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Research article

An estimation of enteric methane emissions from cattle in Bangladesh

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ABSTRACT

In Bangladesh, cattle are increasing day by day as not only unemployed people but also employed people are doing farming now-a-days. It is a matter of great concern for Bangladesh that effects of greenhouse gases also increasing gradually because some of greenhouse gases e.g., methane, carbon dioxide, nitrous oxide are also component of expiratory gases of cattle respiration. This studyestimatedthe enteric methane emission from cattle in Bangladesh. Inter-governmental Panel on Climate Change (IPCC) guidelines were followed in the whole study. As IPCC guidelines, Tier-1 and Tier-2 methods for the calculation of total methane emission from cattle were used. In calculation, the study has recorded the emission of methane from cattle using Tier-1 method based on emission factors provided by both IPCC-2006 (T1) and IPCC-2019 (T1a). It also showed the emission value by using Tier-2 system based on dry matter intake. Finally, the study compared our different calculated values for different IPCC provided emission factors and for different methods. After calculation, in 2016, 2017, 2018, 2019 and 2020-2021 total emission of methane from cattle using T1 method based on the emission factors provide by IPCC-2006 were 932.43, 938.08, 942.48, 947.15 and 1177.18gigagram respectively and based on emission factors provided by IPCC-2019 (T1a) total emission were 1348.93, 1357.10, 1364.08, 1371.52 and 1577.04gigagram respectively. Using Tier-2 method, total emission of methane in those years were 970.95, 976.51, 981.20, 986.19 and 1203.74gigagram respectively. IPCC 2019 (T1a) based cattle methane emissions appear to overestimate than the T1 and Tier 2 calculations, suggesting that Tier 2 method which is variable enriched than T1 should be adapted to estimate national cattle methane emissions.

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1.INTRODUCTION

The effects of greenhouse gas emissions on global warming increase day by day. Among the four greenhouse gases (carbon dioxide, methane, nitrous oxide, F-gases), methane contributes 16% of total greenhouse gases produced (GGA 2014). Almost 27% of this methane comes fromenteric fermentation by ruminant livestock in the USA (USEPA, 2024).In cattle, methane is produced as a by-product of enteric fermentation of feed. During enteric fermentation, 2-12 % of dietary gross energy is lost as methane (Das et al., 2020; Beauchemin et al., 2009). The numbers of cattle have increased in the last four years (2016-2019) being 23.935 million, 24.086 million, 24.238 million and 24.391million (DLS 2021) in Bangladesh. Following this increasing cattle population, methane emissions also increases day by day but there is limited information about latest enteric methane emission data. So the objectives of this study were undertaken to calculate the total enteric methane emission from cattle in Bangladesh using Tier-1 and Tier-2 methods and compare them for suggesting suitable method of enteric methane estimation.

2.MATERIALS AND METHODS

Here, we use two Tier-1 (T1 and T1a) methods and a Tier-2 method tocalculateenteric methane emissions based on IPCC guidelines (IPCC-2006, IPCC-2019).

Tier-1 method

For this method, total cattle population subdivided is into two categories dairy and others(non-dairy) andfor each category the IPCC providesannual emission factorsfor the Indian subcontinent (Table 1). Then the number of cattle in each category was multiplied by the respective emission factor and divided by 10^6 providing the sum of total cattle methane emissions

Total emission= $\sum EF(T) * \frac{N(T)}{10\hat{}6}$Gigagram(Gg) CH_4 yr^{-1}

Where,

EF=Emission Factorof each category

N=Number of Cattle in each category

T=Category (Dairy/Others)

Table 1. Tier 1 Emission factors for the Indian Subcontinent in IPCC-2006.

Category (Dairy/Others)	Emission Factor (EF) (kg/cattle/year)
Dairy	58
Others	27

In the IPCC-2019 guidelines, the Tier-1 method was updated which is called the T1a methodand updated emission factors are presented in Table 2. For the T1a method, dairy and other cattle categories are furthersubdivided into high and low productivity categories with emission factor for each subcategory. Then total methane emissions were calculated as:

Enteric fermentation emission from a livestock category

$E(T) = \sum(P)\ EF(T,P) * (\frac{N(T,P)}{10^6})$

Where,

E(T)= Methane emission from enteric fermentation within animal category T, Gg CH_4 yr^{-1}

EF(T,P)= Emission factor for the defined livestock category'T' and productivity class'P', Kg CH_4/head/year

N(T,P)= The number of livestock within category 'T' and productivity class 'P'

Table2. T1a Emission factors for the Indian subcontinentin IPCC-2019.

Animal category	Emission factor for Tier-1 (kg/cattle/year)	Definition
Dairy cattle (Average production)	73	Average milk production of 1900kg/head/year
Dairy cattle (High productive)	70	Average milk production of 2600kg/head/year
Dairy cattle (Low productive)	74	Average milk productionof 1700 kg/head/year
Other cattle (Average)	46	Includes mature females, mature males, growing animal and calves.
Other cattle (High productive)	41	
Other cattle (Low productive)	47	

Total emission from livestock enteric fermentation

Total CH_4 enteric = ∑ E ip

Where,

Ei,p = is the emission for the i^{th} livestock category and subcategories based on production system (P)

Tier-2 method

Lastly, total methane emissions were calculated using the Tier-2 method of IPCC-2019. There are three steps to calculate methane emissions with the Tier-2 method.

Step-1: Data of cattle population numbers within subcategories are collected e.g. Dairy cattle(High, medium and low productivity), other cattle(High, medium and low productivity).

Step-2: Calculation of emission factor.
Emission factor (kg/head/year) canbe calculated based on 'gross energy intake' or 'dry matter intake'.
Two sub steps need to follow for development of Tier 2 emission factors.

Methane conversion factor(Ym)

The extent to which feed energy is converted to CH_4(Ym; % of gross energy intake; GEI)depends on several interacting feed and animal factors.This can also be calculated on a 'Dry matter Intake (DMI)' basis expressed as 'Methane Yield(MY; g CH_4/kg DMI)'. IPCC provided both Ym and MY fordifferentcattle categories, production level categories and diet categories (Table 3 and 4). Gross energy intake and DMI can be predicted or be based on local measurement data by cattle category.

Table 3. Methane conversion factors (Ym and MY) for dairy cattle provided by T2 (IPCC-2019).

Description	**Feed quality,Digestible energy (DE % of GEI) and Neutral Detergent Fiber (NDF, % DMI)**	**MY, (g CH_4/kg DMI)**	**Ym** (% of GEI)
High milk-producing cows(>8500 kg/head/yr-1)	DE ≥ 70 NDF ≤ 35	19	5.70
High milk-producing cows (>8500 kg/head/yr-1)	DE ≥ 70 NDF ≥ 35	20	6
Medium milk producing cows (5000 – 8500 kg yr-1)	DE 63-70 NDF > 37	21	6.30
Low milk producing cows (<5000 kg yr-1)	DE ≤ 62 NDF >38	21.40	6.50

Table 4. Methane conversion factors (Ym and MY) for other cattle provided by T2 (IPCC-2019).

Description	**Feed quality, Digestible energy (DE % of GIE) and Neutral Detergent Fiber (NDF, % DMI)**	**MY, (g CH_4/kg DMI)**	**Ym^3 (% of GEI)**
> 75 % forage	DE ≤ 62	23.30	7
Rations of >75% high quality forage and/or mixed rations, forage of between 15 and 75% the total ration mixed with grain, and/or silage.	DE 62–71	21	6.30
Feedlot (all other grains, 0-15% forage)	DE ≥ 72	13.60	4
Feedlot (steam-flaked corn, ionophore supplement - 0-10% forage)	DE > 75	10	3

Emission factor calculation

Based on gross energy intake, the emission factor was calculated as:

Methane emission factors for enteric fermentationfrom a livestock category

$$EF = \frac{GE.\left(\frac{Ym}{100}\right).365}{55.65}$$

Where,

EF = Emission factor, kg CH_4 $head^{-1}$ yr^{-1}

GE= Gross energy intake, MJ $head^{-1}$ day^{-1}

Ym= Methane conversion factor, per cent of gross energy in feed converted to methane

55.65=The factor 55.65 (MJ/kg CH_4) is the energy content of methane

Based on dry matter intake, the emission factor will be calculated as:

Methane emission factors for enteric fermentation from a livestock category

$$EF = DMI.\left(\frac{MY}{1000}\right).365$$

Here,

EF= Emission factor, kg CH_4 head-1 yr^{-1}

DMI = kg DMI day^{-1}

MY= Methane yield, g CH_4 kg DMI^{-1}

365 = Days per year

1000 = Conversion from g CH_4 to kg CH_4

Step-3: Total emissions estimation.

To calculatetotal cattle population methane emissions, the emission factors are multiplied withthe animal population number as described above for Tier-1.

Emissions of methaneby cattle in Bangladesh based on Tier-1 method

Three steps are taken for the calculation of the Tier-1 emissions:

- **Step-1:** Categorize the cattle population and collated number of animals in each category (Table 5). The data were collected from Das et al. (2020), where the dairy cattle and other cattle population was calculated by following the ratio reported by Huque(2014)and extrapolated according to their annual growth rate(AGR%)which was calculated by considering their population growth between 2005 and 2013(15 years). The cattle population by category was collated for 2016 to 2019.

Table 5. Total cattle, dairy and other cattle population in Bangladesh between 2016 and 2019.

Years	Total cattle (10^6)	Dairy cattle(10^6)	Other cattle(10^6)
2016	23.86	9.31	14.55
2017	24.01	9.34	14.68
2018	24.16	9.36	14.80
2019	24.31	9.38	14.93
2020-2021	24.54	16.60	7.94

Source: DLS (2021); Huque et al. (2014); Das et al. (2020)

- **Step-2**Select the relevant emission factors from the IPCC guidelines of 2006 and 2019.
- **Step-3** Estimation of total methane emissions by multiplying cattle population with emission factors.

Emissions of methane by cattle in Bangladesh based on Tier-2 method

Table 6. Methane yield (MY) for dairy and non-dairy cattle according to T2 (IPCC-2019).

Livestock Category	Description	MY (gCH4 kg DMI^{-1})
Dairy cattle	Milk production <5000 kg per year	21.40
Non-dairy cattle	Rations of >75% high quality forage and/or mixed rations, forage of between 15 and 75% the total ration mixed with grain, and/or silage.	21

Emission factor calculation: The emission factor was developedbased on DMI. For ration formulation in Bangladesh, feed dry matter is supplied at 3 % of body weight for dairy cattleand 2-2.5 % of body weight for non-dairy cattle (Hossain et al., 2020). The body weight of different cattle subcategories was collected from Hoqueet al. (2014) which is shown in Table7.

From this, average body weight(Table7),DMI was calculatedfor dairy and non-dairy cattle. Then, DMI of the cattle category is multiplied with the methane conversion factor (g/kg DMI) (Table 6) and then multiplied with the number of cattle in the category.

Table 7. Body weight of different cattle subcategories in Bangladesh (Hoque et al. 2017)

Indigenous cattle (type/age)	Average body weight(kg) for indigenous cattle	Average body weight(kg) for crossbred cattle
Bull calves(1-2 years)	132.45	151.62
Breeding bull	259.87	270.41
Bullocks	261.23	273.87
Heifer calves(1-2 years)	131.87	162.60
Milking cows	203.45	296.70
Dry cows	201.34	293.80

3. RESULTS AND DISCUSSION

For Tier-1 method

The data presented compares emissions from dairy cattle and other cattle based on emission factors provided by the Intergovernmental Panel on Climate Change (IPCC) in T1 andT1a for the years 2016 to 2021. Across all years, emissions from both dairy cattle and other cattle show an increase when calculated using the updated IPCC-2019 (T1a) emission factors compared to the IPCC-2006 (T1) factors. Specifically, emissions from dairy cattle demonstrate a notable rise from 539.58 Gigagrams per year in 2016 on IPCC 2006 basis to 1211.8Gigagrams per year in 2020-21 on IPCC 2019 basis. Conversely, emissions from other cattle show an increase from 392.85 Gigagrams per year in 2016 to 365.24Gigagrams per year in 2020-21 based on the updated emission factors. Consequently, the total emissions also exhibit a significant upward trend over the six-year period, rising from 932.43 Gigagrams per year in 2016 to 1577.04Gigagrams per year in 2019 under the updated emission factors. According to DLS provided data on cattle population for the fiscal year 2020-2021, methane emission was highest 1577.04 Gigagram (Gg) on the basis of IPCC 2019 emission factor.

In the Tier-1 method, emission of methaneof this study was around 150 Gigagram greater every year for dairy cattle when calculating T1 (IPCC-2006)vs.T1a (IPCC-2019). This was due to the greater emission factor on T1a (IPCC-2019).

The emission of methane every year was 250 Gigagram greater for other cattle category when calculating using the Tier 1 methods of IPCC-2006 vs. IPCC-2019. Based on the IPCC-2006 Tier 1 method, total methane emission in 2017 was 938.08 Gigagramand the average methane per animal was 39.31 kg/year, which is similar to that estimated by Das et al. (2017) being 41.13 kg/year for cattle in Bangladesh. On the other hand, the Tier 2 calculations based on IPCC-2019 result in much greater values ofper average cattle in Bangladesh.

Table 8. Comparison between emission (Gigagram per year) based on emission factors provided by IPCC in 2006 and 2019.

Years	Emission from dairy cattle based on IPCC-2006	Emission from dairy cattle based on IPCC-2019	Emission from other cattle based on IPCC-2006	Emission from other cattle based on IPCC-2019	Total emission based on IPCC-2006	Total emission based on IPCC-2019
2016	539.58	679.63	392.85	669.30	932.43	1348.93
2017	541.72	681.82	396.36	675.28	938.08	1357.10
2018	542.88	683.28	399.60	680.80	942.48	1364.08
2019	544.04	684.74	403.11	686.78	947.15	1371.52
2020-2021	962.80	1211.8	214.38	365.24	1177.18	1577.04

For Tier-2 method

The methane emissions (in Gigagrams per year) originating from both dairy and non-dairy cattle over the course of five years, from 2016 to 2021. The data illustrates a consistent pattern of emissions from both categories of cattle across the given timeframe.Dairy cattle contribute a substantial portion of methane emissions, with figures ranging from 544.63 Gigagrams in 2016 to 971.10Gigagrams in 2020-21. Conversely, emissions from non-dairy cattle display a slightly lower but still significant trend, fluctuating from 426.31 Gigagrams in 2016 to 232.64Gigagrams in 2020-21. Furthermore, the total emissions, which represent the cumulative methane release from both dairy and non-dairy cattle, show a gradual increase over the specified period, rising from 970.95 Gigagrams in 2016 to 1203.74Gigagrams in 2020-21. This upward trajectory underscores the importance of addressing methane emissions in the agricultural sector to mitigate their impact on climate change.

Table 9. Average body weight, dry matter intake, methane yield and emission factor for dairy and non-dairy cattle.

Category	Average BW[1] (kg)	DMI[2] (% of BW)	MY[3] (gCH_4 kg DMI^{-1})	Emission Factor[4] (kg per cattle per year)
Dairy	250.07	3	21.40	58.58 (58.50)
Non-Dairy	171.87	2.25	21	29.31 (29.30)

[1]Hoque et al. (2017); [2]Hossain et al. (2020); [3,4] IPCC-2019

Table 10. Emission of methane in Gigagram per year from dairy and non-dairy cattle

Years	Number of dairy cattle (10^6)	Number of non-dairy Cattle (10^6)	Emission from dairy cattle	Emission from non-dairy cattle)	Total emissions
2016	9.31	14.55	544.63	426.31	970.95
2017	9.34	14.68	546.39	430.12	976.51
2018	9.36	14.80	547.56	433.64	981.20
2019	9.38	14.93	548.73	437.44	986.19
2020-2021	16.60	7.94	971.10	232.64	1203.74

Table 11. Comparison between emission factor (kg per cattle per year)

Category	Tier 2 calculation	T1 (IPCC-2006) provided value	T1a (IPCC 2019) provided value
Dairy	58.50	58	74 (low productive)
Non-dairy	29.30	27	47 (low productive)

Comparative analysis of methane emissions (in Gigagrams per year) from dairy and non-dairy cattle utilizing Tier-1 and Tier-2 methodologies as outlined by the IPCC-2006 guidelines. This juxtaposition allows for an evaluation of the differences in emission estimates derived from these two approaches over the span of six years from 2016 to 2021.

Across the board, emissions from both dairy and non-dairy cattle appear to be slightly higher when calculated using the Tier-2 method compared to the Tier-1 method. Specifically, methane emissions from dairy cattle range from 539.58 to 962.80Gigagrams per year under Tier-1, while Tier-2 estimates range from 544.63 to 971.10gigagrams per year over the same period. Similarly, emissions from non-dairy cattle follow a similar pattern up to 2019 but decreases in 2020-2021 for low non-dairy cattle population, with Tier-1 estimates ranging from 392.85 to 214.38 gigagrams per year and Tier-2 estimates ranging from 426.31 to 232.64gigagrams per year.When considering the total emissions from both dairy and non-dairy cattle combined, the differences between the Tier-1 and Tier-2 methodologies become more pronounced. Total emissions calculated using the Tier-1 method range from 932.43 to 1177.18 gigagrams per year, while those calculated using the Tier-2 method range from 970.95 to 1203.74 Gigagrams per year.

Using the Tier 2 method, the calculated emission factors for dairy and non-dairy cattle were 58.50 and 29.30 kg/cattle/year, respectively, which was also much less than the IPCC 2019 Tier 1 emission factors, suggesting that those values might be suitable for use with cattle in Bangladesh.Jahan and Azad (2013) were shown a gradual increase of emission methane from 1983 to 2009. In this study,it was also seen the gradual increase in the emission of methane from 2016 to 2021 by using every method of calculation.

Table 12. Comparison of methane emission (Gigagram per year) betweenTier-1 system based on IPCC-2006 and Tier-2 system.

Years	Emission from dairy cattle based on Tier-1 method	Emission from dairy cattle based on Tier-2 method	Emission from non-dairy cattle based on Tier-1 method	Emission from non-dairy cattle based on Tier-2 method	Total emission based on Tier-1 method	Total emission based on Tier-2 method
2016	539.58	544.63	392.85	426.31	932.43	970.95
2017	541.72	546.39	396.36	430.12	938.08	976.51
2018	542.88	547.56	399.60	433.64	942.48	981.20
2019	544.04	548.73	403.11	437.44	947.15	986.19
2020-21	962.80	971.10	214.38	232.64	1177.18	1203.74

4. CONCLUSION

In Bangladesh, emission of methane from cattle is gradually increasing following the gradual increase of the cattle population. The IPCC 2019, T1a emission factors recommended for use to estimate cattle methane emissions appear to overestimate methane emissions for cattle in Bangladesh based on T1 and Tier 2 calculations, suggesting that Tier 2 method which is more variable enriched than T1 should be adopted to enable more accurate estimation of national cattle methane emissions. Data on updated animal population, body weight and dry matter intake (DMI) is very limited. Trapping of the exhale gas of cattle and convert it into burning fuel can be the solution of this problem.

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