An estimation of greenhouse gas emission from livestock in Bangladesh

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ABSTRACT

Objectives: The study was undertaken to investigate the greenhouse gas (GHG) emission from livestock in Bangladesh.

Materials and Methods: The GHG emission inventory of livestock in Bangladesh was estimated according to the tier 1 approach of the Intergovernmental Panel on Climate Change (IPCC) using livestock population data from 2005 to 2018. It was also extrapolated for the next three decades, according to the growth of the livestock population.

Results: According to the calculation, the GHG emission from livestock was 66,586 Gg/year CO₂ equivalent (CO₂e) in 2018. This emission may rise to 69,869, 80,618, 94,638, and 113,098 Gg/year CO₂e in 2020, 2030, 2040, and 2050, respectively. The share of enteric methane, manure methane, direct nitrous oxide emission, and indirect nitrous oxide emission in the total GHG emissions represented 44.0%, 3.6%, 51.5%, and 0.9%, respectively, in 2018. It may rise at a rate of 1.54%–1.74% annually until 2050.

Conclusion: The GHG inventory may guide professionals to formulate and undertake the effective mitigation measures of GHG emissions from livestock in Bangladesh. However, this inventory can be amended following the tier 2 approach recommended by the IPCC if necessary data are available at the national level.

Introduction

The emission of anthropogenic greenhouse gasses (GHGs) is a global concern because of their huge climate change impacts. The primary GHG emission that leads to global warming is carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and different chlorofluorocarbons. However, significant sources of different atmospheric GHGs are various. For example, agriculture is mainly responsible for the atmospheric rise of CH₄ and N₂O, whereas the burning of fossil fuel and changing land-use patterns lead to higher CO₂ in the air [1]. The estimated global anthropogenic CH₄ emission was about 6,875 × 10⁶ ton CO₂ equivalent (CO₂e) with the share of enteric fermentation of ruminants and their manure management by 29% and 4%, respectively, which may rise to about 7,904 × 10⁶ ton CO₂ by 2020 [2]. According to Van der Maas et al. [3], enteric fermentation of ruminants shares about 69% of agricultural CH₄ emission, of which 89% from cattle. The enteric fermentation is an indispensable biological phenomenon of ruminants, which may cause about 2%–12% of dietary gross energy loss as gas production, particularly CH₄ [4]. This gaseous energy loss by the enteric fermentation is significantly affected by the quality and composition of the diet of ruminants [5]. About 6.5% of dietary gross energy loss was reported when cattle were fed moderate- to high-quality diets, whereas it was only about 3% if fed high-grain diets [5].

In Bangladesh, the population of different livestock categories is vast, where the density of ruminant livestock is about 376 heads/km² [6]. Along with the increased livestock population, intensive farming of animals and its associated technologies also contribute to GHG emission [7]. Although GHG emission inventory from livestock and its mitigation at global, national, and local levels are reported in many studies [8–10], it is scanty in Bangladesh.

The emission of CH₄ from livestock was reported by some studies [11,12], but they did not produce a report on GHG emission, including future predictions, suitable for professionals in taking mitigation strategies to achieve...
climatic-smart livestock production. Therefore, the objectives of the study were to analyze the trends of GHG from livestock over the past 13 years (2005–2018) and its predicted emissions over the next three decades (up to 2050).

Materials and Methods

The estimation of GHG emission from livestock was done by following the tier 1 method of the Intergovernmental Panel on Climate Change (IPCC) [5]. Considering the average temperature of the country over the past 25 years (1991–2015; 25.27°C) [13], all necessary emission factors reported by the IPCC [5] for the warm climatic zone were used in the estimation. The emission of CH₄ and N₂O is expressed in CO₂e by considering their global warming potential (25 and 298 times, respectively) [14]. All the estimated values were expressed in gigagram (Gg; 1 Gg = 10³ t = 10⁶ kg). The details of the methods are as follows.

Categorization of livestock population data

The principal livestock categories (T) in Bangladesh which contribute to GHG emission are cattle, buffalo, goat, sheep, and poultry. Data on different livestock categories were collected from Department of Livestock Services [6], and it was expressed as an annual average livestock population in a million heads (10⁶) in each calendar year. The dairy cattle and other cattle population was calculated following the ratio reported by Huque [15] and extrapolated according to their annual growth rate (AGR, %). The AGR of different livestock categories was calculated by considering their population growth from 2005 to 2018 (13 years), and it was used for calculating the predicted livestock population in 2020, 2030, 2040, and 2050 (Table 1). The average animal live weight, the emission factor for enteric fermentation and manure management, nitrogen excretion rate, manure management systems, direct and indirect N₂O-N emission factors in different manure management systems, and nitrogen volatilization of different livestock categories were taken from the IPCC [5].

Enteric methane emission

The enteric CH₄ emission of ruminants was calculated according to the following equation:

$$\text{CH}_4\text{ Enteric} = \frac{\sum T (N_{(T)} \times \text{EF}_{(E,T)})}{10^6} 	imes 25, \text{Gg/year CO}_2\text{e}$$

where CH₄ Enteric = the total CH₄ emissions for enteric fermentation of ruminants, Gg/year CO₂e

Nₜ = the heads of livestock species/category T in the country

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Methane emission from the manure of animals

The manure management of different livestock species that contributes to CH₄ emission was calculated according to the following equation:

$$\text{CH}_4\text{ Manure} = \frac{\sum T \times \text{EF}_{(M,T)} \times N_{(T)}}{10^6} \times 25, \text{Gg/year CO}_2\text{e}$$

where, CH₄ Manure = total CH₄ emissions from the different manure management systems of different livestock categories, Gg/year CO₂e; EFₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑ euler e

Nitrous oxide emission

The N₂O emission may occur directly or indirectly from different manure management systems. The direct N₂O emission was calculated by the following equation:

$$\text{N}_2\text{O}_{D(mm)} = \sum T [(\sum T \times N_{(T)} \times \text{EF}_{(S,T)}} \times \text{MS}_{(S,T)}]] \times \text{EF}_{3(S)}$$

$$\times \frac{44}{28} \times 298 \times \frac{1}{10^6}, \text{Gg/year CO}_2\text{e}$$

where, N₂O_D(mm) = total direct N₂O emission for the different manure management systems of different livestock categories (kg/year); Nₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑ euler e
where, $N_{O(G:mm)}$ – total indirect N$_2$O emission from different manure managements of livestock, Gg/year CO$_2$e; $N_{volatilization-MMS(T)}$ – the loss of manure nitrogen of a livestock species/category “T,” kg/year; EF$_4$ – N$_2$O emission factor for the deposition of nitrogen on soils and water surfaces, kg N$_2$O-N/kg NH$_3$-N and NO$_x$-N volatilized; and 44/28 – conversion of N$_2$O-N to N$_2$O emission. The $N_{volatilization-MMS(T)}$ was calculated by the following equation:

$\text{AGR}$ = annual growth rate of livestock species (%)

| Parameters | Dairy cattle | Other cattle | Buffalo | Goat | Sheep | Poultry |
|------------|--------------|--------------|---------|------|-------|---------|
| $EF_{(E,T)}$ | 58           | 27           | 55      | 5    | 5     | -       |
| $EF_{(M,T)}$ | 5           | 2            | 5       | 0.22 | 0.20  | 0.02    |
| LW         | 275          | 110          | 295     | 30   | 28    | 1.50    |
| $N_{ex}$   | 0.47         | 0.34         | 0.32    | 1.37 | 1.17  | 0.82    |

$EF_{(E,T)} = $ enteric methane emission factor (kg/head/year CH$_4$); $EF_{(M,T)} = $ methane emission factor for manure management (kg/head/year CH$_4$); LW = default live weight of animals (kg); $N_{ex}$ = nitrogen excretion in manure of different livestock categories (kg/1,000 kg animal mass/day); and - = not reported.

Results

Methane emission from livestock

The CH$_4$ emissions from both the enteric fermentation and manure management sources of different livestock categories are presented in Table 5. The highest CH$_4$ emission was estimated from the enteric fermentation of dairy cattle from 2005 to 2018, followed by other cattle, goats, buffalo, and sheep. The position of the different livestock categories in terms of enteric CH$_4$ emission may remain the same until 2050. Regarding manure management, the
dairy cattle had the highest emission from 2005 to 2018, followed by other cattle, buffalo, poultry, goat, and sheep. This position of livestock categories may remain the same in 2020. However, in the next two decades (2030–2050), manure CH$_4$ emission from poultry may be higher than buffalo. The total emission of CH$_4$ from all livestock categories in 2018 was 31,741 Gg/year CO$_2$e, consisting of 29,313 and 2,428 Gg/year CO$_2$e from enteric fermentation and manure management, respectively.

**Nitrous oxide emission from livestock**

The N$_2$O emission from different livestock categories is presented in Table 6. The direct N$_2$O emission from the manure management of dairy cattle was the highest between 2005 and 2018, followed by the goat, other cattle, poultry, buffalo, and sheep. In 2020, the highest direct N$_2$O may come from goat, followed by dairy cattle, other cattle, poultry, buffalo, and sheep. In 2030 and 2040, poultry manure may produce higher direct N$_2$O emission than other cattle category, and it may excel the dairy cattle, reaching the second most source of emission in 2050. The highest indirect N$_2$O emission from 2005 to 2018 was from the poultry, followed by the goat, dairy cattle, sheep, and other cattle. The position of them may remain the same in 2020 and 2030. In 2040 and 2050, the indirect N$_2$O emission from sheep may excel the dairy cattle category. The total N$_2$O emission from all livestock categories in 2018 was 34,845 Gg/year CO$_2$e, consisting of 34,259 and 586 Gg/year CO$_2$e from the direct and indirect emissions, respectively.
Total GHG emission from livestock

The GHG emissions from different livestock categories are presented in Table 7. The share of different livestock categories and greenhouse gases in total GHG emission in 2018 is presented in Figures 1 and 2, respectively. Overall, the estimated GHG emission from dairy cattle was the highest in 2005 to 2018, followed by other cattle, goats, poultry, buffalo, and sheep. According to future predictions, a similar trend will exist until 2020. In 2030 and 2040, the emission from goats may be higher than other cattle and take the second position, next to dairy cattle. In 2050, the GHG emission from goats may be the highest, followed by dairy cattle, other cattle, poultry, buffalo, and sheep. The rate of increase in annual total GHG emissions from 2005 to 2018 was 1.16% (57,887 and 66,586 Gg/year in 2005 and 2018, respectively).
The rate of total GHG emission may be 1.54%, 1.74%, and 1.95% in the next three decades (2020–2050). The share of dairy cattle, other cattle, goats, poultry, buffalo, and sheep in total GHG emission in 2018 was 39.7%, 24.3%, 21.2%, 7.0%, 5.4%, and 2.4%, respectively (Fig. 1). The GHG emission in 2018 was accounted for 44.0%, 3.6%, 51.5%, and 0.9% of enteric CH$_4$, manure CH$_4$, direct N$_2$O emission from manure, and indirect N$_2$O emission from manure, respectively (Fig. 2).

**Discussion**

The emission of enteric CH$_4$ (28,831 Gg/year CO$_2$e, Table 5) and CH$_4$ and N$_2$O from manure in 2015 (2,380 and 558, Gg/year CO$_2$e, respectively, Tables 5 and 6) was equal to 9.5%, 7.7%, and 14.0%, respectively, of emission from Indian livestock, according to its livestock population in 2012 [18]. Compared to the GHG emission of 7.1 ×10$^9$ t/year from global livestock [19], the total GHG emission from livestock of Bangladesh in 2015 (65,189 Gg/year CO$_2$e, Table 7) represented only 0.92%. In 2020, the GHG emission from livestock of Bangladesh (69,869 Gg/year CO$_2$e, Table 7) may represent about 0.88% of emissions from global livestock (7.9×10$^9$ t/year CO$_2$e) [2]. The annual increase of GHG emission from the livestock in Bangladesh (1.16%, Table 7) from 2005 to 2018 was higher than that in India and the globe from 1961 to 2010 (0.92% and 1.13%, respectively) [20]. The difference in the proportion of different livestock categories in the total livestock population results in the changes of GHG emission.

The estimated GHG emission based on the annual average livestock population and growth of different livestock categories according to the IPCC [5] provides us an assumption about the level of GHG emission from livestock in the country. Such an assumption may help in producing different country reports, taking necessary climatic policies, development activities, and projects to fight climate change issues. However, the inventory based on default

### Table 7. Greenhouse gas emission from different livestock categories (Gg/year CO$_2$e).

| Livestock category | Estimated | Projected |
|--------------------|-----------|-----------|
| Dairy cattle       | 25,471    | 26,197    | 26,447 | 26,570 | 27,325 | 28,103 | 28,402 |
| Other cattle       | 15,024    | 15,793    | 16,190 | 16,197 | 17,027 | 17,899 | 18,816 |
| Buffalo            | 2,771     | 3,551     | 3,587  | 4,051  | 5,192  | 6,654  | 8,529  |
| Goat               | 10,544    | 13,853    | 14,122 | 16,026 | 21,054 | 27,660 | 36,339 |
| Sheep              | 1,149     | 1,506     | 1,597  | 1,739  | 2,279  | 2,987  | 3,915  |
| Poultry            | 2,929     | 4,290     | 4,643  | 5,286  | 5,826  | 6,654  | 8,529  |
| **Total**          | 57,887    | 65,189    | 66,586 | 69,869 | 80,618 | 94,638 | 11,3098|

**Figure 1.** Share of livestock categories in greenhouse gas emission (% CO$_2$e) in 2018.

**Figure 2.** Share of different gases in total greenhouse gas emission (% CO$_2$e) in 2018.
nurtritional and management characteristics of different livestock categories and emission factors according to the IPCC [5] may not represent the actual GHG emission from indigenous livestock. Therefore, determining the GHG emission factor, characterizing livestock population data, and studying feeds and nutrition of indigenous livestock are important. In particular, the dietary intake of energy and digestibility are the main determinant of the enteric CH\textsubscript{4} emission from different livestock categories. Similarly, the nitrogen excretion rate of different livestock categories, the volatile solid contents of manure management system countrywide determine the CH\textsubscript{4} and N\textsubscript{2}O emission from manure. Furthermore, the growth of the livestock population many not follow a numerical trend in a country for a long period of time. Increasing productivity rather than increasing the livestock population is considered to meet the growing demand for animal-sourced foods of a country. As a result, intensive farming of improved livestock breeds/varieties is growing and may be the necessity of rearing low-producing huge indigenous stock. The change in the livestock production system and its future prediction is of importance to study.

**Conclusion**

It may be concluded that total GHG emissions from the livestock in Bangladesh were 66,586 Gg/year CO\textsubscript{2}e in 2018. The share of enteric CH\textsubscript{4}, manure CH\textsubscript{4}, direct N\textsubscript{2}O emission, and indirect N\textsubscript{2}O emission to the total GHG emissions represented 44.0%, 3.6%, 51.5%, and 0.9%, respectively. The predicted GHG emissions may raise at the rate of 1.54%–1.95% up to 2050.

**Conflict of interests**

The authors declare that there is no conflict of interests with any scientists or organizations.

**Authors’ contribution**

Nani Gopal Das and Nathu Ram Sarker contributed equally in calculating the greenhouse gas (GHG) emission from livestock and preparing the manuscript. Md. Najmul Haque was involved in editing and reviewing the article.

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