Abstract

In Bangladesh, population of 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. In our study, we have discussed about methane emission from cattle in Bangladesh. We followed Intergovernmental Panel on Climate Change (IPCC) guidelines in our whole study. As IPCC guidelines, we use Tier-1 and Tier-2 methods for the calculation of total methane emission from cattle. In calculation, we showed the emission of methane from cattle using Tier-1 method based on emission factors provided by both IPCC-2006 and IPCC-2019. We also showed the emission value by using Tier-2 system based on dry matter intake. Finally, we have compared our different calculated values obtained by using Tier-1 method for different IPCC provided emission factors and have also shown the comparison of the calculated values obtained from Tier-1 and Tier-2 methods. After calculation, in 2016, 2017, 2018 and 2019 total emission of methane from cattle using Tier-1 method based on the emission factors provide by IPCC-2006 are 932.43, 938.08, 942.48 and 947.15 gigagram respectively and based on emission factors provided by IPCC-2019 total emission are 1348.93, 1357.10, 1364.08 and 1371.52 gigagram respectively. Using Tier-2 method, total emission of methane in those years are 970.95, 976.51, 981.20 and 986.19 gigagram respectively.

Chapter-I

Introduction

Effects of greenhouse gases are increasing day by day. Among the four greenhouse gases (carbon di-oxide, methane, nitrous oxide, F-gases) methane occupied 16% of total amount greenhouse gas[1]. Almost 27% of this methane comes from enteric fermentation[2].

Cattle are one of the herbivores. In cattle, methane is produced as a by-product of enteric fermentation. In enteric fermentation, (2-12) % of dietary gross energy loss as gas production particularly methane[5,6].

In Bangladesh, number of cattle are increasing day by day. Watching last four years, the uprising numbers of cattle are 239.35 lakh, 240.86 lakh, 242.38 lakh and 243.91 lakh[7]. Following this increasing cattle population, emission of methane is also increasing day by day.

Agriculture, fossil fuel, koal, livestock, livestock manure all are various source of CH_4 emission. In our study, we will show different methods of methane estimation from cattle and will show the calculation of total methane emission from cattle on Bangladesh perspective.

Objectives: Here, we will calculate total methane emission from cattle by enteric fermentation using Tier-1 method based on emission factors provided by IPCC at 2006 and 2019 and also calculate using Tier-2 method based on 'Dry Matter Intake'. Then we will compare our calculations between the values obtained from using Tier-1 method considering both IPCC-2006 and IPCC-2019 and between the values obtained from Tier-1 and Tier-2 system.

Chapter-II

Review of literature

As IPCC has provided three different methods for estimation of methane emission from livestock by enteric fermentation, different times any of those three methods was used to calculate amount of methane emission from livestock. Among them Tier-1 method is most popular.

For, Tier-1 method, emission factor for different livestock categories and subcategories are provided by IPCC-2006 and IPCC-2019. Calculation is very simple as to obtain total emission from a category or subcategory, we need to multiply emission factor with the total population for a specific category or subcategory.

For, Tier-2 system, emission factor for different livestock categories and subcategories need to be developed. Development of emission factor should be done either on dry matter intake basis or gross energy basis. Then final calculation is same as Tier-1 method.

For, Tier-3 method, it is country specific. In different countries like Japan, France this method is used for calculating emission more accurately.

According to Hoque SM *et al.*, 2017[9], total methane emission from enteric fermentation of ruminant livestock are estimated. Here, Tier-2 method was used. Emission factor is calculated based on dry matter intake of ruminants. In our report, body weight of different cattle categories are collected from here.

In another study, emission of all greenhouse gases (CH_4, N_2O and CO_2) from livestock sector of Bangladesh are calculated (Jahan S *et al.*, 2013)[11]. Here, for estimation of methane, Tier-1 method is used and emission factors are collected from IPCC-1996. A gradual increase of emission of greenhouse gases are shown here.

In 2020, another study of estimation of greenhouse gases was done (Das NG *et al.*, 2020)[5]. Here, Tier-1 method is used for estimation of methane from livestock enteric fermentation. Here, after calculation, amount of methane is converted to CO2 equivalent.

Greenhouse gases estimation on dairy farming level also done in 2017 (Das AK *et al.*, 2017)[10]. Here, Tier-1 method is used. Emission of methane per head per year was also shown here.

According to Eugene M *et al.*, 2019[12], Tier-3 method was used in France to estimate total emission of methane from livestock. The method was developed at the national institute for agricultural research (INRA) in France.

Chapter-III

Materials and Methods

Based on IPCC guidelines, there are three methods (Tier-1, Tier-2 and Tier-3) for estimation of methane produced by enteric fermentation[7,8]. Here we will describe all three methods and will show our calculation based on Tier-1 and Tier-2 method.

3.1 Tier-1 Method:

Most simplified method. Here total cattle population will be subdivided into two categories (dairy and others). For each category there is IPCC provided emission factors[7,8]. Then every category will be multiplied by respective emission factor and divided by 10^6. The sum total of total methane emission from each category will so us total methane emission from cattle[7,8].

$$\text{Total Emission} = \sum EF(T).\frac{N(T)}{10\text{^}6} \text{ Gigagram } CH_4 \text{ } yr^{-1}$$

Here,

EF=Emission Factor

N=Number of Cattle

T=Category (Dairy/Others)

For Indian Subcontinent, IPCC-2006 provided emission factor for different cattle category (Table-1)

Table-1: Emission Factor Provided by IPCC-2006[7]

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

Based on IPCC-2019, there is an updated form of Tier-1 method which is called as Tier-1a method[8]. In case of T-1a system, dairy and other cattle are again subdivided into High and low productivity. IPCC-2019 also provided emission factor for each subcategory. Then the calculation rule is similar as Tier-1a method.

Enteric Fermentation Emission from a Livestock Category

$$E(T) = \sum(P) \text{ } EF(T,P) \cdot \left(\frac{N(T,P)}{10^6}\right)$$

Here,

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

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

N(T,P)= The number of livestock species/category 'T' in the country classified as productivity system P

T= Species/Category of livestock

P= Productivity system, either high or low productivity for use in advanced Tier-1a omitted if using Tier-1 approach

Total Emission from Livestock Enteric Fermentation

$$\text{Total } CH_4 \text{ enteric} = \sum E_{ip}$$

Here,

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

For Indian Subcontinent, IPCC-2019 provide emission factor for high and low productive cattle (Table-2)

Table-2: Emission Factor Provided by IPCC-2019[8]

Animal Category	**Emission Factor for Tier-1 and Tier-2 (kg/cattle/year)**	**Definition**
Dairy Cattle (Average Production)	73	Average milk production of 1900 kg/head/year
Dairy Cattle (High Productive)	70	Average milk production Of 2600 kg/head/year
Dairy Cattle (Low Productive)	74	Average milk production of 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	

3.2 Tier-2 Method

Final calculation of Tier-2 system is same as Tier-1 system. But in case of Tier-2 system we need to calculate specific emission factor for each category of cattle while in Tier-1 and Tier-1a system emission factor is provided by IPCC. There are three steps of Tier-2 method[7,8].

Step-1: Specific cattle population with subcategories should be collected e.g., Dairy cattle(High, medium and low productivity), Others cattle (High, medium and low productivity).

Step-2: Calculation of emission factor.

Emission factor should be calculated based on 'Gross Energy' or 'Dry Matter Intake'. Two sub steps need to follow for development of emission factor.

Development of Methane Conversion Factor (Ym)[7,8]:

The extent to which feed energy is converted to CH_4 depends on several interacting feed and animal factors and that rate of conversion is embodied in the methane conversion factor (Ym), defined as the percentage of gross energy intake converted to methane. If we calculate based on 'Dry matter Intake' another parameter 'Methane Yield (MY)' come. IPCC provided both Ym and MY for specific cattle category.

Table-3: Ym and MY for Dairy Cattle[7,8]

Description	**Feed quality Digestibility (DE %) and Neutral Detergent Fiber (NDF, % DMI**	**MY (g CH_4 kg DMI^{-1})**	**Ym[3]**
High-producing cows (>8500 kg/head/yr-1)	DE ≥ 70 NDF ≤ 35	19	5.7
High-producing cows (>8500 kg/head/yr-1)	DE ≥ 70 NDF ≥ 35	20	6.0
Medium producing cows (5000 – 8500 kg yr-1)	DE 63-70 NDF > 37	21	6.3
Low producing cows (<5000 kg yr-1)	DE ≤ 62 NDF >38	21.40	6.5

Table-4: **Ym and MY for Other Cattle**[7,8]

Description	**Feed quality Digestibility (DE %) and Neutral Detergent Fiber (NDF, % DMI)**	**MY (g CH_4 kg DMI^{-1})**	**Ym[3]**
> 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 Development:

Based on gross energy intake equation of emission factor will be:

METHANE EMISSION FACTORS FOR ENTERIC FERMENTATION FROM A LIVESTOCK CATEGORY

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

Here,

EF= emission factor, kg CH_4 per head per yearr EF
GE= gross energy intake, MJ per head per day GE
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 equation of emission factor will be:

METHANE EMISSION FACTORS FOR ENTERIC FERMENTATION FROM A LIVESTOCK CATEGORY

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

Here,

EF = emission factor, kg CH_4 $head^{-1}$ yr^{-1}
DMI = kg DMI per day
MY = Methane yield, kg CH_4 kg DMI^{-1}
365 = days per year
1000 = conversion from g CH_4 to kg CH_4

Step-3: Total emissions

To estimate total emissions, the selected emission factors are multiplied by the associated animal population and summed. As described above under Tier-1, the emissions estimates should be reported in gigagrams (Gg).

3.3 Tier-3 Method

Increased accuracy and identification of causes of variation in emissions are at the heart of inventory purpose. Improvements in country methodology, whether as components of current Tier 1 or 2 or if additional refinements are implemented with Tier 3, are encouraged.

Japanese T-3 Method

$$Y= -17.766 + (42.793*DMI) - (0.849*DMI)$$

$$MEF= (Y/22.4) * 0.016 * 365$$

Here,

Y=Daily Enteric Methane Emission per Head of Cattle (Gigagram CH_4/year)
MEF=Methane Emission Factor (kg CH_4/head/year)

Emission of Methane
Based on Tier-1 system

Three steps for completing our calculation of Tier-1 system:

- **Step-1:** Categorization and estimation of cattle population. Categories are shown in Table-5. Number of cattle of different categories are also shown in table-5. Here, both data are collected from Das NG *et al*., 2020[5], where the dairy cattle and other cattle population was calculated by following the ratio reported by Huque KS, 2014[4] and extrapolated according to their annual growth rate (AGR%)[4] which was calculated by considering cattle population growth from 2005 to 2013 (15 years). We will show total methane emission from cattle from 2016 to 2019.

Table-5: **Total cattle, dairy and other cattle population**[4,5]

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

We will also calculate total methane emission from cattle in 2020-2021 by considering the numbers of dairy cattle provided by Department of Livestock Service (DLS). Based on DLS total cattle population in 2020-2021 is 24.54 million where 16.6 million is dairy cattle.

- **Step-2:** Emission factor collection from IPCC guidelines. There is a huge change of emission factor between 2006 and 2019. Here, we will show our calculation by considering both emission factors provided by IPCC in 2006 and 2019.IPCC-2019 provide emission factors for both average categories and subcategories, in our calculation we will calculate by considering the average emission factor. Then we will compare our calculation obtained from considering both emission factors.

- **Step-3:** Estimation of total methane emission by multiplying cattle population with emission factors.

Emission of Methane
Based on Tier-2 System

- **Step-1 (Methane yield development):** Here methane yield is provided by IPCC for different cattle categories and subcategories. For our Bangladesh perspective methane yield will be:

Table-6: MY for Dairy and Non-Dairy Cattle[7,8]

Livestock Category	Description	MY ($g\ CH_4\ kg\ DMI^{-1}$)
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

- **Step-2 (Emission factor Development):** Here we will calculate our emission factor based on dry matter intake. In our normal ration formulation, we supply the dry matter as 3 % of body weight for dairy cattle and (2-2.5) % of live body weight. We have collected body weight of different cattle subcategories from literature by Haque SM *et al.,* 2014[9], which is shown in Table-7. From this, we have calculated average body weight for dairy and non-

dairy cattle (Table-12). From our calculated weight, we have calculated total dry matter intake and emission factor which are shown in Table-12.

Table-7: Body weight of Different Cattle Subcategories[9]

Indigenous cattle (Type/Age)	**Average Live Body Weight(kg) for Indigenous Cattle**	**Average Live Body Weight(kg) for Crossbreed Cattle**
Male Calves (<1 year)	61.22	70.54
Bull Calves (1-2 years)	132.45	151.62
Breeding Bull	259.87	270.41
Bullocks	261.23	273.87
Female Calves (<1year)	60.23	74.90
Heifer Calves (1-2 years)	131.87	162.60
Milking Cows	203.45	296.70
Dry Cows	201.34	293.80

Here, milking cows of both categories will be classified as dairy cow and other subcategories will be classified as non-dairy cattle.

- **Step-3 (Total Emission Calculation):** Total emission will be calculated by multiplying the number of cattle with emission factor.

Chapter-IV
Results

4.1 For Tier-1 Method:

Here our calculated values are showing in table form. In Table-8 we have shown methane emission in Gigagram per year based on emission factor provided by IPCC-2006. In Table-9 we have shown methane emission in Gigagram per year based on emission factor provided by IPCC-2019.In Table-10, there is Comparison between Emission Gigagram per Year) based on emission factors provided by IPCC at 2006 and 2019 and in Table-11 we have shown total methane emission (Gigagram per year) in 2020-2021 from cattle based on cattle number provided by DLS with considering emission factor provided by IPCC-2019.

Table-8: Methane emission (Gigagram per year) based on emission factor provided by IPCC-2006

Years	Emission from Dairy Cattle	Emission from Other Cattle	Total Emission
2016	539.58	392.85	932.43
2017	541.72	396.36	938.08
2018	542.88	399.60	942.48
2019	544.04	403.11	947.15

Table-9: Methane emission in Gigagram per year based on emission factor provided by IPCC-2019

Years	Emission from Dairy Cattle	Emission from Other Cattle	Total Emission
2016	679.63	669.30	1348.93
2017	681.82	675.28	1357.10
2018	683.28	680.80	1364.08
2019	684.74	686.78	1371.52

Table-10: Comparison between Emission (Gigagram per Year) based on Emission Factors provided by IPCC at 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

Table-11: Total methane emission (Gigagram per year) in 2020-2021 from cattle based on cattle number provided by DLS with considering emission factor provided by IPCC-2019

Years	Dairy Cattle (*10^6)	Other Cattle (*10^6)	Total Cattle(*10^6)	Emission from Dairy Cattle	Emission from other Cattle	Total Emission
2020-2021	16.60	7.94	24.54	1211.80	365.24	1577.04

4.2 For Tier-2 System:

In Table-12, comparison of emission factor between our calculation and IPCC-2006 provided data are shown. Our calculation of methane emissions based on Tier-2 system are shown in Table-13. In Table-14, there is a comparison between the calculation of methane emission using Tier-1 and Tier-2 system.

Table-12: Average Body Weight, Dry Matter Intake, Methane Yield[1,2] and Emission Factor for Dairy and Non-Dairy Cattle

Category	Average BW(kg)	DMI (% of BW)	MY (gCH4 kg DMI^{-1})	Emission Factor (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)

Table-13: Emission of methane in Gigagram per year from Dairy and Non-Dairy Cattles

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

Table-14: Comparison Between Emission Factor (kg/cattle/year) between our calculation and IPCC-2006 provided value

Category	Our Calculation	IPCC-2006 Provided Value
Dairy	58.50	58
Non-Dairy	29.30	27

Table-15: Comparison of Methane Emission (Gigagram per year) between Tier-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

Chapter-V
Discussions:

5.1 For-Tier-1 Method:

Here, based on IPCC-2006 in 2016,2017,2018 and 2019, total methane emission from dairy cattle are 539.58, 541.72, 542.88 and 544.04 gigagram respectively and based on IPCC-2019 these are 679.63, 681.82, 683.28 and 684.74 gigagram respectively. So, we are seeing that for the difference of emission factor at IPCC-2006 and IPCC-2019 there are difference of around 150 gigagram emission of methane in every year from dairy cattle.

In case of those cattle other than dairy, in 2016, 2017, 2018 and 2019, methane emissions based on IPCC-2006 are 392.85, 396.36, 399.60, 403.11 gigagram respectively and based on IPCC-2019 these are 932.43, 938.08, 942.48 and 947.15 gigagram respectively. Here, we can see a huge difference of methane emission from the cattle other than dairy for the difference in emission factor. There is a difference of more than 250 gigagram emission of methane in every year. Here, based on IPCC-2006 total emission in 2017 was 938.08 gigagram where in average 39.31 kg methane was emitted from every cattle. According to Das AK *et al.*, 2017, 41.13 kg methane emitted from every livestock in a year. Our calculated value is almost similar with that. In this study, the calculation of total methane emission based on IPCC-2006 is same as Das NG *et al.*, 2020 when their calculated value is reverted in methane from CO_2 equivalent. But, our calculation based on IPCC-2019 is different from them as emission factors provided by IPCC-2019 are different from emission factors provided by IPCC-2006.

If we discuss about total emissions from dairy and other cattle in 2016, 2017, 2018 and 2019, based on IPCC-2006 these are 932.43, 938.08, 942.48 and 947.15 gigagram of methane respectively. Based on IPCC-2019 those calculations are 1348.93, 1357.10, 1364.08 and 1371.52 gigagram respectively. So, the difference of methane emissions in every year is around 400 gigagram.

In 2021, when IPCC already updated there value of 'methane emission factor', DLS provided us total dairy cattle number of 16.6 million out of 24.54 million of total cattle population where cattle other than dairy are 7.94 million. Our calculation is, in 2021 methane emission from dairy is 1211.80 gigagram and emission from cattle other than dairy is 365.24 gigagram and total emission is 1577.04 gigagram of methane.

5.2 For Tier-2 Method:

Here, our calculated emission factor for dairy and non-dairy cattle are 58.50 and 29.30 kg/cattle/year respectively which are slightly different from IPCC-2006 provided value.

In 2016, 2017, 2018 and 2019 our calculated emissions of methane from dairy cattle are 544.63, 54.39, 547.56 and 548.73 gigagram of methane respectively and from non-dairy cattle emissions of methane are 426.31, 430.12, 433.64 and 437.44 gigagram of methane respectively.

If we see the our calculation of total emissions based on Tier-1 (IPCC-2006) and Tier-2 (DMI basis), in 2016, 2017, 2018 and 2019 total emissions of methane calculated using Tier-1 method

are 932.43, 38.08, 942.48 and 947.15 gigagram of methane respectively and on the basis of Tier-2 method total emissions are 970.95,976.514, 981.2 and 986.19 gigagram of methane respectively. We can see a difference of around 38 gigagram of methane emission between the calculation using Tier-1 and Tier-2 method in every year.

Our calculated values based on Tier-2 system are different from Das NG *et al.*, 2020 in where Tier-1 method is used. The differences are due to the variation of emission factor as they used emission factors provided by IPCC-2006 and in our study emission factors are determined for Tier-2 method. A little bit of different between emission factors is responsible for the variation in calculation.

In 2017, based on Tier-2 method, there is a total 976.514 gigagram emission of methane from cattle. Where in average 40.92 kg of methane emitted from every cattle per year which is almost similar to the calculation of Das AK *et al.*, 2017 where in average 41.13 kg methane emitted from every cattle per year is shown.

In Jahan S *et al.*, 2013, a gradual increase of emission methane from 1983 to 2009 was shown. In our study we can also see the gradual increase in the emission of methane from 2016 to 2019 by using every methods of calculation.

Chapter-VI
Conclusion

In our country, mission of methane from cattle is increasing gradually following the gradual increase of dairy cattle. Following this, green house effects are uprising. Increasing global warming, respiratory diseases, air pollution are common results of this situation. This is high time, we can make change. Collection of the expiratory gases of cattle and processing them into useful things can be solution of this problem.

Chapter-VII
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