Scholars Journal of Agriculture and Veterinary Sciences
OPEN ACCESS
Abbreviated Key Title: Sch J Agric Vet Sci
ISSN 2348–8883 (Print) | ISSN 2348–1854 (Online)
Journal homepage: https://saspublishers.com

Estimation of Methane Gas Emission by Enteric Fermentation from Goat in Bangladesh

Md. Rabbi Rahul[1], Md. Jobair Haque Emon[1], Md. Shohel Al Faruk[2], Md. Ashraf Ali Biswas[3*]

[1]Faculty of Veterinary Medicine, Chattogram Veterinary and Animal Sciences University, Khulshi-4225, Chattogram, Bangladesh
[2]Department of Physiology, Biochemistry and Pharmacology, Chattogram Veterinary and Animal Sciences University, Khulshi-4225, Chattogram, Bangladesh
[3]Department of Animal Science and Nutrition, Chattogram Veterinary and Animal Sciences University, Khulshi-4225, Chattogram, Bangladesh

DOI: https://doi.org/10.36347/sjavs.2025.v12i11.001 | **Received:** 15.09.2025 | **Accepted:** 27.10.2025 | **Published:** 03.11.2025

***Corresponding author:** Md. Ashraf Ali Biswas
Department of Animal Science and Nutrition, Chattogram Veterinary and Animal Sciences University, Khulshi-4225, Chattogram, Bangladesh

Abstract **Original Research Article**

The goat population in Bangladesh is steadily increasing, raising concerns about its potential contribution to the country's greenhouse gas emissions. For climate policies to be effective, it is crucial to assess these emissions accurately. This study aimed to evaluate methane (CH_4) emissions resulting from enteric fermentation in the Bangladeshi goat population, utilizing both the standard (Tier-1) and the more advanced, country-specific (Tier-2) methodologies outlined in the IPCC 2019 guidelines. The findings from these two approaches were then compared. The entire goat population was categorized into two breeds: Black Bengal (90%) and Jamunapari (10%). For the Tier-2 analysis, breed-specific emission factors (EFs) were determined using local data on mature body weight and gross energy intake. These EFs were subsequently applied to annual population data from 2016–17 to 2020–21. The results from the Tier-2 method indicated EFs of 2.24 kg CH_4 head^{-1} year^{-1} for Black Bengal goats and 3.01 kg CH_4 head^{-1} year^{-1} for Jamunapari goats, representing reductions of 55% and 40%, respectively, compared to the IPCC Tier-1 default EF of 5 kg CH_4 head^{-1} year^{-1}. Consequently, the Tier-2 method estimated that overall national methane emissions increased gradually from 60.11 to 61.67 Gigagrams (Gg) per year during the study period. In contrast, the Tier-1 method produced estimates that were approximately 115% higher, ranging between 129.65 and 133.00 Gg CH_4 per year. The application of the IPCC Tier-2 methodology with country-specific data reveals that the baseline for methane emissions from Bangladesh's goat sector is significantly lower than the estimates produced by Tier-1. This finding underscores the need for developing localized emission factors to ensure accurate national greenhouse gas inventories and to inform targeted mitigation strategies within the livestock sector.

Keywords: Methane; Black Bengal; Jamunapari; Enteric Fermentation; Greenhouse; Climate change.

Copyright © 2025 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution **4.0 International License (CC BY-NC 4.0)** which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.

INTRODUCTION

Livestock is an integral part of agriculture and a crucial instrument for the economic growth and development of Bangladesh, providing livelihood security to millions (Moller *et al.*, 2023; Hoque *et al.*, 2017). However, the agricultural sector is also the second largest contributor to global anthropogenic greenhouse gas (GHG) emissions, with livestock accounting for approximately 39% of all anthropogenic methane (CH_4), a potent greenhouse gas with a global warming potential far exceeding that of carbon dioxide (FAO, 2020; Patra, 2012; Reisinger *et al.*, 2021). Within Bangladesh's livestock sector, goats represent a particularly vital resource (Kerven, 2024; Sarkwa *et al.*, 2025). They are a major means of employment and income for women, children, and aged people, reared for their high prolificacy, adaptability to changing climates, and unique browsing potential (Bezabih *et al.*, 2014; Feleke *et al.*, 2016; Yemane *et al.*, 2020). Reflecting this importance, the national goat population has shown consistent growth, increasing from 25.93 million in 2016-17 to 26.60 million in 2020-21 (DLS, 2021; Gawat *et al.*, 2023; Mugoti *et al.*, 2025). This upward trend underscores the need for a precise understanding of the environmental impact of this expanding sub-sector. (Reddy *et al.*, 2019; Silva *et al.*, 2022)

Accurate quantification of methane emissions from enteric fermentation is essential for developing effective national climate strategies (Maze *et al.*, 2024; Patra, 2012). The Intergovernmental Panel on Climate Change (IPCC) provides standardized methodologies for this purpose, ranging from the default Tier-1 approach to the more advanced Tier-2 and Tier-3 methods (IPCC, 2019; Pison *et al.*, 2018; Roques *et al.*, 2023). Previous national inventories in Bangladesh have primarily relied on the Tier-1 method, which applies a generic emission factor to livestock populations (Das *et al.*, 2020; Hoque *et al.*, 2017; Yona *et al.*, 2020). While valuable for initial assessments, this approach lacks country-specificity, as it does not account for the distinct physiological characteristics and feeding practices of indigenous livestock (Korir *et al.*, 2023; Ndung'u *et al.*, 2018). The Tier-1 emission factor for goats, for instance, is based on a standardized animal live weight that does not reflect the smaller stature of dominant Bangladeshi breeds like the Black Bengal and Jamunapari (Khan and Naznin, 2013). Consequently, existing national estimates may not accurately represent the true scale of emissions, creating a significant knowledge gap. (Raihan *et al.*, 2023)

To address this gap, our study employs the IPCC Tier-2 method to provide a more refined and accurate estimation of methane emissions from the Bangladeshi goat population. This method allows for the development of country-specific emission factors based on local data for average body weight and gross energy intake (Das *et al.*, 2020; Fernández, 2018). The study has been designed to estimate total annual emissions through the development of country-specific emission factors for the dominant goat breeds, to assess the temporal trend in emissions driven by population growth, and to conduct a critical comparative analysis between the Tier-1 and Tier-2 outcomes. By providing a robust, data-driven baseline that reflects local conditions, this work aims to enhance the scientific integrity of Bangladesh's climate reporting and to inform evidence-based policy decisions that can reconcile agricultural development with climate action.

METHODOLOGY

Study Area Description

This study was conducted at the national level for Bangladesh. Bangladesh is located in South Asia and possesses a predominantly subtropical monsoon climate, characterized by high humidity, heavy seasonal rainfall, and warm temperatures. This climate supports an agricultural system where livestock, particularly small ruminants like goats, are integral to the rural economy. The research utilized national-scale data, with the analysis being conducted at the Department of Animal Science and Nutrition, Chattogram Veterinary and Animal Sciences University.

Livestock Population

The total goat population data for Bangladesh for the fiscal years 2016-17 to 2020-21 was obtained from the official "Annual Report on Livestock 2021" published by the Department of Livestock Services (DLS), Bangladesh (DLS, 2021). The national herd was categorized into its two predominant breeds: the Black Bengal and the Jamunapari. Based on the study by Khan and Naznin (2013), the breed distribution was defined as 90% Black Bengal and 10% Jamunapari. The annual populations for each breed were calculated accordingly and are presented in Table 1.

Livestock Production System

The goat production system in Bangladesh was classified as a low-productivity system according to the IPCC (2019) categorization. This classification is based on the relatively low average mature body weights of the local breeds compared to international standards, and the common practice of extensive and semi-intensive management. The system is primarily subsistence-oriented, with limited use of commercial feed supplements, relying mainly on natural grazing, roadside vegetation, and seasonal crop residues.

Livestock Management System

The management system is largely characterized by smallholder, rural-based farming with minimal input. Animals are typically reared under a scavenging or grazing system, where they walk to obtain feed and water. This level of activity was a key factor in the energy calculations for the Tier-2 method. The feeding situation corresponds to the IPCC (2019) classification for animals that graze on lowland pastures.

Methane Emission Calculation

Methane (CH_4) emissions from enteric fermentation were estimated following the IPCC (2019) guidelines for national greenhouse gas inventories. Two distinct methodological tiers were employed and compared, Tier-1 and Tier-2 Method. The total emissions for each breed and year were calculated using the fundamental formula:

In Tier-1 method, the total goat population is subdivided into two categories (Black Bengal and Jamunapari), then the population of each category will be multiplied by the IPCC, 2019 provided emission factor and dived by 10^6. The sum total of methane emission from each category is the total methane emission from goat.

The formula for emissions from a livestock category according to Tier 1 method as provided by IPCC, 2019 guidelines is:

$$\boxed{E_T = \sum_{(p)} EF_{(T,P)} \times \left(\frac{N_{(T,P)}}{10^6}\right)}$$

Where E_T means methane emissions from Enteric Fermentation in animal category T, Gg CH_4 yr^{-1}. $EF_{(T,P)}$ is the emission factor for the defined livestock population T and the productivity system P, in kg CH_4 head^{-1} yr^{-1}. $N_{(T,P)}$ is the number of head of livestock species / category, T in the country classified as productivity system, P. T means species/category of livestock and P is the productivity system, either high or low productivity.

Formula for total emission from livestock enteric fermentation is:

$$Total\ CH_4\ enteric = \sum E\ ip$$

Here E ip is the emission from ith livestock category and subcategories based on production system (P).

For the Tier-1 calculation, the emission factor for goats in low-productivity systems, as provided by IPCC (2019), was used. This value is 5 kg CH_4 head^{-1} year^{-1}. For the Tier-2 calculation, breed-specific EFs were developed. The EF was calculated based on the Gross Energy (GE) intake required by the animal, using the following equation from IPCC (2019):

EF (kg CH_4/head/year) = [GE (MJ/day) × (Y_m/100) × 365] / 55.65

Where **GE** is the Gross Energy intake (MJ/head/day), $\mathbf{Y_m}$ is the Methane conversion factor, representing the percentage of gross energy in feed converted to methane. The default value for goats is **5.5%** (IPCC, 2019). **55.65** is the Energy content of methane (MJ/kg CH_4).

In **Tier-2 method,** specific emission factors for each category of goat needs to be calculated. There are three steps of the Tier-2 method (IPCC,2019). In first step, specific goat populations with subcategories has to be collected e.g., Black Bengal goat, Jamunapari goat. In second step, the emission factor should be calculated based on 'Gross Energy' (GE) (IPCC,2019). Animal performance and diet data are used to estimate feed intake which is the amount of energy (MJ/day) animal needs for maintenance and for such as growth, lactation, and pregnancy. In third step, the methane emissions from each livestock category are calculated using the formula provided by IPCC, 2019 guidelines.

IPCC Equations for Gross Energy (GE) Intake

The Gross Energy (GE) intake for a mature animal was calculated by summing the net energy requirements for various physiological functions and dividing by the efficiency of energy utilization. The following IPCC (2006) equations and default coefficients were used:

Net Energy for Maintenance (NE_m) is the amount of energy needed to keep the animal in equilibrium where body energy is neither gained nor lost.

$$NE_m = Cfi \bullet (Weight)^{0.75}$$

Where NE_m is the net energy required by the animal for maintenance, MJ day^{-1}. Cfi is the coefficient that varies for each animal category (Coefficients for calculating NE_m), MJ day^{-1}kg^{-1}. Weight is the live weight of animal, kg. Coefficient for calculating net energy for maintenance (NE_m) for goat is, Cfi = 0.315 MJd^{-1}kg^{-1} (IPCC,2019)

Net energy for activity (NE_a) is the energy needed for animals to obtain their food, water, and shelter.

$$NE_a = C_a \bullet (Weight)$$

Where NE_a is the net energy for animal activity, MJ day^{-1}. C_a is the coefficient corresponding to animal's feeding situation, MJ day^{-1} kg^{-1}. Weight is the live weight of animal, kg. The coefficient corresponding to animal's feeding situation (C_a) for lowland goats where animals walk and graze lowland pasture is, C_a= 0.019MJday^{-1}kg^{-1} (IPCC,2019).

Net energy for growth (NE_g) is the net energy needed for growth (i.e. weight gain) for goats is:

$$NE_g = \frac{WG_{kid} \cdot (a + 0.5b(BW_i + BW_f))}{365}$$

Where NE_g is the net energy needed for growth, MJ day^{-1}. WG_{kid} is the weight gain ($BW_f - BW_i$), kg yr^{-1}. BW_i is the live bodyweight at weaning, kg and BW_f is the live bodyweight at 1-year old or at slaughter (live-weight) if slaughtered prior to 1 year of age, kg. a, b is constants.

The live body weight at weaning of Black Bengal goat is 5.35 kg and of Jamunapari goat is 6.69 kg. And the live body weight of a mature Black Bengal goat is 9.53 kg and of a mature Jamunapari goat is 13.65 kg (Khan and Naznin,2013). The constants for use in calculating NE_g for goats are, a = 5.0 MJKg^{-1} and b = 0.33 MJKg^{-1} (IPCC,2019).

Net energy for lactation (NE_l) is the net energy for lactation. The net energy for lactation if the milk production is unknown is calculated as.

$$NE_l = \left[\frac{(5 \cdot WG_{wean})}{365}\right] * EV_{milk}$$

Where NE_l is net energy for lactation, MJ day^{-1}. WG_{wean} is the weight gain of the kid between birth and weaning, kg and EV_{milk} is the energy required to produce 1 kg of milk, MJ kg^{-1}. A default EV_{milk} value of 3 MJ/kg can be used which corresponds to a milk fat content of 3.8 percent by weight for goats (IPCC,2019). The average weight gain of kids of Black Bengal and Jamunapari breeds between birth and weaning is 4.157 kg and 5.225 kg respectively (Khan and Naznin,2013).

Net energy for pregnancy (NE_p) is the energy required for pregnancy. For goats, the NE_p requirement is estimated for the 147-day gestation period, although the percentage varies with the number of kids born.

$$NE_p = C_{pregnancy} \cdot NE_m$$

Where NE_p is the net energy required for pregnancy, MJ day^{-1}. $C_{pregnancy}$ is the pregnancy coefficient and NE_m is the net energy required by the animal for maintenance, MJ day^{-1}. The pregnancy coefficient for double birth (twins) in goats is, $C_{pregnancy}$ = 0.126 (IPCC,2019).

The ratio of net energy available in the diet for maintenance to digestible energy consumed (REM): For sheep and goats, the ratio of net energy available in a diet for maintenance to digestible energy (REM) is estimated using the following equation:

$$REM = [\ 1.123 - (4.092*10^{-3}*DE) + (1.126*10^{-5}*(DE)^2) - (25.4/DE)\ ]$$

Where REM is the ratio of net energy available in the diet for maintenance to digestible energy and DE is the digestibility of feed expressed as a fraction of gross energy (digestible energy/gross energy).

The ratio of net energy available for growth in a diet to digestible energy consumed (REG): For sheep and goats the ratio of net energy available for growth (including wool growth) in a diet to digestible energy consumed (REG) is estimated using the following equation:

$$REG = [\ 1.164 - (5.16*10^{-3}*DE) + (1.308*10^{-5}*(DE)^2) - (37.4/DE)\ ]$$

Where REG is the ratio of net energy available for growth in a diet to digestible energy consumed and DE is the digestibility of feed expressed as a fraction of gross energy (digestible energy/gross energy). The digestibility of feed in growing dairy goats is 0.7246 (DE/GE) or 72.46% (Souza *et al.*,2020).

Gross energy (GE) is derived based on the summed net energy requirements and the energy availability characteristics of the feed(s).

$$GE = \left[\frac{\left(\frac{NE_m + NE_a + NE_l + NE_p}{REM}\right) + \left(\frac{NE_g + NE_{wool}}{REG}\right)}{DE} \right]$$

Where GE is the gross energy, MJ day^{-1}. NE_m is the net energy required by the animal for maintenance, MJ day^{-1}. NE_a is net energy for animal activity, MJ day^{-1}. NE_l is net energy for lactation, MJ day^{-1}. NE_{work} is the net energy for work, MJ day^{-1}. NE_p is the net energy required for pregnancy, MJ day^{-1}. REM is the ratio of net energy available in a diet for maintenance to digestible energy. NE_g is the net energy needed for growth, MJ day^{-1}. REG is the ratio of net energy available for growth in a diet to digestible energy consumed. NE_{wool} is net energy required to produce a year of wool, MJ day^{-1} and DE is the digestibility of feed expressed as a fraction of gross energy (digestible energy/gross energy).

Emission Factor Development: Based on the gross energy intake equation of emission factor will be:

$$EF = \left[\frac{GE * (Y_m/100) * 365}{55.65} \right]$$

Where EF is the emission factor, kg CH_4 $head^{-1}$ $year^{-1}$. GE is the gross energy intake, MJ $head^{-1} day^{-1}$ and Y_m is the methane conversion factor; percent of gross energy in feed converted to methane. The factor 55.65 (MJ/kg CH4) is the energy content of methane. The methane conversion factor (Y_m) for goats is 5.5% (IPCC,2019).

Total emissions calculation: The methane emissions from each livestock category are calculated using the following formula:

$$Emissions = EF_T * (N_T/10^6)$$

Where EF_T means emission factor for each livestock category and N_T means the number of populations in each livestock category.

Categorization of Total Goat Population

The categories of goat population are shown in Table-1. The Black Bengal goat is 90% and the Jamunapari goat is 10% of the total goat population (Khan and Naznin,2013).

Table-1: Total goat and Black Bengal and Jamunapari goat population of BD (DLS,2021)

Year	Total Goat (millions)	Black Bengal (millions)	Jamunapari (millions)
2016-2017	25.93	23.34	2.59
2017-2018	26.10	23.49	2.61
2018-2019	26.27	23.64	2.63
2019-2020	26.44	23.79	2.64
2020-2021	26.60	23.94	2.66

We will calculate the methane emissions from Black Bengal and Jamunapari goats separately from their total population and add the emissions to get the total picture.

RESULTS

Developed Breed-Specific Emission Factors

Using the Tier-2 method, which incorporates local data on body weight and energy requirements, we developed specific emission factors for the two primary goat breeds in Bangladesh. The calculated EF for the Black Bengal goat was 2.24 kg CH_4 head^{-1} year^{-1}, while for the larger Jamunapari breed, it was 3.01 kg CH_4 head^{-1} year^{-1}.

Table 2: Developed Emission Factors (EF) for Bangladeshi Goat Breeds using the IPCC Tier-2 Method

Breed	Black Bengal	Jamunapari
Average Mature Body Weight (kg)	9.53	13.65
Calculated Tier-2 Emission Factor (kg CH_4 head^{-1} yr^{-1})	2.24	3.014
IPCC Tier-1 Method EF (kg CH_4 head^{-1} yr^{-1})	5	
Percentage Difference from Tier-1 Default	-55.20%	-39.70%

These values are substantially lower than the default Tier-1 EF of 5 kg CH_4 head^{-1} year^{-1} provided by the IPCC for goats in low-productivity systems. Specifically, the EF for Black Bengal goats is 55% lower, and for Jamunapari goats, it is 40% lower than the IPCC default Tier-1 Method. This discrepancy is primarily attributable to the lower average mature body weights of goats in Bangladesh (Black Bengal: 9.53 kg; Jamunapari: 13.65 kg) compared to the 28 kg live weight assumption underlying the IPCC's default EF for low-productivity systems.

National Methane Emissions Estimated by Tier-2 Method

Applying the developed breed-specific EFs to the national population data, the total methane emissions from enteric fermentation in goats were calculated for the fiscal years 2016-17 to 2020-21 (Table 3). The results show a consistent year-on-year increase in emissions, directly correlated with the rising goat population.

Table 3: Annual Methane Emissions from Bangladeshi Goats Calculated Using the Tier-2 Method (Gg CH_4/year)

Year	Emission from Black Bengal	Emission from Jamunapari	Total
2016-2017	52.297	7.815	60.112
2017-2018	52.638	7.866	60.504
2018-2019	52.975	7.916	60.891
2019-2020	53.314	7.967	61.281
2020-2021	53.654	8.018	61.673

Total emissions rose from 60.11 Gigagrams (Gg) CH_4 per year in 2016-17 to 61.67 Gg CH_4 per year in 2020-21, representing an increase of approximately 2.6% over the five-year period. Throughout this period, Black Bengal goats, due to their overwhelming majority (~90% of the population), constituted the dominant source of emissions, contributing between 86.9% and 87.0% of the total. Jamunapari goats, despite their higher per-capita EF, contributed a smaller portion (12.9-13.0%) due to their smaller population share (~10%).

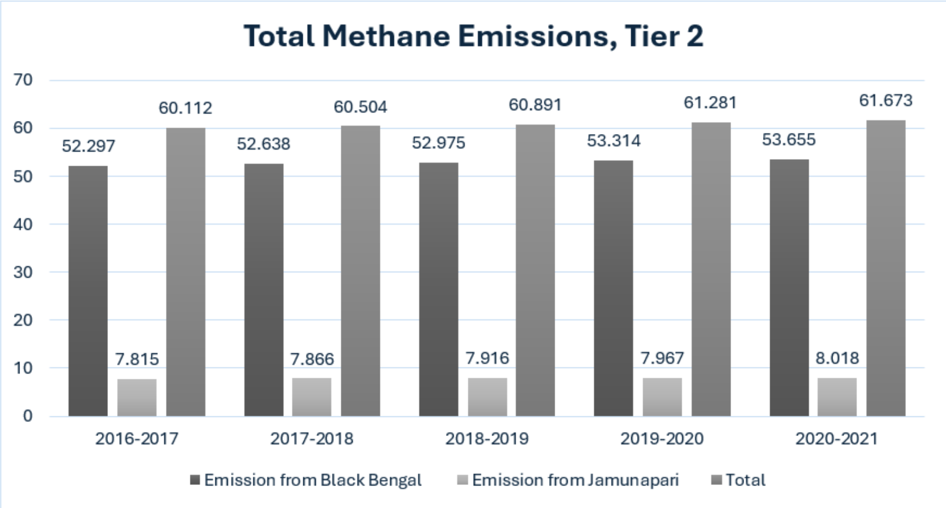

Figure 1: Annual Methane Emissions from the Goat Population of Bangladesh based on the Tier-2 Method.
Comparison of Tier-1 and Tier-2 Emission Estimates

A critical finding of this study is the significant quantitative difference between the Tier-1 and Tier-2 estimation methods.

Table 4: Comparison of Annual Methane Emissions (Gg CH_4/year) Estimated by IPCC Tier-1 and Tier-2 Methods

Year	Tier-1 (Total)	Tier-2 (Total)	Absolute Difference (T1 - T2)	Percentage Overestimation by T1
2016-2017	129.65	60.112	69.538	115.70%
2017-2018	130.5	60.504	69.996	115.70%
2018-2019	131.35	60.891	70.459	115.70%
2019-2020	132.15	61.281	70.869	115.70%
2020-2021	133	61.673	71.327	115.70%

As summarized in Table 4, the Tier-1 method produced markedly higher emissions estimates across all years and for both breeds. For the total goat population, the Tier-1 method yielded estimates that were, on average, 115% higher than those from the Tier-2 method. For instance, in the 2020-21 period, the Tier-1 estimate was 133.00 Gg CH_4/year, compared to the Tier-2 estimate of 61.67 Gg CH_4/year. This pattern held for both breeds individually, with Tier-1 estimates being 123% higher for Jammapari and 116% higher for Black Bengal goats. This systematic overestimation by the Tier-1 method underscores the importance of using country-specific parameters.

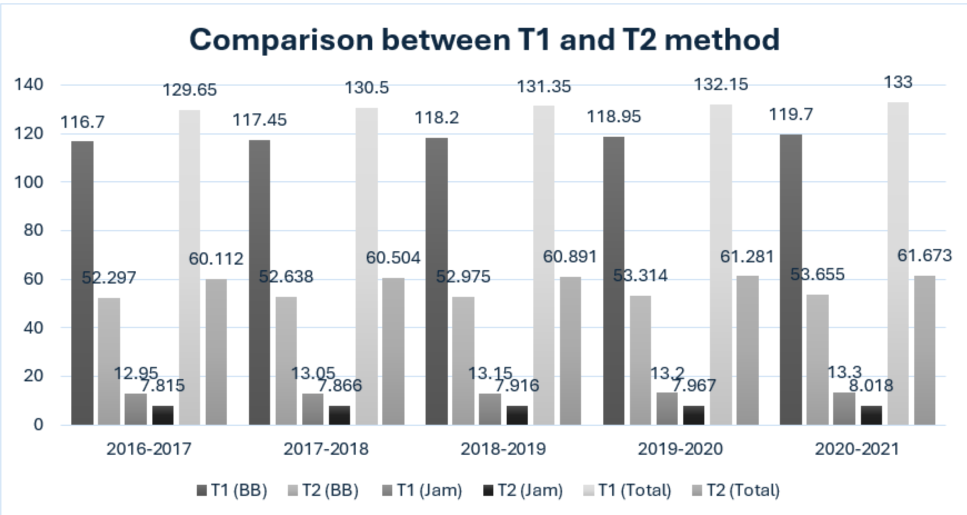

Figure 2: Comparison of Total Annual Methane Emissions from Bangladeshi Goats Estimated by Tier-1 and Tier-2 Methods

Trend Analysis and Emission Intensity

While absolute emissions are rising with the population, it is essential to consider the emission intensity. The per-capita emission, as defined by our Tier-2 EF, remained constant for each breed over the study period. Consequently, the growth in total national emissions is driven entirely by the increase in animal numbers, not by the rise in individual animal productivity that would alter the EF. This linear relationship highlights that population control or management is a key determinant of future emission trajectories from this sub-sector.

DISCUSSION

The findings of this study provide a critical, data-driven reassessment of methane emissions from Bangladesh's goat population. The application of the IPCC Tier-2 method revealed that the breed-specific emission factors (EFs) for Black Bengal (2.24 kg CH_4 head^{-1} year^{-1}) and Jamunapari (3.01 kg CH_4 head^{-1} year^{-1}) goats are substantially lower than the IPCC Tier-1 method of 5 kg CH_4 head^{-1} year^{-1} for low-productivity systems. This discrepancy is directly attributable to the fundamental parameter of animal size. (Goopy *et al.*, 2021) The Tier-1 method EF is predicated on a standard live weight of 28 kg (IPCC, 2019). However, local data confirms that the average mature body weights of indigenous Bangladeshi goats are significantly lower, at 9.53 kg for Black Bengal and 13.65 kg for Jamunapari breeds (Khan and Naznin, 2013). Since feed intake and resultant methane production are strongly correlated with body weight (Lassey, 2008; Patra, 2012), the use of an EF based on a much heavier animal inherently leads to a substantial overestimation of emissions for the smaller-statured goat population typical of Bangladesh (Goopy *et al.*, 2021). This highlights the critical importance of utilizing localized, breed-specific data for accurate greenhouse gas inventory assessments, particularly in regions with diverse livestock populations and production systems.

The implications of this difference are profound for the national greenhouse gas inventory. Our analysis demonstrates that the Tier-1 method overestimates methane emissions from the goat sector by approximately 115% compared to the Tier-2 method. This suggests that previous national estimates, which may have relied on Tier-1 approaches (e.g., Das *et al.*, 2020), likely significantly overstated the contribution of goats to Bangladesh's agricultural emissions (Sapkota *et al.*, 2021) The Tier-2 method, by incorporating country-specific data on breed distribution and animal physiology, provides a more accurate and defensible baseline (IPCC, 2019). This refined baseline is not merely an academic exercise; it is essential for formulating effective and efficient climate change mitigation policies (Niloofar *et al.*, 2021). Accurate data ensures that resources are allocated appropriately and that the success of emission reduction strategies can be measured reliably, thereby enhancing the integrity of Bangladesh's national reporting under international climate agreements.

While this study strengthens the inventory through localized EFs, certain limitations should be acknowledged. The calculations relied on several IPCC default coefficients, such as the methane conversion factor (Ym) and energy availability ratios (REM, REG), which may not capture the full variability of Bangladeshi feeding systems (Habib *et al.*, 2023). Furthermore, the energy requirement calculations involved assumptions, such as the use of a default value for the energy content of milk. Future research should aim to derive these parameters from direct measurements on local feedstuffs and animal performance to further refine the accuracy of the estimates. However, for non-cattle livestock, the IPCC Tier 1 method utilizes default emission factors from literature with indicated live-weight, which may not always accurately represent the specific conditions of a region like Bangladesh due to the limitations of expert opinion in establishing these factors (Chang *et al.*, 2019).

Despite the lower per-capita emissions identified in this study, the absolute methane output from Bangladesh's goat population is projected to continue its gradual increase, driven solely by the consistent growth in animal numbers. This trend underscores a critical challenge: balancing the socio-economic importance of goats for rural livelihoods (Bezabih and Berhane, 2014; Feleke *et al.*, 2016) with the environmental imperative of managing greenhouse gas emissions. Therefore, future mitigation efforts should not focus on curbing the population of this vital livestock resource, but rather on exploring strategies to improve feed efficiency and productivity at the individual animal level. This approach can enhance food security and farmer income while potentially stabilizing or even reducing the emission intensity per unit of product, aligning agricultural development with climate goals.

CONCLUSION

This study shows that applying the IPCC Tier-2 technique, which is based on data from each country, changes the estimation of methane emissions from Bangladesh's goat sector in a big way. The emission factors for Black Bengal and Jamunapari goats, which are 2.24 and 3.01 kg CH_4 head^{-1} year^{-1}, are far lower than the IPCC Tier-1 baseline. This suggests that earlier estimates of emissions were probably too high by about 115%. The main reason for this difference is that indigenous Bangladeshi goats are much smaller than the normal weight used to set the Tier-1 default value. So, we strongly suggest that Bangladesh's national greenhouse gas inventory officially use Tier-2 methods to set a more accurate and defensible baseline. This precise baseline is an essential requirement for formulating effective and targeted mitigation methods. Even while the total emissions are going up with the population, the low per-capita emission intensity means that future efforts should be on making animals more productive and efficient with their food instead of reducing their numbers. This would help both climate and livelihood goals. To improve these estimations even further and come up with useful ways to reduce methane emissions in the cattle sector, future research has to focus on finding region-specific coefficients for energy conversion and methane yield.

Acknowledgement

The author wishes to express his gratitude to the Department of Animal Science and Nutrition and kindly thank the staffs and friends for their unwavering helps.

REFERENCES

- Bezabih, M., & Gebreyohannes, B. (2014). Livestock production systems analysis: review.
- Das, N. G., Sarker, N. R., & Haque, M. N. (2020). An estimation of greenhouse gas emission from livestock in Bangladesh. *Journal of advanced veterinary and animal research*, *7*(1), 133.
- DLS (Department of Livestock Services). 2021. Livestock economy at a glance (2020-2021).
- FAO. 2020. Emissions due to agriculture. Global, regional and country trends 2000-2018. FAOSTAT Analytical Brief Series No 18. Rome.
- Feleke, F. B., Berhe, M., Gebru, G., & Hoag, D. (2016). Determinants of adaptation choices to climate change by sheep and goat farmers in Northern Ethiopia: The case of Southern and Central Tigray, Ethiopia. *SpringerPlus*, *5*(1), 1692.
- Fernández, C. (2018). Dynamic model development of enteric methane emission from goats based on energy balance measured in indirect open circuit respiration calorimeter. *Global Ecology and Conservation*, *15*, e00439.
- Foris, B., Thompson, A. J., Von Keyserlingk, M. A. G., Melzer, N., & Weary, D. M. (2019). Automatic detection of feeding-and drinking-related agonistic behavior and dominance in dairy cows. *Journal of dairy science*, *102*(10), 9176-9186.
- Gawat, M., Boland, M., Singh, J., & Kaur, L. (2023). Goat meat: Production and quality attributes. *Foods*, *12*(16), 3130.
- Goopy, J. P., Ndung'u, P. W., Onyango, A., Kirui, P., & Butterbach-Bahl, K. (2021). Calculation of new enteric methane emission factors for small ruminants in western Kenya highlights the heterogeneity of smallholder production systems. *Animal Production Science*, *61*(6), 602-612.
- Habib, M. A., Islam, S. M., Haque, M. A., Hassan, L., Ali, M. Z., Nayak, S., ... & Gaihre, Y. K. (2023). Effects of irrigation regimes and rice varieties on methane emissions and yield of dry season rice in Bangladesh. *Soil Systems*, *7*(2), 41.
- Hoque, S. M., Islam, M. M., Selim, A. S. M., Ahmed, S., & Rahman, M. M. (2017). Estimation of total methane emission from enteric fermentation of ruminant livestock in Bangladesh. *Asian Journal of Medical and Biological Research*, *3*(2), 245-253.
- Intergovernmental Panel on Climate Change (IPCC). (2019). *2019 Refinement to the 2006 IPCC guidelines for national greenhouse gas inventories*.
- Kerven, C. (2024). Contribution of goats to climate change: how and where?. *Pastoralism: Research, Policy and Practice*, *14*, 13988.
- Khan, M. K., & Naznin, M. (2013). Study the live weight and live weight gain of black bengal and jamunapari goat breeds by fitting the linear regression under semi-intensive conditions. *Pakistan Journal of Biological Sciences: PJBS*, *16*(19), 998-1003.
- Korir, D., Ndung'u, W. P., Onyango, A., Arndt, C., Goopy, J., Marquardt, S., & Eckard, R. (2023). IPCC Tier 1 methodology overestimates the carbon footprint of smallholder cattle production systems in Kenya.
- Lassey, K. R. (2008). Livestock methane emission and its perspective in the global methane cycle. *Australian Journal of Experimental Agriculture*, *48*(2), 114-118.
- Maze, M., Taqi, M. O., Tolba, R., Abdel-Wareth, A. A., & Lohakare, J. (2024). Estimation of methane greenhouse gas emissions from livestock in Egypt during 1989 to 2021. *Scientific Reports*, *14*(1), 14992.
- Moller, K., Eeswaran, R., Nejadhashemi, A. P., & Hernandez-Suarez, J. S. (2023). Livestock and aquaculture farming in Bangladesh: Current and future challenges and opportunities. *Cogent Food & Agriculture*, *9*(1), 2241274.
- Mugoti, A., Nyamukanza, C., Munengwa, A., Moyo, S., & Chikumba, N. (2025). Effects of climate change on goat production and mitigatory measures in semiarid savanna ecosystems. *Journal of Integrative Environmental Sciences*, *22*(1), 2513899.
- Ndung'u, P. W., Bebe, B. O., Ondiek, J. O., Butterbach-Bahl, K., Merbold, L., & Goopy, J. P. (2018). Improved region-specific emission factors for enteric methane emissions from cattle in smallholder mixed crop: livestock systems of Nandi County, Kenya. *Animal Production Science*, *59*(6), 1136-1146.
- Niloofar, P., Francis, D. P., Lazarova-Molnar, S., Vulpe, A., Vochin, M. C., Suciu, G., ... & Bartzanas, T. (2021). Data-driven decision support in livestock farming for improved animal health, welfare and greenhouse gas emissions: Overview and challenges. *Computers and Electronics in Agriculture*, *190*, 106406.
- Patra, A. K. (2012). Estimation of methane and nitrous oxide emissions from Indian livestock. *Journal of Environmental Monitoring*, *14*(10), 2673-2684.

- Pison, I., Berchet, A., Saunois, M., Bousquet, P., Broquet, G., Conil, S., ... & Yver Kwok, C. (2018). How a European network may help with estimating methane emissions on the French national scale. *Atmospheric Chemistry and Physics*, *18*(5), 3779-3798.
- Raihan, A., Muhtasim, D. A., Farhana, S., Hasan, M. A. U., Pavel, M. I., Faruk, O., ... & Mahmood, A. (2023). An econometric analysis of Greenhouse gas emissions from different agricultural factors in Bangladesh. *Energy Nexus*, *9*, 100179.
- Reddy, P. R. K., Kumar, D. S., Rao, E. R., Seshiah, C. V., Sateesh, K., Rao, K. A., ... & Hyder, I. (2019). Environmental sustainability assessment of tropical dairy buffalo farming vis-a-vis sustainable feed replacement strategy. *Scientific Reports*, *9*(1), 16745.
- Reisinger, A., Clark, H., Cowie, A. L., Emmet-Booth, J., Gonzalez Fischer, C., Herrero, M., ... & Leahy, S. (2021). How necessary and feasible are reductions of methane emissions from livestock to support stringent temperature goals?. *Philosophical Transactions of the Royal Society A*, *379*(2210), 20200452.
- Roques, S., Martinez-Fernandez, G., Ramayo-Caldas, Y., Popova, M., Denman, S., Meale, S. J., & Morgavi, D. P. (2024). Recent advances in enteric methane mitigation and the long road to sustainable ruminant production. *Annual Review of Animal Biosciences*, *12*(1), 321-343.
- Sapkota, T. B., Khanam, F., Mathivanan, G. P., Vetter, S., Hussain, S. G., Pilat, A. L., ... & Krupnik, T. J. (2021). Quantifying opportunities for greenhouse gas emissions mitigation using big data from smallholder crop and livestock farmers across Bangladesh. *Science of the Total Environment*, *786*, 147344.
- Sarkwa, F. O., Timpong-Jones, E. C., Adogla-Bessa, T., & Antwi, V. (2025). Methane emission of goats fed fifteen diets: on-farm observations. *Online J. Anim. Feed Res*, *15*(2), 69-78.
- Silva, S. R., Sacarrão-Birrento, L., Almeida, M., Ribeiro, D. M., Guedes, C., González Montaña, J. R., ... & de Almeida, A. M. (2022). Extensive sheep and goat production: The role of novel technologies towards sustainability and animal welfare. *Animals*, *12*(7), 885.
- Yemane, G., Melesse, A., & Taye, M. (2020). Evaluation of production systems and husbandry practices of Ethiopian indigenous goats. *Online J. Anim. Feed Res*, *10*(6), 268-277.
- Yona, L., Cashore, B., Jackson, R. B., Ometto, J., & Bradford, M. A. (2020). Refining national greenhouse gas inventories. *Ambio*, *49*(10), 1581-1586.

© 2025 Scholars Journal of Agriculture and Veterinary Sciences | Published by SAS Publishers, India