# A STUDY ON ESTIMATION OF ENTERIC METHANE GAS EMISSION FROM BUFFALO OF BANGLADESH


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# A STUDY ON ESTIMATION OFENTERIC METHANE GAS EMISSION FROM BUFFALO OF BANGLADESH

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# Table of contents

# Chapter I: Abstract

This study aims to estimate the enteric methane emissions from buffalo in Bangladesh using different methods, including Tier-1, Tier-2, GLEAM-i software, and the IFCN method. The research is conducted based on the IPCC 2019 guidelines and incorporates data on buffalo population, feed quality, dry matter intake, and methane yield. The results are compared across these methods to understand variations in emission estimates. The Tier-1 method, a simpler approach, estimates methane emissions using emission factors provided by IPCC (2019) and calculated results was 126.31, 126.90, 127.50 and 128.18 Gigagram (Gg) in the year of 2018-19, 2019-20, 2020-21 and 2021-22 respectively. Tier-2 is a more detailed method, considering factors like dry matter intake and feed composition and our calculated value was 114.74, 115.28, 115.82 and 116.44 Gg as the year mentioned in Tier-1. GLEAM-i software, a comprehensive tool, accounts for various parameters at a regional scaleand here we only calculated the baseline 'BDLivstock2020' value 169.63 Gg. The IFCN method, modified Tier-2 method, focused on farm-level emissions, factors in animal categories and production systems. According to IFCN calculation the results are 104.26, 104.75, 105.24 and 105.80 Gg in same year range in Tier-1 and Tier-2 method. The study found that different methods yield varying estimates of methane emissions, highlighting the importance of methodological choices and data accuracy in such assessments.

# Chapter II: Introduction

Green House Gases (GHGs) are now a global concern due to global warming and climate change. $CO_2$, $CH_4$, $N_2O$ are the major greenhouse gas where methane is 20% more potent than $CO_2$. According to the International Energy Agency (IEA), global methane emission amount is 135 million tons in 2021. About 39% of total emission comes from the agricultural subsector activity. Livestock production is a vital component of global agriculture and also a significant contributor to anthropogenic GHG emissions (Pragna et al., 2021). Methane is produced by buffalo like other ruminants as a product of the fermentation of ingested feed. Ruminants contribute 2,098,787.77 Gg $CO_2$-eq of enteric $CH_4$ to the global GHG pool where buffalo contributes 238,632.78 Gg of $CO_2$-eq enteric $CH_4$ (Faostat). These animals produce $CH_4$ mainly through two pathways, via midgut fermentation and hindgut fermentation. Midgut fermentation or enteric fermentation solely accounts for 91% of total $CH_4$ emission from buffalo (Pragna et al., 2021). In Bangladesh there is less approach to estimate livestock methane emission. Buffalo is a major livestock rearing in Bangladesh. In this study we tried to estimate only enteric methane emission from buffalo in Bangladesh. We followed here Tier-1 and Tier-2 method according to IPCC 2019 guidelines. We also used here GLEAM-i software provided by FAO and IFCN method which is a version of Tier-2 method.

# Chapter III: Methods and Materials

## Tier-1

The easiest method IPCC provides emission factor for Tier-1 to calculate emission from buffalo. We use emission factor provided for Indian subcontinent where smallholder buffalo sector feeding poor quality roughages and crop residues. Buffaloes are mainly free grazing. Concentrates are feed to dairy buffaloes at the last month of pregnancy. This emission factor covers breeding and working bulls, growing animals and calves (Eggelosten et al., 2019).

Total emission for enteric fermentation = $\sum \{EF\ (E, T).\ N\ (T)\}\ /10^6 GgCH_4$/year

Here,

EF=Emission factor

N=Number of buffalo

T=Category (beef/ others) (Eggelosten et al., 2019).

## Tier-2

Tier-2 is more complicated method than Tier-1. In case of Tier-1 the emission factor was provided by IPCC but we need to calculate the emission factor for Tier-2 method. There are three steps in Tier-2 method (Eggelosten et al., 2019)

**Step 1:** Livestock population should be obtained with related activity data.

**Step 2: Calculation of emission factor**

Emission factor should be calculated for each category of buffalo based on dry matter intake and methane conversion factor for each category. The gross energy intake data should be obtained using the following formulas. The following sub-steps need to be completed to calculate the emission factor under the tier-2 method (Eggelosten et al., 2019).

Mainly we have performed the calculation of methane emission based on dry matter intake.

So, Emission factor (EF) = DMI× (MY).365/1000

Here,

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

DMI = kg DMI per day

MY = Methane yield, g $CH_4$ kgDMI-1

Than,

$$DMI= BW^{0.75}\times \{(0.0582\times NE_{mf} - 0.00266\times NE_{mf}\times 2 - 0.0869)/0.239\times NE_{mf}\}$$

Here,

DMI = Dry matter intake

$NE_{mf}$ = Estimated dietary net energy concentration of the feed or diet

BW = Body weight.

**Table 1:** Examples of $NE_{mf}$ content of typical diets fed to cattle for estimation of dry matter intake (Eggelosten et al., 2019).

| **Diet type** | **$NE_{mf}$ (MJ (kg dry matter)-1)** |
|---|---|
| High grain diet > 90% | 7.5 - 8.5 |
| High quality forage (e.g., vegetative legumes & grasses ) | 6.5 - 7.5 |
| Moderate quality forage (e.g., mid-season legume & grasses) | 5.5 - 6.5 |
| Low quality forage (e.g., straws, mature grasses) | 3.5 - 5.5 |

**Obtaining the methane conversion factor ($Y_m$)**

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 ($Y_m$), defined as the percentage of gross energy intake converted to methane ( Eggelosten et al., 2019). If we calculate based on 'dry matter Intake' another parameter 'Methane Yield (MY)' comes. IPCC provided both $Y_m$ and MY for specific cattle category (Eggelosten et al., 2019).

**Table 2:** (Eggelosten et al., 2019)

| Livestock category | Description | Feed quality digestibility (DE %) and neutral detergent fibre (NDF, % DMI). | MY (g $CH_4$ kgDMI-1) | $Y_m$ |
|---|---|---|---|---|
| Dairy Buffalo | High-producing cows (>8500 kg/head/yr-1) | DE ≥ 70<br>NDF ≤ 35 | 19.0 | 5.7 |
| | High-producing cows (>8500 kg/head/yr-1) | DE ≥ 70<br>NDF ≥ 35 | 20.0 | 6.0 |
| | Medium producing cows (5000 – 8500 kg yr-1) | DE 63-70<br>NDF> 37 | 21.0 | 6.3 |
| | Low producing cows (<5000 kg yr^-1 | DE ≤ 62<br>NDF>38 | 21.4 | 6.5 |
| Non-dairy and multi-purpose Buffalo | > 75 % forage | DE ≤ 62 | 23.3 | 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 | 6.3 |
| | Feedlot (all other grains, 0-15% forage). | DE ≥ 72 | 13.6 | 4 |
| | Feedlot (steam flaked corn, ionophore- | DE > 75 | 10 | 3 |

| | | | | |
|---|---|---|---|---|
| | supplement in 0-10% forage). | | | |

**Step-3:** 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) (Eggelosten et al., 2019).

## 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**

$$Y= -17.766 + (42.793 \times DMI) - (0.849 \times DMI)$$

$MEF= (Y/22.4) \times 0.016 \times 36$

Here,

Y = Daily enteric methane emission per head of cattle (Gigagram$CH_4$/year)

MEF = Methane emission factor (kg $CH_4$/head/year) (Eggelosten et al., 2019).

## GLEAM-i software

The GLEAM-i model stands for Global Livestock Environmental Assessment Model – interactive (GLEAM). It is an online, user-friendly and livestock specific tool designed to support governments, project planners, producers, industry and civil society organizations to calculate greenhouse gas emissions using IPCC Tier 2 methods (Resources | Global Livestock Environmental Assessment Model (GLEAM) | Food and Agriculture Organization of the United Nations, n.d.). It can be used in the preparation of national inventories and in ex-ante project evaluation for the assessment of intervention scenarios in animal husbandry, feed and manure management (Berhe et al., 2020).

The GLEAM-i model is based on the FAO Global Livestock Environmental Assessment Model (GLEAM), which is a spatially explicit life cycle assessment model that estimates greenhouse gas emissions from the main livestock commodities such as meat and milk from cattle, sheep, goats and buffalo; meat from pigs; and meat and eggs from chickens. The GLEAM model considers emissions arising from each stage of production, such as feed production, enteric fermentation, manure management, processing and transport.
The GLEAM-i calculation consists of four modules for data input and output, representing the main livestock production stages (Food and Agriculture Organization [FAO], 2017):

- **Herd module:** This module allows the user to define the animal population, the herd structure, the animal performance and the mortality rates for each livestock species and production system.
- **Feed module:** This module allows the user to define the feed ration, the feed digestibility and the feed losses for each livestock species and production system.
- **Manure module:** This module allows the user to define the manure management system, the manure excretion and the manure application for each livestock species and production system.
- **System module:** This module allows the user to define the processing and transport of livestock products, such as meat, milk and eggs, as well as the land use change associated with feed production.

The GLEAM-i calculation also requires the user to select a **region** and a **scenario**. The region defines the geographical scope of the analysis, while the scenario defines the baseline and alternative conditions for comparison. The user can choose from predefined regions and scenarios or create custom ones.

## IFCN method

The **IFCN method** is a methodology developed by the **International Farm Comparison Network (IFCN)** to estimate livestock methane emissions and emission intensities at the farm level. The IFCN method is based on the following procedures (IFCN, n.d.):

**1. Data Collection**: Gather information on the cattle population, including the number of animals, their weight, and the type of diet they are consuming.

**2. Diet Composition**: Determine the composition of the cattle's diet in terms of different feed sources such as grains, forage, and concentrates.

**3. Methane Factors Conversion:** Calculate the methane conversion factors for each type of feed. These factors indicate the amount of methane produced per unit of feed consumed. These factors can vary based on factors like the type of feed, animal size, and management practices.

**4. Enteric Fermentation**: Multiply the amount of each feed type consumed by its respective methane conversion factor to estimate methane emissions.

**5. Total emissions of Methane**: Sum up the methane emissions from enteric fermentation for each feed category to get the total methane emissions from the cattle population.

The IFCN method uses data from various sources, such as FAOSTAT, GLEAM, national statistics, scientific literature and expert opinions. The IFCN method also uses a model farm approach, which means that representative farms are selected for each animal category and production system in each country or region, and their methane emissions and emission intensities are calculated and extrapolated to the national or regional level.
The IFCN Tier 2 method takes into account various factors such as animal performance, feed intake, and feed composition to provide more accurate estimates of enteric methane emissions from cattle. It is important to use locally relevant data and validated estimation methods to ensure accurate and reliable results (Hemme et al., 2019).

## Estimation by different models

**Emission of methane based on tier-1 system:**

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

**Step 1:** Estimation of buffalo numbers. Here is no categorization of buffalo for Tier-1 method because IPCC didn't provide any emission factor for category or subcategory. Here, the buffalo population data in table 3 are collected from DLS (Department of Livestock Service [DLS], 2023).

**Table 3: The buffalo population of Bangladesh (in lakh number)**

| **Year** | **Total Buffalo** |
|---|---|
| 2018-19 | 14.86 |
| 2019-20 | 14.93 |
| 2020-21 | 15.00 |
| 2021-22 | 15.08 |

**Step 2:** Collection of emission factor from IPCC guideline 2019.For Indian subcontinent IPCC-2019 provided emission factor for Buffalo is 85.

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

## Emission of methane based on tier-2 system (2019)

**Step 1 (Methane yield development)**

Here methane yield is provided by IPCC-2019 for different buffalo categories and subcategories. For Bangladesh perspective methane yield showed in Table 2.

**Step 2 (Emission factor development)**

To develop emission factor we need DMI value. Again to estimate DMI value we need the data of body weight followed by estimated dietary net energy concentration of the feed or diet ($NE_{mf}$). The $NE_{mf}$ values are given in table 1. The body weight of buffalo at growing stage is on average 220 kg (Jainudeen, 2002) before first conception.

**Step 3 (Total emission calculation)**

Total emission will be calculated by multiplying the number of buffalo with emission factor.

## Emission of methane based on GLEAM-i software

In case of GLEAM-i method we need to input data for herd module, feed module, manure module and system module. Besides these data we also need to select base line and scenario. All the data inputted in gleam-i app is given below.

**Region:** South Asia

**Country:** Bangladesh

**Animal species:** Buffalo

**Production system:** Grassland, Mixed

**Orientation:** Meat, Dairy

**Selection of parameters:** All parameters except for production and feedlot (herd), adult females and meat animals (feed).

**Baseline name:** BDLivestock2020

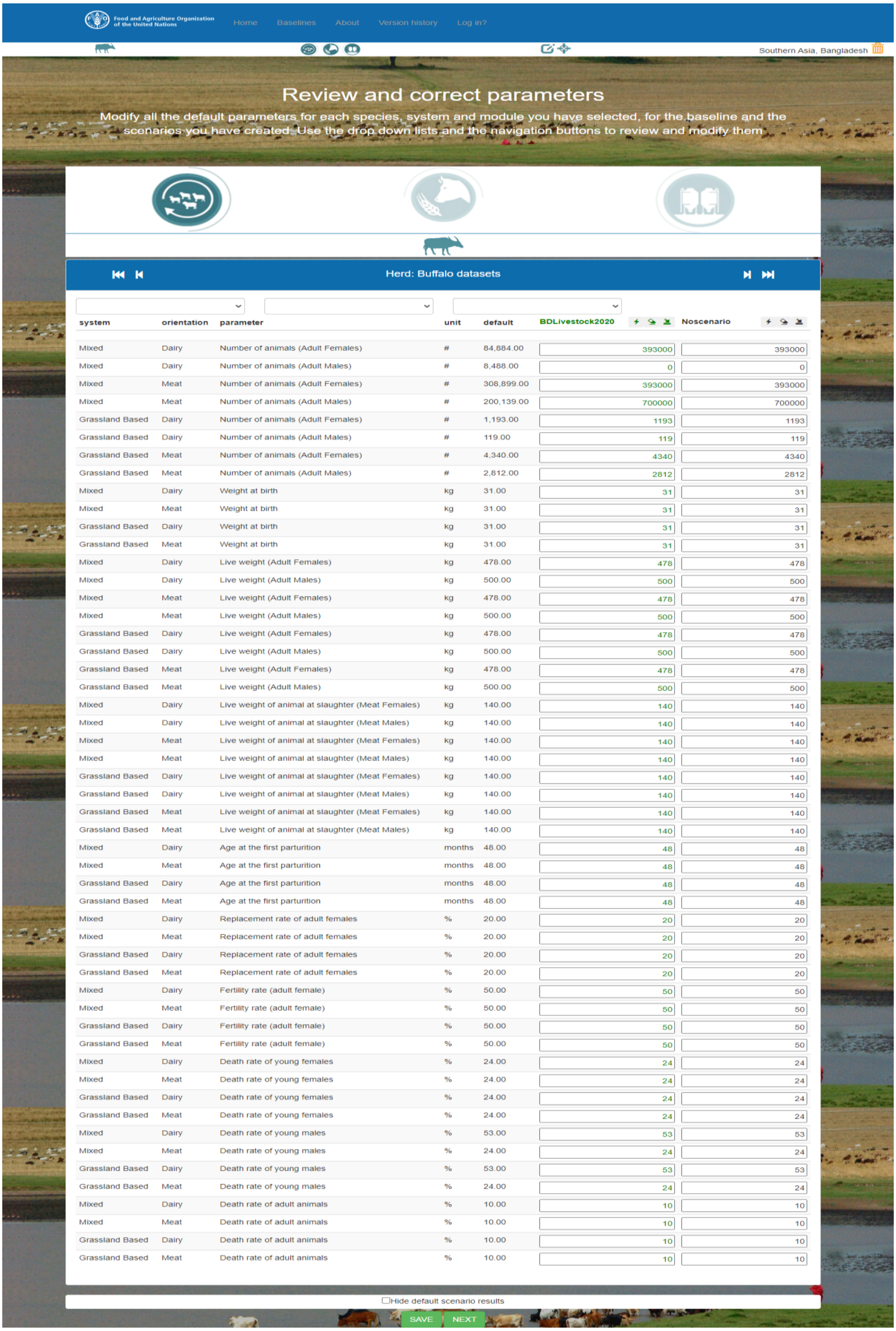
**Scenario name:** NoScenario

In our study we didn't work with the scenario (NoScenario), we didn't compare BDLivestock2020 baseline with this scenario. This was inputted as compulsory category of software. So the scenario data are as same as baseline data.

We only simulated the calculation with the baseline BDLivestock2020 because we don't have sufficient data of herd, feed and manure module for every year in Bangladesh.

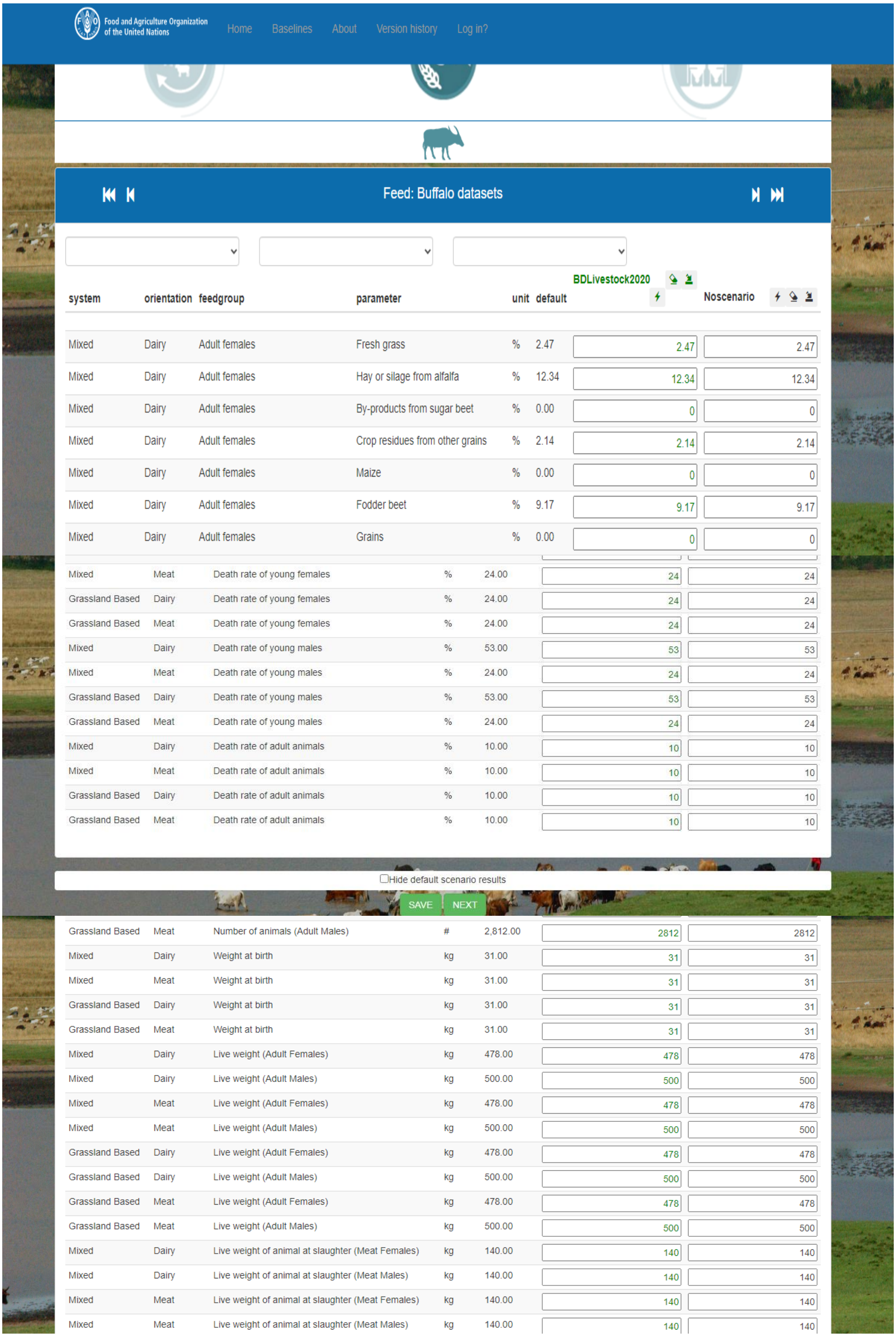
Therefore, the baseline and scenario data will be as like figure-1 (herd module), figure-2 (feed module) and figure-3 (manure module).

**Figure 1:** Herd data for buffalo (FAO, n.d)




| system | orientation | parameter | unit | default | BDLivestock2020 | Noscenario |
|---|---|---|---|---|---|---|
| Mixed | Dairy | Number of animals (Adult Females) | # | 84,884.00 | 393000 | 393000 |
| Mixed | Dairy | Number of animals (Adult Males) | # | 8,488.00 | 0 | 0 |
| Mixed | Meat | Number of animals (Adult Females) | # | 308,899.00 | 393000 | 393000 |
| Mixed | Meat | Number of animals (Adult Males) | # | 200,139.00 | 700000 | 700000 |
| Grassland Based | Dairy | Number of animals (Adult Females) | # | 1,193.00 | 1193 | 1193 |
| Grassland Based | Dairy | Number of animals (Adult Males) | # | 119.00 | 119 | 119 |
| Grassland Based | Meat | Number of animals (Adult Females) | # | 4,340.00 | 4340 | 4340 |
| Grassland Based | Meat | Number of animals (Adult Males) | # | 2,812.00 | 2812 | 2812 |
| Mixed | Dairy | Weight at birth | kg | 31.00 | 31 | 31 |
| Mixed | Meat | Weight at birth | kg | 31.00 | 31 | 31 |
| Grassland Based | Dairy | Weight at birth | kg | 31.00 | 31 | 31 |
| Grassland Based | Meat | Weight at birth | kg | 31.00 | 31 | 31 |
| Mixed | Dairy | Live weight (Adult Females) | kg | 478.00 | 478 | 478 |
| Mixed | Dairy | Live weight (Adult Males) | kg | 500.00 | 500 | 500 |
| Mixed | Meat | Live weight (Adult Females) | kg | 478.00 | 478 | 478 |
| Mixed | Meat | Live weight (Adult Males) | kg | 500.00 | 500 | 500 |
| Grassland Based | Dairy | Live weight (Adult Females) | kg | 478.00 | 478 | 478 |
| Grassland Based | Dairy | Live weight (Adult Males) | kg | 500.00 | 500 | 500 |
| Grassland Based | Meat | Live weight (Adult Females) | kg | 478.00 | 478 | 478 |
| Grassland Based | Meat | Live weight (Adult Males) | kg | 500.00 | 500 | 500 |
| Mixed | Dairy | Live weight of animal at slaughter (Meat Females) | kg | 140.00 | 140 | 140 |
| Mixed | Dairy | Live weight of animal at slaughter (Meat Males) | kg | 140.00 | 140 | 140 |
| Mixed | Meat | Live weight of animal at slaughter (Meat Females) | kg | 140.00 | 140 | 140 |
| Mixed | Meat | Live weight of animal at slaughter (Meat Males) | kg | 140.00 | 140 | 140 |
| Grassland Based | Dairy | Live weight of animal at slaughter (Meat Females) | kg | 140.00 | 140 | 140 |
| Grassland Based | Dairy | Live weight of animal at slaughter (Meat Males) | kg | 140.00 | 140 | 140 |
| Grassland Based | Meat | Live weight of animal at slaughter (Meat Females) | kg | 140.00 | 140 | 140 |
| Grassland Based | Meat | Live weight of animal at slaughter (Meat Males) | kg | 140.00 | 140 | 140 |
| Mixed | Dairy | Age at the first parturition | months | 48.00 | 48 | 48 |
| Mixed | Meat | Age at the first parturition | months | 48.00 | 48 | 48 |
| Grassland Based | Dairy | Age at the first parturition | months | 48.00 | 48 | 48 |
| Grassland Based | Meat | Age at the first parturition | months | 48.00 | 48 | 48 |
| Mixed | Dairy | Replacement rate of adult females | % | 20.00 | 20 | 20 |
| Mixed | Meat | Replacement rate of adult females | % | 20.00 | 20 | 20 |
| Grassland Based | Dairy | Replacement rate of adult females | % | 20.00 | 20 | 20 |
| Grassland Based | Meat | Replacement rate of adult females | % | 20.00 | 20 | 20 |
| Mixed | Dairy | Fertility rate (adult female) | % | 50.00 | 50 | 50 |
| Mixed | Meat | Fertility rate (adult female) | % | 50.00 | 50 | 50 |
| Grassland Based | Dairy | Fertility rate (adult female) | % | 50.00 | 50 | 50 |
| Grassland Based | Meat | Fertility rate (adult female) | % | 50.00 | 50 | 50 |
| Mixed | Dairy | Death rate of young females | % | 24.00 | 24 | 24 |
| Mixed | Meat | Death rate of young females | % | 24.00 | 24 | 24 |
| Grassland Based | Dairy | Death rate of young females | % | 24.00 | 24 | 24 |
| Grassland Based | Meat | Death rate of young females | % | 24.00 | 24 | 24 |
| Mixed | Dairy | Death rate of young males | % | 53.00 | 53 | 53 |
| Mixed | Meat | Death rate of young males | % | 24.00 | 24 | 24 |
| Grassland Based | Dairy | Death rate of young males | % | 53.00 | 53 | 53 |
| Grassland Based | Meat | Death rate of young males | % | 24.00 | 24 | 24 |
| Mixed | Dairy | Death rate of adult animals | % | 10.00 | 10 | 10 |
| Mixed | Meat | Death rate of adult animals | % | 10.00 | 10 | 10 |
| Grassland Based | Dairy | Death rate of adult animals | % | 10.00 | 10 | 10 |
| Grassland Based | Meat | Death rate of adult animals | % | 10.00 | 10 | 10 |

**Figure 2**: Feed data for buffalo (FAO, n.d)



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Feed: Buffalo datasets

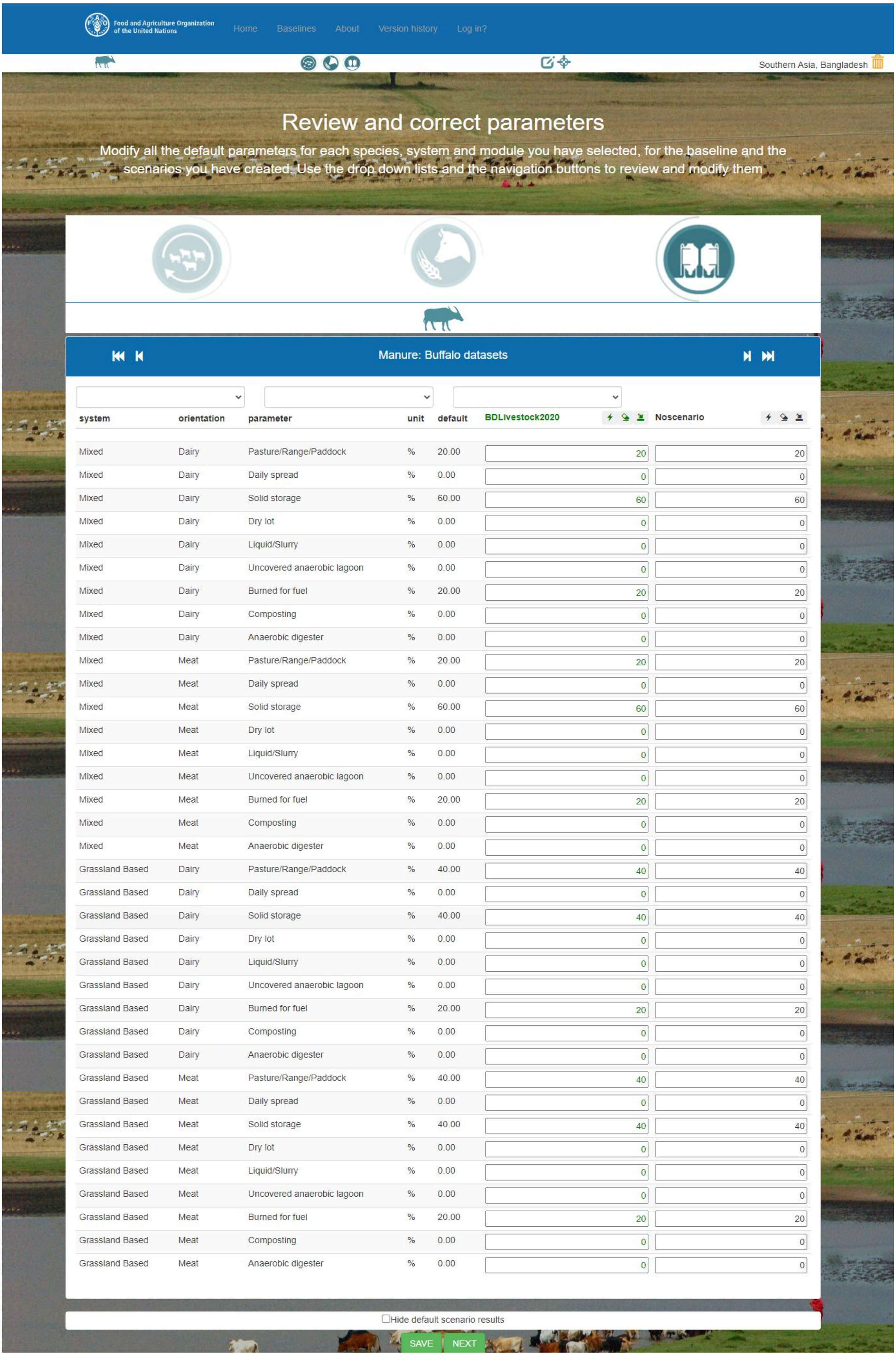
| system | orientation | feedgroup | parameter | unit | default | BDLivestock2020 | Noscenario |
|---|---|---|---|---|---|---|---|
| Mixed | Dairy | Adult females | Fresh grass | % | 2.47 | 2.47 | 2.47 |
| Mixed | Dairy | Adult females | Hay or silage from alfalfa | % | 12.34 | 12.34 | 12.34 |
| Mixed | Dairy | Adult females | By-products from sugar beet | % | 0.00 | 0 | 0 |
| Mixed | Dairy | Adult females | Crop residues from other grains | % | 2.14 | 2.14 | 2.14 |
| Mixed | Dairy | Adult females | Maize | % | 0.00 | 0 | 0 |
| Mixed | Dairy | Adult females | Fodder beet | % | 9.17 | 9.17 | 9.17 |
| Mixed | Dairy | Adult females | Grains | % | 0.00 | 0 | 0 |
| Mixed | Meat | | Death rate of young females | % | 24.00 | 24 | 24 |
| Grassland Based | Dairy | | Death rate of young females | % | 24.00 | 24 | 24 |
| Grassland Based | Meat | | Death rate of young females | % | 24.00 | 24 | 24 |
| Mixed | Dairy | | Death rate of young males | % | 53.00 | 53 | 53 |
| Mixed | Meat | | Death rate of young males | % | 24.00 | 24 | 24 |
| Grassland Based | Dairy | | Death rate of young males | % | 53.00 | 53 | 53 |
| Grassland Based | Meat | | Death rate of young males | % | 24.00 | 24 | 24 |
| Mixed | Dairy | | Death rate of adult animals | % | 10.00 | 10 | 10 |
| Mixed | Meat | | Death rate of adult animals | % | 10.00 | 10 | 10 |
| Grassland Based | Dairy | | Death rate of adult animals | % | 10.00 | 10 | 10 |
| Grassland Based | Meat | | Death rate of adult animals | % | 10.00 | 10 | 10 |

Hide default scenario results

SAVE  NEXT

| system | orientation | parameter | unit | default | BDLivestock2020 | Noscenario |
|---|---|---|---|---|---|---|
| Grassland Based | Meat | Number of animals (Adult Males) | # | 2,812.00 | 2812 | 2812 |
| Mixed | Dairy | Weight at birth | kg | 31.00 | 31 | 31 |
| Mixed | Meat | Weight at birth | kg | 31.00 | 31 | 31 |
| Grassland Based | Dairy | Weight at birth | kg | 31.00 | 31 | 31 |
| Grassland Based | Meat | Weight at birth | kg | 31.00 | 31 | 31 |
| Mixed | Dairy | Live weight (Adult Females) | kg | 478.00 | 478 | 478 |
| Mixed | Dairy | Live weight (Adult Males) | kg | 500.00 | 500 | 500 |
| Mixed | Meat | Live weight (Adult Females) | kg | 478.00 | 478 | 478 |
| Mixed | Meat | Live weight (Adult Males) | kg | 500.00 | 500 | 500 |
| Grassland Based | Dairy | Live weight (Adult Females) | kg | 478.00 | 478 | 478 |
| Grassland Based | Dairy | Live weight (Adult Males) | kg | 500.00 | 500 | 500 |
| Grassland Based | Meat | Live weight (Adult Females) | kg | 478.00 | 478 | 478 |
| Grassland Based | Meat | Live weight (Adult Males) | kg | 500.00 | 500 | 500 |
| Mixed | Dairy | Live weight of animal at slaughter (Meat Females) | kg | 140.00 | 140 | 140 |
| Mixed | Dairy | Live weight of animal at slaughter (Meat Males) | kg | 140.00 | 140 | 140 |
| Mixed | Meat | Live weight of animal at slaughter (Meat Females) | kg | 140.00 | 140 | 140 |
| Mixed | Meat | Live weight of animal at slaughter (Meat Males) | kg | 140.00 | 140 | 140 |

**Figure 3:** Manure data for buffalo (FAO, n.d)




| system | orientation | parameter | unit | default | BDLivestock2020 | Noscenario |
|---|---|---|---|---|---|---|
| Mixed | Dairy | Pasture/Range/Paddock | % | 20.00 | 20 | 20 |
| Mixed | Dairy | Daily spread | % | 0.00 | 0 | 0 |
| Mixed | Dairy | Solid storage | % | 60.00 | 60 | 60 |
| Mixed | Dairy | Dry lot | % | 0.00 | 0 | 0 |
| Mixed | Dairy | Liquid/Slurry | % | 0.00 | 0 | 0 |
| Mixed | Dairy | Uncovered anaerobic lagoon | % | 0.00 | 0 | 0 |
| Mixed | Dairy | Burned for fuel | % | 20.00 | 20 | 20 |
| Mixed | Dairy | Composting | % | 0.00 | 0 | 0 |
| Mixed | Dairy | Anaerobic digester | % | 0.00 | 0 | 0 |
| Mixed | Meat | Pasture/Range/Paddock | % | 20.00 | 20 | 20 |
| Mixed | Meat | Daily spread | % | 0.00 | 0 | 0 |
| Mixed | Meat | Solid storage | % | 60.00 | 60 | 60 |
| Mixed | Meat | Dry lot | % | 0.00 | 0 | 0 |
| Mixed | Meat | Liquid/Slurry | % | 0.00 | 0 | 0 |
| Mixed | Meat | Uncovered anaerobic lagoon | % | 0.00 | 0 | 0 |
| Mixed | Meat | Burned for fuel | % | 20.00 | 20 | 20 |
| Mixed | Meat | Composting | % | 0.00 | 0 | 0 |
| Mixed | Meat | Anaerobic digester | % | 0.00 | 0 | 0 |
| Grassland Based | Dairy | Pasture/Range/Paddock | % | 40.00 | 40 | 40 |
| Grassland Based | Dairy | Daily spread | % | 0.00 | 0 | 0 |
| Grassland Based | Dairy | Solid storage | % | 40.00 | 40 | 40 |
| Grassland Based | Dairy | Dry lot | % | 0.00 | 0 | 0 |
| Grassland Based | Dairy | Liquid/Slurry | % | 0.00 | 0 | 0 |
| Grassland Based | Dairy | Uncovered anaerobic lagoon | % | 0.00 | 0 | 0 |
| Grassland Based | Dairy | Burned for fuel | % | 20.00 | 20 | 20 |
| Grassland Based | Dairy | Composting | % | 0.00 | 0 | 0 |
| Grassland Based | Dairy | Anaerobic digester | % | 0.00 | 0 | 0 |
| Grassland Based | Meat | Pasture/Range/Paddock | % | 40.00 | 40 | 40 |
| Grassland Based | Meat | Daily spread | % | 0.00 | 0 | 0 |
| Grassland Based | Meat | Solid storage | % | 40.00 | 40 | 40 |
| Grassland Based | Meat | Dry lot | % | 0.00 | 0 | 0 |
| Grassland Based | Meat | Liquid/Slurry | % | 0.00 | 0 | 0 |
| Grassland Based | Meat | Uncovered anaerobic lagoon | % | 0.00 | 0 | 0 |
| Grassland Based | Meat | Burned for fuel | % | 20.00 | 20 | 20 |
| Grassland Based | Meat | Composting | % | 0.00 | 0 | 0 |
| Grassland Based | Meat | Anaerobic digester | % | 0.00 | 0 | 0 |

## Emission of methane based on IFCN method

### Step 1: Data Collection

Number of buffalo data collected from table-3. We assumed that 85%-90% of buffalo are straw and grassland base in Bangladesh. Along with grass about 10%-15% buffalos are fed some grains and seasonal leguminous forage.

### Step 2: Diet Composition

Rice straw and grass have low quality nutrients with cellulose, hemi-cellulose, low amount of crude protein and some vitamins and minerals. These types of grasses have less than 62% digestibility (Eggelosten et al., 2019). The grains lugume forages have digestibility within 70%  (Eggelosten et al., 2019).

### Step 3: Methane conversion factor

Methane conversion factor and $NE_{mf}$ for each feed type are taken from table-1 and table-2. Here we calculated methane emission factor from methane conversion factor by Tier 2 method based on dry matter intake. We got several emission factors for each feed type.

### Step 4: Enteric fermentation or emission

Methane emission is calculated for each feed category and subcategories by Tier 2 formula.

### Step 5: Total emissions of Methane

Sum up the methane emissions from enteric fermentation for each feed category to get the total methane emissions from the cattle population.

# Chapter III: Results

**For Tier-1 Method:**

Here, our calculated values of methane emission from buffalo are showing in table-5. In table-5 we have shown methane emission in Gigagram per year based on emission factor provided by IPCC 2019.

**Table 5:** Methane emission (Gigagram per year) based on emission factor by IPCC 2019.

| Year | Total Buffalo (in lakh number) | Emission from Buffalo (Gg) |
|---|---|---|
| 2018-19 | 14.86 | 126.31 |
| 2019-20 | 14.93 | 126.90 |
| 2020-21 | 15.00 | 127.50 |
| 2021-22 | 15.08 | 128.18 |

**For Tier-2 Method:**

Our calculation of methane emissions based on tier-2 system is shown in table-6 according to IPCC-2019. In Table-7, there is a comparison between the calculation of methane emission using tier-1 and tier-2 system.

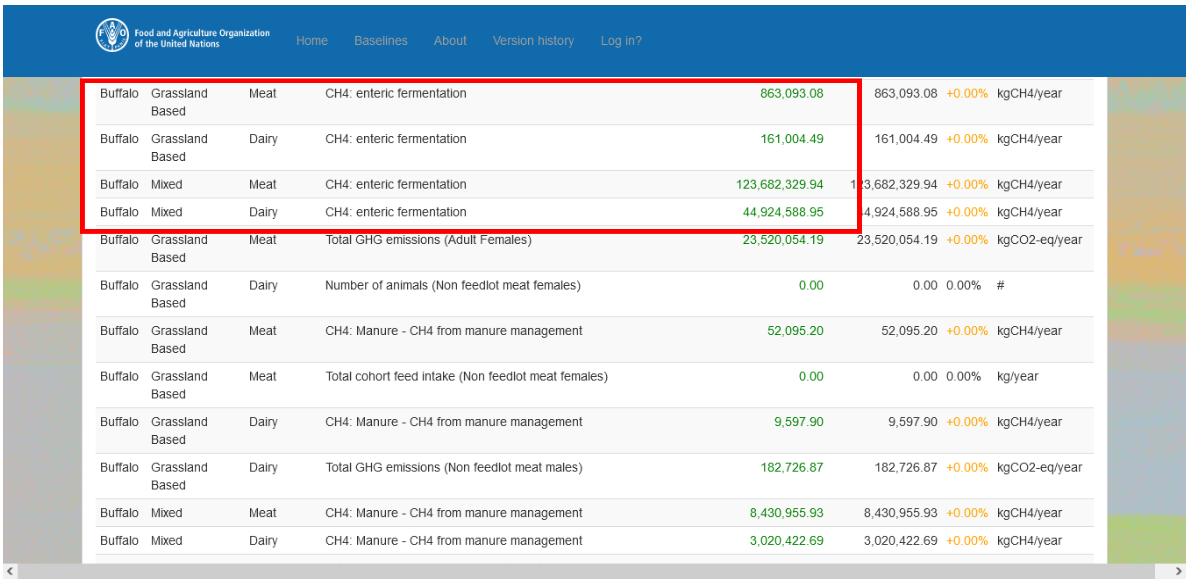
**Table 6:** Methane emission (Gigagram per year) based on Tier-2 method

| Year | Total Buffalo (in lakh number) | Emission from Buffalo (Gg) |
|---|---|---|
| 2018-19 | 14.86 | 114.74 |
| 2019-20 | 14.93 | 115.28 |
| 2020-21 | 15.00 | 115.82 |
| 2021-22 | 15.08 | 116.44 |

**For GLEAM-i software:**

Here we only calculated enteric methane emission from the whole sophisticated result.

**Figure 4:** Enteric $CH_4$emission (red box) from buffalo




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Buffalo | Grassland Based | Meat | CH4: enteric fermentation | 863,093.08 | 863,093.08 | +0.00% | kgCH4/year |
| Buffalo | Grassland Based | Dairy | CH4: enteric fermentation | 161,004.49 | 161,004.49 | +0.00% | kgCH4/year |
| Buffalo | Mixed | Meat | CH4: enteric fermentation | 123,682,329.94 | 1[illegible]3,682,329.94 | +0.00% | kgCH4/year |
| Buffalo | Mixed | Dairy | CH4: enteric fermentation | 44,924,588.95 | [illegible]4,924,588.95 | +0.00% | kgCH4/year |
| Buffalo | Grassland Based | Meat | Total GHG emissions (Adult Females) | 23,520,054.19 | 23,520,054.19 | +0.00% | kgCO2-eq/year |
| Buffalo | Grassland Based | Dairy | Number of animals (Non feedlot meat females) | 0.00 | 0.00 | 0.00% | # |
| Buffalo | Grassland Based | Meat | CH4: Manure - CH4 from manure management | 52,095.20 | 52,095.20 | +0.00% | kgCH4/year |
| Buffalo | Grassland Based | Meat | Total cohort feed intake (Non feedlot meat females) | 0.00 | 0.00 | 0.00% | kg/year |
| Buffalo | Grassland Based | Dairy | CH4: Manure - CH4 from manure management | 9,597.90 | 9,597.90 | +0.00% | kgCH4/year |
| Buffalo | Grassland Based | Dairy | Total GHG emissions (Non feedlot meat males) | 182,726.87 | 182,726.87 | +0.00% | kgCO2-eq/year |
| Buffalo | Mixed | Meat | CH4: Manure - CH4 from manure management | 8,430,955.93 | 8,430,955.93 | +0.00% | kgCH4/year |
| Buffalo | Mixed | Dairy | CH4: Manure - CH4 from manure management | 3,020,422.69 | 3,020,422.69 | +0.00% | kgCH4/year |

So, from the figure-4 the total calculated enteric methane emission from buffalo is 169.63 Gg in the year of 2020.

**For IFCN method**

**Table7**: Emission (Gigagram) estimation by IFCN method

| Year | Buffalo population (in lakh number) | Emission from buffalo (Gg) |
|---|---|---|
| 2018-19 | 14.86 | 104.26 |
| 2019-20 | 14.93 | 104.75 |
| 2020-21 | 15 | 105.24 |
| 2021-22 | 15.08 | 105.80 |

Here are the results for IFCN Tier 2 method.

# Chapter IV: Discussions and Comparisons

**For tier-1 method:**

Here, based on IPCC-2019 in 2018-19, 2019-20, 2020-21, 2021-22 total methane emission from buffalos are 126.31, 126.90, 127.50 and 128.18 Gg respectively. We found that every year methane emission is increasing gradually because the number of buffalo is increasing. The increasing rate is about 0.6 Gg per year. Besides increasing number of buffalo, breed, dry matter intake, management practices, environmental stress are some of the factors influencing enteric methane production (Sejian et al., 2010).

**For tier-2 method:**

In 2018-19, 2019-20, 2020-21 and 2021-22 our calculated emissions of methane from buffalos are 114.74, 115.28, 115.82 and 116.44 Gg respectively based on IPCC 2019. Here is also an increasing trend of methane emission in Tier-2 method may be because of dietary composition, amounts of digestible nutrients, type/population rumen microbe and feeding strategies etc. We can also see a difference of around 11.5 Gg of methane emission between the calculation using Tier-1 and Tier-2 method in every year. This difference is because for slightly lower value of emission factor calculated in Tier-2 method.

**For GLEAM-i software:**

As we have inadequate of herd, feed and manure module data for each year in Bangladesh, we calculated only based on the provided baseline 'BDLivestock2020' and escaped the scenario. Our calculated value of enteric methane emission is 169.63 Gg in the year of 2020.

**For IFCN method:**

According to IFCN Tier 2 (IPCC 2019) method in 2018-19, 2019-20, 2020-21 and 2021-22 our calculated emissions of methane from buffalos are 104.26, 104.75, 105.24 and 105.80 gigagram respectively. Here is also a increasing trend of emission due to increasing of buffalo population every year. Results are lower than Tier 1 and Tier 2 method because IFCN method takes into account various factors such as animal performance, feed intake, and feed composition to provide more accurate estimates of enteric methane emissions from buffalo.

**Table8**: Comparison of methane emission (Gigagram per year) between tier-1, tier-2, IFCN and GLEAM-i method.

| Year | Emission by Tier-1 | Emission by Tier-2 | Emission by IFCN | Emission by GLEAM-i in 2020 |
|---|---|---|---|---|
| 2018-19 | 126.31 | 114.74 | 104.26 | 169.63 |
| 2019-20 | 126.90 | 115.28 | 104.75 | |
| 2020-21 | 127.50 | 115.82 | 105.24 | |
| 2021-22 | 128.18 | 116.44 | 105.80 | |

## Comparison between Tier-2 and GLEAM

The Tier 2 method and the GLEAM (Global Livestock Environmental Assessment Model) software are two different approaches for estimating methane emissions from livestock, including ruminants like cattle and sheep. Here are the key differences between Tier 2 and GLEAM:

**1. Methodology:** The Tier 2 method is a more detailed and complex approach that involves estimating methane emissions based on factors like dry matter intake, feed composition, and animal performance. It takes into account specific parameters related to individual animals or specific production systems. GLEAM, on the other hand, is a comprehensive model that incorporates a broader set of variables, including animal characteristics, management practices, and regional data to estimate greenhouse gas emissions from the entire livestock sector at national or global scales.

**2. Data Requirements:** The Tier 2 method requires detailed data on animal performance, feed composition, and management practices. It relies on specific inputs such as dry matter intake, gross energy intake, methane yield coefficients, and methane conversion factors. In contrast, GLEAM requires a broader range of data, including livestock populations, production systems, feed availability, and management data at a regional or national level.

**3. Application:** The Tier 2 method is typically used for on-farm or localized assessments of methane emissions, providing more detailed estimates at a specific scale. It is often employed by researchers, consultants, or experts to evaluate methane emissions from specific livestock operations. GLEAM, on the other hand, is a tool used at a national or global level to assess and compare greenhouse gas emissions from the livestock sector across different countries or regions. It helps policymakers and researchers to analyze and understand the overall contribution of livestock to global emissions and evaluate potential mitigation strategies.

**4. Complexity:** The Tier 2 method requires manual calculations and data entry based on specific equations and parameters. It involves more hands-on work and may require expert knowledge in livestock emissions estimation. GLEAM, on the other hand, is a software-based model that automates calculations using built-in algorithms and databases. It offers a user-friendly interface and incorporates various input datasets, making it more accessible to a wider range of users.

Both the Tier 2 method and GLEAM have their strengths and limitations. The Tier 2 method provides more localized and detailed estimates, while GLEAM offers a comprehensive and scalable approach for assessing livestock emissions at larger scales. The choice between the two methods depends on the specific needs and goals of the assessment, as well as the available data and expertise.

# Chapter V: Conclusion

The global concern over greenhouse gas emissions and their impact on climate change makes it crucial to estimate methane emissions from livestock. Using different methods, this study shows the complexities and variations of estimating buffalo methane emissions. This study highlights the importance of picking the right method based on the scale of the assessment, data availability, and research goals. Additionally, it emphasizes the need for accurate and consistent data collection to improve emissions estimates. We have to refine and enhance the emission estimation methods for developing effective mitigation strategies and policies in the livestock sector to face climate change challenges.

# Chapter VI: References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# Chapter VII: Review of literature

Enteric methane ($CH_4$) is a greenhouse gas (GHG) produced by ruminant animals during the digestion of feed. About 44 percent of livestock emissions are in the form of methane ($CH_4$). The remaining part is almost equally shared between Nitrous Oxide ($N_2O$, 29 percent) and Carbon Dioxide ($CO_2$, 27 percent) (FAO.2013).

It accounts for about 14.5% of the total anthropogenic GHG emissions from the agriculture sector (Malik et al., 2021a). According to Das et al. (2020) livestock greenhouse gas emissions in Bangladesh was estimated to 30,124 gigagram from enteric fermentation (Das et al., 2020). Buffalo are one of the major sources of enteric $CH_4$ emissions, especially in Asia, where they are widely used for milk, meat, and draught purposes (J. Gibbs et al., 2019). Estimating enteric $CH_4$ emissions from buffalo is important for developing mitigation strategies and assessing their contribution to climate change.

The Intergovernmental Panel on Climate Change (IPCC) provides guidelines for estimating enteric $CH_4$ emissions from livestock using different methods, namely Tier 1, Tier 2, and Tier 3 (Estimating Methane Emissions from Enteric Fermentation Using Tier 2 Method, n.d.). Tier 1 is the simplest and most widely used method, which involves multiplying the number of animals by a default emission factor (EF) for each animal category. Tier 2 is a more accurate and country-specific method, which requires data on animal characteristics, feed intake, and digestibility to calculate the EF. Tier 3 is the most complex and detailed method, which involves using process-based models or direct measurements to estimate the emissions.

Besides the IPCC methods, there are other tools and approaches that can be used to estimate enteric $CH_4$ emissions from buffalo, such as the Global Livestock Environmental Assessment Model interactive (GLEAM-i) and the International Farm Comparison Network (IFCN) method. GLEAM-i is a web-based tool developed by the Food and Agriculture Organization (FAO) that allows users to estimate GHG emissions from livestock production systems at different scales (Krishna & Anggraeny, 2019). IFCN is a network of researchers and experts that provides data and analysis on dairy farm economics and environmental impacts in different countries (Widiawati et al., 2016).

Several studies have compared the enteric $CH_4$ emissions from buffalo estimated by different methods and tools. For example, (Malik et al.,2021b) compared the enteric $CH_4$ yield (g $CH_4$/kg dry matter intake) and diversity of ruminal methanogens in cattle and buffaloes fed on the same diet using the $SF_6$ technique (a Tier 3 method) and found that there was no significant difference between the two species. They also found that the ruminalarchaea community structure was similar in both hosts, with *Methanobrevibacter gottschalkii* being the most dominant species.

According to Hoque et al.(2017), total methane emissions from enteric fermentation of ruminant livestock were estimated. In this study, the Tier-2 method was used. The emission factor for the livestock categories was calculated based on dry matter intake.

Another study by Prasetyo (Prasetyo et al., 2020) compared the enteric $CH_4$emission factors (EFs) for beef cattle in Indonesia using Tier 1, Tier 2, GLEAM-i, and IFCN methods and found that Tier 2 resulted in the lowest EFs, followed by GLEAM-i, IFCN, and Tier 1. They also found that the EFs varied depending on the animal category, feed quality, and production system.

Another scientific paper that describes how the IFCN method was applied to estimate enteric methane emissions for dairy cows in 52 countries using a simplified Tier 2 approach. The paper also provides a comparison of the results with other methods and data sources (Hemme et al., 2019).

A study by M.J. MacLeod, compared the enteric methane emissions from livestock estimated by GLEAM and other studies and found that GLEAM showed higher results. For dairy cattle, GLEAM's estimates were almost 30% higher than the average of 15 other studies. For buffalo, GLEAM's estimates were almost 15% higher than the average of 6 other studies (MacLeod et al., 2018).

In Jahan and Azad (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 2018 to 2021 by using every methods of calculation.

According to Mahmud and Biswas (2022) the methane emission based on tier 2 method (IPCC 2006) in dairy cattle is 544.63, 546.39, 547.56, 548.73 gigagram in 2016, 2017, 2018, 2019 respectively (Mahmud and Biswas, 2022).

The literature review shows that there is no single best method or tool to estimate enteric $CH_4$ emissions from buffalo, as each method has its own assumptions, data requirements, and uncertainties. Therefore, it is important to use the most appropriate method or tool for a given context and purpose, and to report the results transparently with proper documentation and validation. It is also important to conduct more research on the factors affecting enteric $CH_4$ emissions from buffalo, such as breed, diet, management, health, and climate conditions. This will help to improve the accuracy and reliability of the estimates and to develop effective mitigation options.

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