, there is growing recognition that minimizing the emisssions of SLCPs will quickly, though temporarily, slow the warming of the atmosphere and buy time for the global community to develop solutions to keep temperatures from surpassing the 1.5°C temperature goal set (UNFCCC 2016).

Primary SLCPs include methane (CH_4), black carbon, tropospheric ozone, and hydrofluricarbons. These pollutants have a realtively shorter existence in the atmosphere, but have high warming potential, contributing one third of the current radioactive forcing (RF) from GHGs.

Methane short atmospheric existence

Methane second most abundant GHG (annual emission of anthropogenic was 572 (538-593) million metric ton per year during 2008-2021 which is an increase of 3.6% from 2000-2010 levels. Methane, as one of the primary GHGs, is a short-lived GHG that has a much higher global warming potential than carbon dioxide over a shorter time-period. Methane is responsible for around 14-16% of total global GHG emissions, according to the Intergovernmental Panel on Climate Change. As heat wave occurrences are predicted to occur more frequently and intensely over the planet, climate change is likely to make these problems worse. The parties to the Paris Agreement agreed to limit global warming to 1.5 ◦ C, requiring a reduction in agricultural methane emissions by 24-47% and the achievement of net zero CO_2 emissions by mid-century. In addressing climate change, 195 countries have pledged to decrease greenhouse gas (GHG) emissions as part of the United Nations Framework Convention on Climate Change (UNFCCC) and have presented their national climate action strategies, known as their Nationally Determined Contributions (NDCs). The 195 parties affiliated with the Paris Agreement are obligated to report their national greenhouse gas inventories and progress towards achieving emissions reduction goals. Understanding and controlling methane emissions have become an essential priority as global concerns about climate change continue to rise.

Contributions of livestock in climate change

Livestock operations encompasses a range of activities that contribute to methane emissions. Methane is produced and released during enteric fermentation, the process by which ruminants (cattle, sheep and goat) digest their food. Anaerobic conditions in manure storage systems boost metanogenic bacteria activity resulting in methane production.

Enteric fermentation and manure management together contribute roughly 30% of total anthropogenic CH_4 emissions, including indirect effects, has been estimated at just over 40% of total radiative forcing from human activities.

Considering the differences in livestock categories, ruminants account for the largest share of livestock methane emissions in most countries. Long term metane emisipns have significant climate change implications, worsening the greenhouse effect and further disrupting the earth's climate system.

Methane has a strong warming effect in the short term, making it critical to address these emissions in order to prevent the near-term effects of climate change.

Prospects and methods for livestock methane mitigation

Methane emissions from livestock farms must be accurately estimated in order to mitigate GHG emissions emissions and to explore alternatives to reducing them.

Reductions of livestock CH_4 emissions can occur via supply and demand -side approaches. Supply-side interventions can be grouped into the use of different feed and feed additives, measure to increase feed quality, increased livestock and crop/pasture productivity, and manure management through aeration or biogas production and use. The mitigation potential from these measures varies across studies, with the technical potential to reduce CH_4 emissions from enteric fermentation estimated at up to about 50 Mt $CH_4\ yr$ by 2050 and up to about 5 Mt CH_4 yr from manure management.

Precise quantification of methane emissions offers a baseline for measuring the efficacy of emission reduction efforts show high accuracy compared to the respiration chamber method (golden standard technique in quantifying the methane emission from animals.

The hand laser methane detector (LMD) also has the potential to detect methane emissions from ruminants, accounting for atmospheric variations such as humidity, wind speed, and atmospheric pressure.

Creating strong and accurate estimating methods is critical for addressing the climatic impact of livestock methane emissions.

Estimation methods for methane emissions.

Direct measurement techniques

- Respiration chambers or portable analyzers which capture and quantify methane emissions.

- Sulfur hexafluoride (SF_6)
- Green feed
- Sniffer technique

Indirect estimation approaches

- Model approach to estimation of methane emissions from ruminants.
- Incorporating regional variables for developing accurate methane estimation models

Mitigations techniques for methane reduction in livestock

Relevant technologies include novel feed such as genetically modified ryegrass, physical CH_4 capture and neutralization devices, and feed additives including CH_4 inhibitors, as well as vaccines.

- **Methane inhibitors: synthetic:** A CH_4 inhibitor is a chemical compound that suppresses the activity of CH_4 forming microbes (methanogens) in the rumen. Inhibitors could be delivered as a feed additive or as bolus (a small capsule containing the active compound, inserted into the rumen). 3-Nitrooxypropanol has been shown to consistently reduce methane emissions by around 30 % in total mixed ration farm systems without compromising animal productivity.
- **Methane vaccine:** Vaccination against the rumen methanogens is expected to have broad applicability globally and could be practical and cost effective even in extensive systems.

Major components of a vaccine chain have been demonstrated: genome sequencing of methanogens has identified targets that stimulate antibody production; antibodies have been shown to supress pure methanogens cultures *in vitro*.

Commercial availability of a vaccine is estimated to take few years after demonstration of prototype.

- **Breeding low- emission animals:** Research is underway to develop proxy indicators (e.g. based on milk constituents, rumen microbial profiles) to enable cheap and rapid identification of low emitting animals.

Adoption of breeding approaches is subject to breeding programmes being accessible to farmers and a favourable balance between the oppurtunity cost of selecting for low emissions and policy incentives for reduced emisssions

- **Methane inhibitors: seaweed:** Algae of the genus asparagopsis have been shown to reduce ruminant CH_4 emissions by 20- 98%, although the persistence of this effect over multiple seasons remains unclear. The role of bromoform and bromochloromethane a active ingredients in Aspragopsis raises challenges from a regulatory and market acceptibility perspective, given that both substances may be carcinogens. There are also doubts regarding palatibility to livestock, animal health and the ability to produce and supply seaweed at a large scale.

If these concerns can be addressed, this feed additive can be available within the next few years.

Conclusions

This article investigated the CH_4 estimation in livestock, especially ruminants. Ruminants are one of the biggest anthropogenic sources of CH_4 emissions in the world due to their special digestive system. With the worsening of global warming, humanity has agreed to reduce the amount of greenhouse gases emitted, and various policies for mitigation are being implemented. To ensure the implementation of policies for reduction of CH_4 *emi*ssions from ruminants, it is essential to develop precise methods for CH_4 measurement, but quantifying the CH_4 emissions from ruminants always possesses uncertainty due to random effects. Employing inaccurate methods for measuring CH_4 emissions from ruminants can lead to over or underestimation in setting goals and implementing policies for methane reduction.

The significant potential for the reduction of livestock CH_4 emissions can only be realized if agriculture, and livestock systems, in particular, become part of mainstream climate policies ,while recognizing their unique and multiple interacting social, cultural and environmental functions.

We may contribute to the worldwide effort to combat climate change and promote sustainable livestock production by incorporating accurate estimation into carbon credit evaluation and regulatory fraeworks.