Assessment of Methane Emissions from Dairy Cattle Production in Selected Case Studies in Thailand

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***Abstract*—Thailand's agriculture sector both cultivation and livestock has played a vital role in driving economic growth. Globally, livestock production is estimated to contribute about 18% of Greenhouse Gas (GHG) emissions. Despite its importance, there is a relative lack of research on GHGs assessment in livestock sector in Thailand. The aim of this research was to estimate GHGs emissions from dairy cattle production in selected farm cases in Saraburi and Ratchaburi provinces of Thailand. The 2019 Refinement to the 2006 IPCC guidelines for national greenhouse gas inventories was applied in this research. Methane (CH_4) emissions from the enteric fermentation and manure management from dairy cattle farms in Saraburi and Ratchaburi are in the range of 2.73 – kg 15.67 kg CO_2 eq. Methane emission from enteric fermentation was higher than those from manure management. Therefore, it is necessary for farm managers and related stakeholders to properly manage and focus on the feedstuffs and herd managements including genetic systems and farms to lower methane emissions.**

***Keywords*—enteric fermentation, greenhouse gases emission, manure management**

I. Introduction

The livestock sector plays a crucial role in the contribution of Greenhouse Gas (GHGs) emissions (i.e., carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Due to the rapid population growth around the world, food demand is also higher especially high nutrient products, such as milk and meat consumption that would be twice in 2050 by comparing to 2000 [1]. The food supply is increasing to reach one of the Sustainable Development Goals (SDGs) called zero hunger. The agricultural sector contributes to climate change by emitting GHGs from livestock production particularly in ruminant production; for example, CH_4 emission from enteric fermentation and manure management and N_2O emission from manure management [2]. According to the Environmental Protection Agency (EPA), the agricultural sector emitted about 10–12% of total global anthropogenic GHGs emissions [3]. In global emissions, 44% of CH_4 and 13% of CO_2 are produced by anthropogenic activities, respectively [4]. The emissions from agriculture sector by continent are shown in Fig. 1.

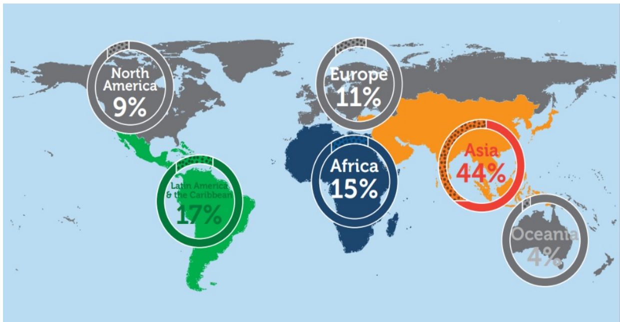

Figure 1. Emissions from agriculture by continent (FAOSTAT, 2016).

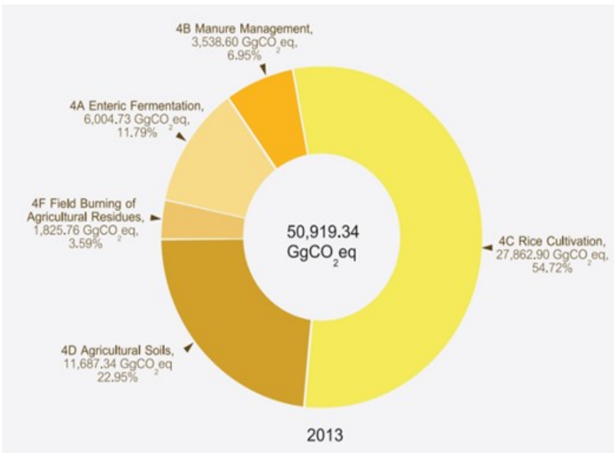

Figure 2. GHGs emissions in the agriculture sector (Ministry of Natural Resources and Environment, Thailand, 2013).

Despite the fact that Thailand acquired much support from many organizations around the world for climate

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change sector improvement, there are still many limitations and gaps in research on GHGs emissions from the agricultural sector [5]. Besides, Thailand has set their nationally determined contribution (NDC) to cut GHGs emissions by 20–25% from Business as Usual (BAU) level by 2030 [6]. As depicted in Fig. 2, enteric fermentation and manure management emitted about 11.79% and 6.95% of total GHGs emissions in the agricultural sector.

This research aimed (i) to estimate total GHGs emissions and identify hotspots of GHGs emissions from the dairy sector in Thailand and (ii) to investigate how manure waste management system affect GHGs emissions from the dairy sector in Thailand. CH_4 emission from enteric fermentation and manure management in each farm case was focused in this research.

II. Literature Review

Ruminant animals produce methane per unit of feed consumed [7]. Aside from the deleterious effects on global warming, CH_4 is also a dietary energy loss and ruminants can lose between 2 and 12% of ingested energy in the form of CH_4 [8]. The different kinds of feedstuffs have a significant effect on enteric emissions particularly CH_4, therefore, nutrition and feeding systems and ration ratios have the highest potential for reducing CH_4 emissions [9].

A. Enteric Fermentation

Enteric fermentation is one of the important sources of CH_4 from livestock production. CH_4 is naturally produced as a product of fermentation, where bacteria break down organic matter hydrogen (H_2), CO_2 and CH_4 in the rumen, of ingested feed by ruminants. As the fermentation is thermodynamically favorable to microbes, most of the methanogenic bacteria in the rumen use H_2 ions to reduce CO_2 to produce CH_4 [10]. CH_4 is emitted mainly through midgut (enteric fermentation) and hindgut fermentation by ruminant animals. Only enteric fermentation produces 89% of total CH_4 emission from the animal. The microorganisms ferment feedstuffs consumed by the animal through the process of enteric fermentation [11].

B. Manure Management

CH_4 and N_2O are the main emissions of improper manure management in farms [12]. In the process of manure storage and processing, manure consists of two chemical components that can be converted into CH_4 [13]. In addition, the temperature and the retention time of the storage unit greatly affect the amount of methane produced [4]. The amount of CH_4 emitted by dairy waste is dependent on the amount of carbon, hydrogen, and oxygen present in the waste, manure storage system, diet, and bedding major contributors to total CH_4 production [14]. (See Fig. 3)

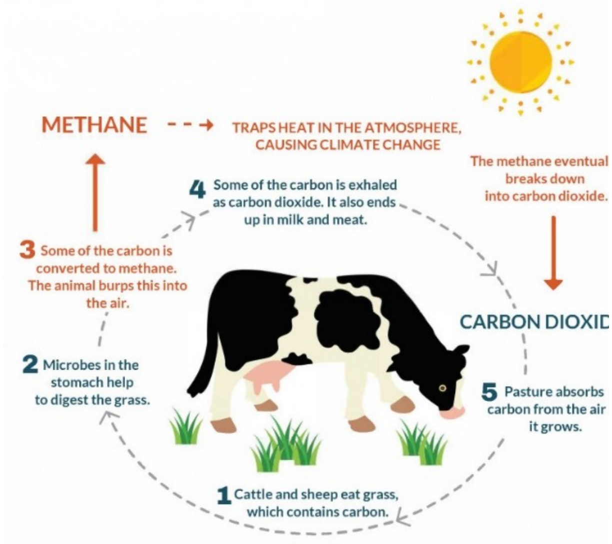


Figure 3. Greenhouse gas emissions from dairy cow (National Institute of Water and Atmospheric Research, New Zealand, 2021).

In Thailand, total GHG emissions from the agriculture sector in 2013 accounted for 50,919.34 $GgCO_2eq$. The emissions from enteric fermentation and manure management were 11.79% and 6.95%, respectively [5]. In global emissions, this accounts for 13% of CO_2, 44% of CH_4 through anthropogenic activities [4]. In late 19th century, the global mean surface temperature has increased to around 0.9°C mainly by CH_4, CO_2, and other anthropogenic emissions [15]. It was estimated that CH_4 emissions from enteric fermentation will gradually increase from 6.0 $MtCO_2eq$ in 2015 to 6.4 $MtCO_2eq$ in 2050 whereas CH_4 emission from manure management would increase from 1.9 $MtCO_2eq$ in 2015 to 3.4 $MtCO_2eq$ in 2050. At the same time, it was estimated that CH_4 emissions from enteric fermentation would be 10.1% while that of CH_4 and N_2O emissions from manure would be 5.3% and 6.6% correspondingly [16]. GHG emissions from the agriculture sector in Thailand in 2013 are presented in Table I.

TABLE I. National Greenhouse Gas Inventory of Thailand in 2013

Greenhouse gas source	CH_4(Gg)	N_2O(Gg)
Agriculture	1,730	47
A. Enteric Fermentation	286	
B. Manure Management	53	8
C. Rice cultivation	1,327	
D. Agricultural Soils	NA	38

III. Materials and Methods

A. Case Studies

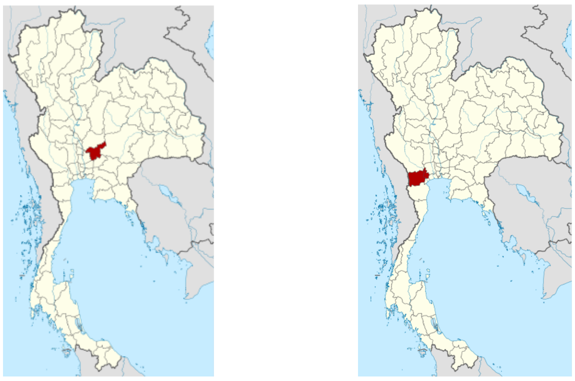
In 2020, Thailand's domestic dairy cows have the capacity to produce raw milk at approximately 3,500 tons per day from about 310,000 cows nationwide. The main provinces of raw milk production in Thailand are Nakhon Ratchasima, Saraburi, Lopburi, Chiang Mai, Ratchaburi and Prachuap Khiri Khan [17]. (See Table II)

TABLE II. LIST OF LIVESTOCK PRODUCTION IN MAIN PROVINCE AREAS IN THAILAND

No.	District	Number of dairy cows	Number of farmers
1.	Ratchaburi	47,143	2,300
2.	Saraburi	155,699	4,521
3.	Nakhon Ratchasima	154,126	4,994
4.	Lopburi	91,603	2,574
5.	Chiang Mai	54,645	1,170

Source: National Economic and Social Development Council, Thailand, 2021

According to the above-mentioned data, there is the highest population of dairy cattle in Saraburi (Fig. 4a), whereas there is the lowest population of dairy cattle in Ratchaburi (Fig. 4b). Therefore, these two provinces are selected as the case studies to evaluate the comparison of the GHGs emission between these two provinces.



(a) (b)

Figure 4. Research case studies in (a) Saraburi and (b)Ratchaburi Provinces, Thailand.

B. Materials and Methods

Estimation of GHGs emissions from the dairy sector. GHG emissions from dairy farms were estimated according to IPCC guidelines from Volume 4: Chapter 10 – Emissions from livestock and manure management. The following sources of emissions will be investigated (i) CH_4 enteric fermentation, (ii) CH_4 manure management.

Methane Emissions from Enteric Fermentation. Under this sector, Tier 2 was applied in accordance with the decision tree mentioned in IPCC, 2019. In Tier2 method, first of all, the population system needs to be defined.

The dairy cow population is generally defined as high-productivity and low-productivity system. High productivity system means that cows are fed by high quality pasture with supplement and the production aims 100% market milk commercial for both national market and or export while in low-productivity system, local roughage and Agricultural by-products are used as feedstuffs and the production aims for only local market [4].

Tier 2 emission requires the following data:

- Live weigh of animals (Kg) – Weight of a living animal before it is slaughtered for meat
- The average live body weight of animals in population (Kg)
- The average daily weight gain
- Feeding situation – Stall, Pasture, Grazing large areas, Crude protein content in diet
- Mature body weight of an adult animal
- Fat content in milk (% by weight)
- Average daily milk production (Kg/day)
- Protein content in milk (%)
- Percent of females that give birth in a year in each farm
- Dry Matter Intake % (DMI %)

Methane Emission from Manure Management: In Tire 2 method, the following data is required to estimate CH4 emissions from manure management:

(1) Manure Characteristics – amount of Volatile Solid (VS), the maximum amount of methane production from manure (B_0),

(2) Animal Waste Management System Characteristics - fraction of livestock category T's manure handled using animal waste management system S in climate region k, dimensionless

(3) Methane conversion factors – based on temperature

(4) Manure management system – Uncovered anaerobic lagoon, Liquid/slurry, Pit storage, Solid storage, Dry Lot, Daily spread, Anaerobic digestion-biogas, Burned for fuel.

C. How Enteric Fermentation Affects Methane Emissions

Improving animal productivity is widely used as a greenhouse gas mitigation strategy. There are situations when increased concentrate feeding reduces GHG emissions and increases farm profitability resulting in a win-win situation. However, many factors affect overall farm emissions, and careful assessments of individual systems are needed to confirm that increasing the proportion of dietary concentrate would result in a net reduction in GHGs emissions [18].

IV. RESULT AND DISCUSSION

Overall, methane emissions from the enteric fermentation and manure management from dairy cattle farms in Saraburi and Ratchaburi are in the range of 2.73 kg CO_2 eq and 15.67 kg CO_2 eq. The methane emission results are shown in Figs. 5 and 6. In this study, the results reveled that total CH_4 emission including from both enteric fermentation and manure management was 135.58 kg CO_2 eq. CH_4 emission from enteric fermentation (135.58 kg CO_2 eq) is much higher than those from manure management (0.001 kg CO_2 eq). While, enteric fermentation emits 99.9% of total CH_4 emission, manure management emits only 0.1% of total CH_4 emissions. Enteric fermentation contributes almost 90% of the total CH_4 emission from ruminants, and the rest comes from hindgut fermentation [19]. Regarding to the size of farm, the total CH_4 emissions from small farms were in range of 3.76 to 15.62 kg CO_2 eq, however, those from medium farms were 2.73–4.21 kg CO_2 eq. In Brazil, methane emission from enteric fermentation was 9.4 million $MTCO_2$eq in 1994 – 93 percent of agricultural emissions and 72 percent of the country's total emissions of methane [20].

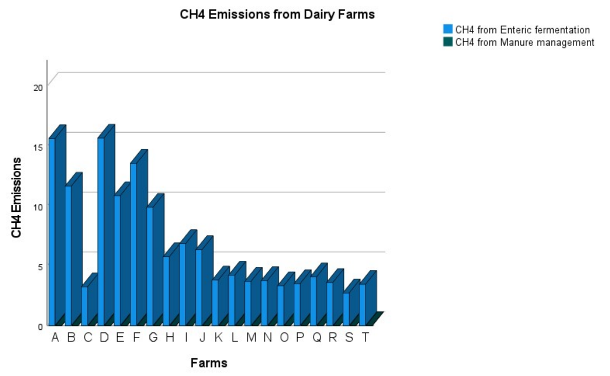


Figure 5. Methane CH_4 emission from dairy farms (kg CO_2eq).

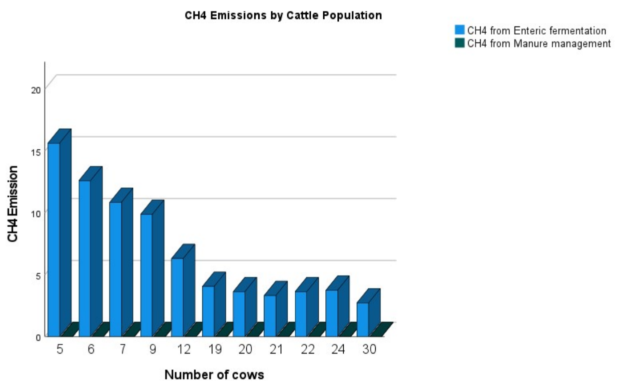


Figure 6. Methane CH_4 emission by farm's size (kg CO_2eq).

CH_4 emission from both enteric fermentation and manure management is assumed as the emission amount based on the feeding systems and the type of feedstuffs. Hence, it is highly recommended to use proper feeding techniques to match animal requirements with dietary nutrient supply, use locally produced feed more and low-emissions feeds such as by-products. Furthermore, emission from manure management is significantly low in this study. However, it is necessary to consider as parts of the mitigation measurements using biogas systems to reduce emissions if it is possible [21].

It was observed that small farms emitted more emissions than medium farms in this study. Smallholders in mixed crop livestock systems in Africa and Asia are characterized by livestock herds with many unproductive animals, small quantities of high-quality feed and large quantities of low-quality feed. (Methane, nitrous oxide emissions and mitigation strategies for livestock in developing countries [22]. It was established that providing feed with higher digestibility would increase productivity and reduce CH_4 and N_2O emissions. However, those options are in conflict with the interests of smallholders. According to the result, there is negative relationship between farms' size (small and medium farms) and GHGs emissions. Improvements in grass silage quality are realistic and have the potential to reduce emission intensities with approximately 10% while keeping the milk yield per cow constant [23]. The superior grass silage quality gave the highest productivity and the lowest CH_4 emission in both dairy and beef production. High-quality grass silages may represent a mitigation option by reducing enteric methane production and increasing productivity, thus reducing greenhouse gas emissions per kg of product (emission intensity) [23]. According to the result data from dairy farms, two thirds of the medium farms use fermented grass or fermented hay that can reduce the emissions. Hence, this is one of the considerations for emitting lesser in medium farms in this study.

A. Potential Mitigation Measures or Recommendations for GHGs (CH_4) Emissions Reduction

There are many factors affecting methane production in ruminant animals, such as the chemical composition of the carbohydrate, retention time of feed in the rumen, the rate of methanogenesis, manure management, using feed additives to enhance production efficiency [24]. Although there are various approaches to reduce CH_4 emissions from livestock, feed manipulation is the particular true way of strategy [25]. Currently, many techniques are widely being used for the measurement of CH_4 from ruminants globally. Moreover, researchers are focusing on feeding strategies as a vital area of research to develop and modify the technologies [26]. Providing alternative forages can reduce CH_4 emissions. By increasing voluntary intake, these alternative forage crops can reduce the ruminal residence time of feeds hence restricting ruminal fermentation and promoting post-ruminal digestion. Dairy operations should use the nutrients and organic matter from the manure to reduce fertilizer and energy costs, while at the same time using treatment systems without having negative effects on air quality, surface water bodies, or groundwater quality [27].

In addition, over the last few years, biogas generation from animal manure has received more attention [28]. Dairy cattle manure has to be considered as a resource and must be managed and used economically without adverse environmental impacts. The properly managed dairy cattle manure can be used to supply some or all of the nutrients to crops with economic profitability and no environmental harm. Once the dairy manure is widely used as a resource rather than a waste, it will be easier to meet government regulatory standards on air and water quality. Government regulations have been passed and are enforced in a number of states to protect surface water and groundwater quality from adverse impact by dairy cattle manure [29].

V. CONCLUSION

Since GHGs emission from livestock production includes as one of the most important parts in emission reduction, it is compulsory to evaluate the emissions from livestock's activities. In this research, CH_4 emission is higher in enteric fermentation than manure management. Both emissions are related to the feeding system, hence, it is necessary to explore more researches related to the feedstuffs that can reduce the emission and can support enough energy to the animals as well. Implementing the mitigation measurements, regular evaluation on GHGs emissions, installing biogas system can contribute to reaching a more sustainable dairy production system. In this research, dairy cattle farms from two provinces were selected as study areas for evaluating the CH_4 emission. However, due to the limited data such as not including feed composition, that was not accomplished in this research. Moreover, emissions are influenced by many factors such as improving genetics, feed consumed. Therefore, further studies may target all emissions by considering most of the factors that can reduce emissions from dairy cattle production in Thailand. Furthermore, Thailand's GHG emissions reduction target of 20 percent by 2030 requires further studies targeting all the emissions from dairy cattle production.

CONFLICT OF INTEREST

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

AUTHOR CONTRIBUTIONS

P.P.P.T. carried out the research, wrote manuscript with support from co-authors. N.A. contributed to data collection from several dairy cattle farms in Thailand. P.P.P.T. and S.K. analyzed the data and discussed the result. All authors approved the final version.

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