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Animal Husbandry Practices and Manure Management for Cost-effective Mitigation of Greenhouse Gas Emissions from Dairy Farms in India

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ABSTRACT: Livestock is the main driver for sustainable development in the Indian agriculture system. Livestock contributes both directly and indirectly to climate change through the emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Through the adaption of best mitigation practices, this livestock sector can reduce its environmental impacts and become more efficient in the use of resources. Hence, this study was planned in order to assess the greenhouse gases (GHGs) emission level in the organized dairy farm with the proposed interventions like improvement in animal reproductive performance, animal health, and manure management. The total GHGs emission in baseline production and the proposed interventions package were 735379 kgCO_2-eq/year and 525231 kgCO_2-eq/year respectively. With the proposed interventions package, a reduction of 40.59% in total CH_4 was observed from the baseline production system. Through the adoption of the manure management system, there was a reduction of 87.42% CH_4 emission and a reduction of 16.97% N_2O emission was observed. Further, there is a reduction of 29.84% in GHG emissions linked to milk production observed in comparison with baseline production. Based on the findings of this study, if there is an improvement in animal reproductive performance, animal health and manure management showed a 28.58% reduction in total GHG emission annually. Hence, if the proposed interventions were to be implemented in the organized dairy cattle farming system, the GHG emission could potentially be mitigated.

Keywords: Climate change mitigation; greenhouse gases; crossbred Jersey cattle; Indian dairy farming.

INTRODUCTION

Climate change is a major threat to the sustainability of livestock production systems around the world (Moss *et al*., 2000). The livestock production system has a key role in bringing food security in both developed and developing countries (Naqvi and Sejian 2011). The livestock sector plays a major role in the rural economy of India. Livestock contributes both directly (emissions from enteric fermentation and manure management) and indirectly (from feed-production activities) to climate change through the emissions of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (Sejian *et al*., 2015; Bhatta *et al*., 2015; Sejian *et al*., 2022). The future growth and sustainability of the Indian livestock sector majorly depend on the rigorous efforts towards intervention measures and mitigation strategies to control GHGs emissions from the livestock.

The CH_4 and CO_2 are natural by-products of microbial fermentation of carbohydrates in the rumen and the hindgut of ruminant animals. The livestock excreta (manure and urine) and its subsequent manure management practices contribute to the emission of CH_4 and N_2O into the atmosphere. Major GHGs emissions in livestock production systems currently arise from enteric fermentation (CH_4) and manure management and fertilizers (N_2O) used in the production of feed for ruminant animals (Hristov *et al*., 2013; Opio *et al*., 2013). The development of management strategies to mitigate GHGs emissions from ruminant livestock is possible and desirable (Bhatta *et al*., 2015; Sejian *et al*., 2022). Hence, high-quality research in animal production science is currently required to sustain livestock production systems in the changing climate scenario (Sejian *et al.*, 2012).

The livestock sector plays a role in Indian agricultural GHGs emissions scenarios, and the adaption of advanced animal husbandry practices is the best mitigation option for reducing the emission of GHGs from the livestock sector. Even though increasing the productivity of the livestock remains the best mitigation option for reducing the emission of GHGs (Capper *et al*., 2009; Bannink *et al*., 2011; Hristov *et al*., 2013), there is a practical limitation in Indian livestock production system. India has vast cattle genetic sources and animals maintained for various reasons. In addition to producing milk and meat, bullocks were used for ploughing, carting, and transport in agricultural operations. Further, cattle are used for sports activity in festival seasons, various socio-religious functions, as a companion animal, and as social security to the owners in terms of their status in society, and rearing of cattle is a part of the Indian culture. Hence, the adaption of advanced animal husbandry practices in cattle rearing systems is the best mitigation option.

Several methods are available forquantifying GHG emissions such as individual animal techniques using respiration chamber, sulphur hexafluoride (SF6) technique, *in vitro* gas production technique (IVGPT), and modelling techniques (Sejian *et al*., 2016; Silpa *et al*., 2021). The selection of the most appropriate method is based on several factors such as cost, time, level of accuracy, and experimental design (Bhatta *et al*., 2006). Dairy production is a complex system involving various inputs like feed and fodder production, farming system, manure management, and transport of animal produce. Hence, measuring GHGs emissions from every input involved in dairy production system would be expensive and time consuming (Sejian *et al*., 2016). Therefore, the modelling techniques are superior to other methods of estimating GHG emissions from large herds of cattle at the country, regional and organized farm levels is an attractive alternative approach (Mottet *et al*., 2017; Herrero *et al*., 2016; Kiggundu *et al*., 2019). There is limited information on GHGs emissions from organized dairy cattle farming systems in India. This GHGs emissions information is critical in designing intervention measures and strategies to mitigate the adverse impacts of climate change on livestock production in the Indian farming system. Therefore, the purpose of this study was to estimate the GHGs emissions from organized dairy cattle farm and quantify the potential benefits of a package of mitigation strategies.

MATERIALS AND METHODS

The present study was carried out at Dairy unit of Livestock Farm Complex, Veterinary College and Research Institute, Orathanadu, Tamil Nadu, India. Crossbred Jersey cows were purchased based on phenotypic characters and production records from milk shed areas in various districts of Tamil Nadu. The exact genetic composition (inheritance level of Jersey/non-descript) of these crossbred cows are unknown. This population constitutes of various inheritances level of Jersey and non-descript cross. All crossbred Jersey animals were kept under same environment with similar management practices. All animals were kept under semi-intensive system of management. The calves were weaned at 2- 3 months after birth. The adult animals fed with 25-30 kg green fodder and 5-7 kg of dry fodder daily. The portable water was given *ad lib*. The concentrate feed of 2 kg was provided for maintenance and additional feed was given at the rate of 400 g for every kg of milk production. Milking was carried out twice a day at 12 hrs interval. Periodical disease screening for Tuberculosis, Johne's disease and Brucellosis was carried out. Animals were vaccinated against Foot-and mouth disease and Hemorrhagic septicaemia. Animals were observed for estrus signs and artificial insemination was carried out after 12 hrs of onset of estrus signs.

Model description. The analysis of GHG emissions (CO_2, CH_4, and N_2O) was undertaken using the Global Livestock Environmental Assessment Model (GLEAM-i) version 2.0 (https://gleami.apps.fao.org/). GLEAM-i is a modelling tool developed by the Food Agricultural Organization (FAO) to enable the livestock sector to assess the GHG emission for the different farming systems. The model calculates total emissions, milk and meat production for a given dairy farming system within a defined area. The emissions per unit of product can also be calculated for combinations of different commodities/farming systems/locations at different spatial scales (FAO, 2017).

Estimation of GHG emissions and production. To estimate the GHG emissions, the data were categorized and analysed under the dairy systems in GLEAM-i version 2.0. Following this configuration, the observed data (Herd, Feed, and manure) for the year 2021 was entered into the baseline cells in GLEAM-i to obtain the baseline production and the corresponding GHG emissions. For Scenario GHG emissions, this study considered interventions for improvement in animal reproductive performance, animal health and manure management system. Considering their physical applicability, the scenario interventions in this study therefore were:

1. **Herd:** A reduction in age at first parturition from 39 months to 36 months and an increasing fertility rate from 75% to 85%.

2. **Herd:** The mortality rate was reduced from 5% to 1 % in adult animals and 10% to 5 % in both young males and female animals.

3. **Manure:** Reduction in liquid/slurry storage use by 75% and increased use of solid storage by 75% in organized dairy farming.

RESULTS AND DISCUSSION

The Global Livestock Environmental Assessment Model is a GIS framework that estimates the greenhouse gas emissions along livestock supply chains under a life cycle assessment approach. The observed data (Herd, Feed, and manure) for the year 2021 was entered into the baseline cells in GLEAM-i to obtain the baseline production and the corresponding GHG emissions. The total GHG emission in baseline production was 735379 kgCO_2-eq/year. Among the three GHGs (carbon dioxide, methane, and nitrous oxide), total methane represented 488560 kgCO_2-eq/year of the total emissions while total nitrous oxide and carbon dioxide estimates were 162151 kgCO_2-eq/year and 84668 kgCO_2-eq/year respectively (Fig. 1). In the baseline dairy production system, the CH_4 emissions from enteric fermentation, CO_2 emissions from feed production, N_2O from fertilizer and crop residues, N_2O from manure applied and deposited, CH4 from manure management, and N_2O from manure management were 60.64%, 14.37%, 8.82%, 6.58%, 4.55% and 3.49% respectively (Table 1). The main sources of GHG emission were CH_4 emission from enteric fermentation and this finding agrees with the findings of studies done by Borhan *et al*. (2012); Thoma *et al*. (2013); Kiggundu *et al*. (2019). The emission intensity per kg of milk and meat protein production was 110 kgCO_2-eq/kg protein and 87 kg CO_2-eq/kg protein respectively (Fig. 2). Kiggundu *et al*.

(2019) reported Uganda's cattle corridor farming systems emission intensity for milk and meat production were 74.9 kg CO_2-eq/kg protein, and 639 kg CO_2-eq/kg protein respectively. Further, Havlík *et al.* (2014) reported the milk and meat emission intensities with a range of 12–140 kg CO_2-eq/kg protein and 58–1000 kg CO_2-eq/kg protein respectively. Hence, the emission intensity of Indian crossbred cattle is agreeing with the findings of previous studies. However, the emission intensities of the European livestock sectors (22.6 kg CO_2-eq per kg for beef and only 1.3 kg CO_2-eq per kg for milk) or developed countries reported are far lower than the intensities in our study (Lesschen *et al.*, 2011). This dissimilarity in intensities could be explained by the major differences in the purpose of the cattle rearing system and the existing agricultural system. For the baseline year (2021), the estimated milk protein production was 6171 kg protein/year while the meat protein estimate was 620 kg protein/year.

With the proposed interventions package, the total GHG emission was 525231 $kgCO_2$-eq/year (Fig. 3). There is a reduction of total GHG emissions of 28.58% (or 210148 $kgCO_2$/year) from the baseline production system to the proposed interventions package that could have been realized (Table 1). Among the three GHGs, total methane represented 290257 $kgCO_2$-eq/year of the total emissions while total nitrous oxide and carbon dioxide estimates were 151971 $kgCO_2$-eq/year and 83003 $kgCO_2$-eq/year respectively (Fig. 3). The emission intensity in the proposed interventions package for per kg of milk and meat protein production were 77 $kgCO_2$-eq/kg protein and 59 $kgCO_2$-eq/kg protein respectively. In the proposed interventions package, the estimated milk protein production was 6171 kg protein/year while the meat protein estimate was 793 kg protein/year.

The mitigation options of reducing the animal's mortality rate and improving the reproductive performances that reduce GHG emissions by increasing herd productivity and enhancing animal health and longevity (Hristov *et al.*, 2013). These intervention practices improve the efficiency of the animal production system and reduce both CH_4 and N_2O emissions from enteric fermentation and animal manure (Stott *et al.*, 2010). The CH_4 and N_2O emission value is greatly increased when the productive potential is reduced due to poor health (Bell *et al.*, 2008). The total CH_4, N_2O and CO_2 emissions in baseline and proposed interventions package were 14,369.42 $kgCH_4$/year, 544.13 kgN_2O/year, 84,668.06 $kgCO_2$/year and 8,536.98 $kgCH_4$/year, 509.97 kgN_2O/year, 83,003.23 $kgCO_2$/year respectively. The emissions from milk production in the baseline and proposed interventions package were 681,401.38 $kgCO_2$/year and 478,102.45 $kgCO_2$/year respectively (Table 1). There is the reduction of 29.84% in GHG emissions linked to milk production was observed in our study.

Improved animal reproductive performance is expected to result in increased herd productivity, thereby diluting CH_4 and N_2O emissions per unit product. Poor fertility increases GHG emissions from livestock production systems. The poor fertility causes livestock producers to maintain a greater number of animals per unit of production and keep more replacement male/female animals to maintain herd size (Garnsworthy 2004; Bell *et al.*, 2008; Crosson *et al.*, 2011). Hence, this will increase the GHG emission level in that dairy farm. The total GHGs emissions from adult females in baseline and proposed interventions packages were 537,167.06 $kgCO_2$/year and 393,944.61 $kgCO_2$/year respectively with a reduction of 26.66%. The total GHGs emissions from replacement females in the baseline and proposed interventions packages were 183,927.54 $kgCO_2$/year and 120,375.34 $kgCO_2$/year respectively with a reduction of 34.55%. The factors such as nutritional status, micronutrient deficiencies, service period, the timing of artificial insemination, dry period, method of estrus detection, and method of pregnancy diagnosis are key factors that determine animal fertility (Mourits *et al.*, 2000). Hence, improvement in animal reproductive performance will lead to decreases in the GHG emission level.

Ina liquid/slurry system of manure management, where dung mixed water and the resulting slurry are removed daily from the animal shed into the pit. This method was easy when animals were maintained in semi loose housing system of organized dairy cattle farming. But, the major problem with this system is the emission of a higher level of CH_4 (6,471.53 $kgCH_4$/year). Hence, the proposed intervention to counter this problem is to increase the solid storage by75% and thereby decrease the CH_4 (814.20 $kgCH_4$/year) emission level upto 87.42% was observed in our study. In solid storage the fresh manure is collected into unconfined piles for several months resulting in microorganisms breaking down organic matter producing GHGs and aeration can potentially result in a reduction in CH_4 and an increase in N_2O (Petersen *et al.*, 2013; Webb *et al.*, 2012). Solid storage is a commonly practiced manure management system in Indian dairy cattle farming. Further, by the adoption of the manure management system, there was a reduction of 87.42% CH_4 emission and a reduction of 16.97% N_2O emission from manure management. With the proposed interventions package, a reduction of 40.59% in total CH_4 was observed from the baseline production system.

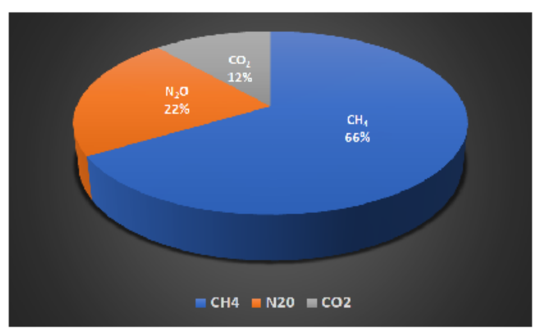

Fig. 1. The proportion of distribution of greenhouse gases (carbon dioxide, methane, and nitrous oxide) emissions from the baseline dairy production system.

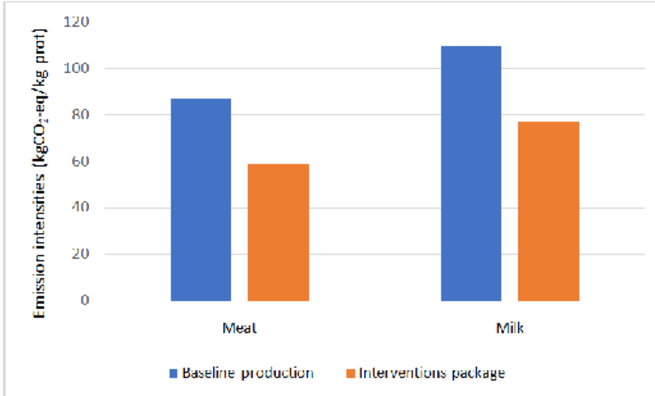

Fig. 2. The emission intensity per kg of milk and meat protein production in the baseline dairy production system and the proposed interventions package system.

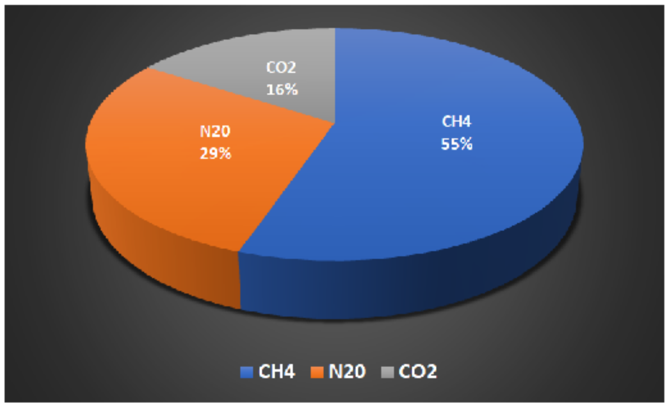

Fig. 3. The proportion of distribution of greenhouse gases (carbon dioxide, methane, and nitrous oxide) emissions from the proposed interventions package system.

Table 1: The greenhouse gas emission level in the baseline dairy production system and the proposed interventions package system.

Sr. No	Parameter	Baseline production	Interventions package	% Change in GHGs emission level	Unit
1.	CH_4: Manure - CH_4 from manure management	6,471.53	814.2	-87.42%	kgCH_4/year
2.	Total CH_4	14,369.42	8,536.98	-40.59%	kgCH_4/year
3.	Total GHG emissions (Replacement Females)	1,83,927.54	1,20,375.34	-34.55%	kgCO_2-eq/year
4.	Meat emission intensity	87.06	59.42	-31.74%	kgCO_2-eq/kgProt
5.	GHG emissions linked to milk production	6,81,401.38	4,78,102.45	-29.84%	kgCO_2/year
6.	Milk emission intensity	110.42	77.48	-29.84%	kgCO_2-eq/kgProt
7.	Total GHG emissions (Replacement Males)	3,436.74	2,414.90	-29.73%	kgCO_2-eq/year
8.	Total GHG emissions	7,35,379.45	5,25,231.40	-28.58%	kgCO_2-eq/year
9.	Total GHG emissions (Adult Females)	5,37,167.06	3,93,944.61	-26.66%	kgCO_2-eq/year
10.	N_2O from manure management	121.84	101.16	-16.97%	kgN_2O/year
11.	Total N_2O	544.13	509.97	-6.28%	kgN_2O/year
12.	Number of heads	157.69	150.51	-4.55%	
13.	Feed: N_2O from manure applied and deposited	311.68	300.65	-3.54%	kgN_2O/year
14.	Feed: CO_2 feed production	47,871.92	46,792.33	-2.26%	kgCO_2/year
15.	FEED: N_2O from fertilizer and crop residues	110.61	108.16	-2.22%	kgN_2O/year
16.	CH_4: enteric fermentation	7,897.89	7,722.78	-2.22%	kgCH_4/year
17.	Total feed intake	3,82,607.07	3,74,227.53	-2.19%	kgDM/year
18.	Total CO_2	84,668.06	83,003.23	-1.97%	kgCO_2/year

CONCLUSION

This study assessed the GHG emission level in the organized dairy farming system with the baseline data and with the proposed interventions like improvement in animal reproductive performance, animal health, and manure management in Indian conditions. The most important GHG emission source was enteric fermentation followed by CO_2 emissions from feed production. With the proposed interventions package, there is a reduction of 28.58% of total GHG emissions annually. Hence, the Indian dairy cattle farming system should address the intervention areas related to animal reproductive performance, animal health, and manure management in order to sustain the livestock production system in the changing climate scenario.

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Conflict of Interest. None.

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