GHG emission inventories: Agriculture Sector

María José (Pepa) López
- Identify major processes leading to emissions in this sector
- Understand the methodological approaches for calculating GHG emissions and their data requirements
- Identify and avoid typical problems with estimating emissions, including issues related to TACCC
- Review Tier methodologies for each category and
- Learn how to use the IPCC software for this sector.
Reporting categories

3 AGRICULTURE, FORESTRY, AND OTHER LAND USE

3A Livestock
   3A1 Enteric Fermentation
   3A2 Manure Management

3B Land
   3B1 Forest Land
   3B2 Cropland
   3B3 Grassland
   3B4 Wetlands
   3B5 Settlements
   3B6 Other Land

3C Aggregate Sources and Non-CO₂ Emissions Sources on Land

3D Other
Introduction- Livestock

• Livestock can result in CH$_4$ emissions from enteric fermentation and both CH$_4$ and N$_2$O emission from livestock manure management systems. Application of manure to soils results in direct and indirect N$_2$O emissions.

• The methods for estimating CH$_4$ and N$_2$O emissions require definitions of livestock subcategories, annual populations and, for higher Tier methods, feed intake and characterizations.
Step 1: Develop Livestock Characterization

**Enhanced**

<table>
<thead>
<tr>
<th>Main categories</th>
<th>Subcategories</th>
</tr>
</thead>
</table>
| **Mature Dairy Cows or Mature Dairy Buffalo**         | • High-producing cows that have calved at least once and are used principally for milk production  
• Low-producing cows that have calved at least once and are used principally for milk production  |
| **Other Mature Cattle or Mature Non-dairy Buffalo**   | • Females:  
  - Cows used to produce offspring for meat  
  - Cows used for more than one production purpose: milk, meat, draft  
  - Males:  
  - Bulls used principally for breeding purposes  
  - Bullocks used principally for draft power  |
| **Growing Cattle or Growing Buffalo**                 | • Calves pre-weaning  
• Replacement dairy heifers  
• Growing / fattening cattle or buffalo post-weaning  
• Fattened-calf cattle on diets containing > 50% concentrates  |
| **Mature Ewes**                                       | • Breeding ewes for production of offspring and wool production  
• Milking ewes where commercial milk production is the primary purpose  |
| **Other Mature Sheep (>1 year)**                      | • No further sub-categorization recommended  |
| **Growing Lambs**                                     | • Intact males  
• Castrates  
• Females  |
| **Mature Swine**                                      | • Sows in gestation  
• Sows which have farrowed and are nursing young  
• Boars that are used for breeding purposes  |
| **Growing Swine**                                     | • Nursery  
• Finishing  
• Gilts that will be used for breeding purposes  
• Growing bears that will be used for breeding purposes  |
| **Chickens**                                          | • Broiler chickens grown for producing meat  
• Layer chickens for producing eggs, wherepurchase is managed in dry systems (e.g., high-rise houses)  
• Layer chickens for producing eggs, where purchase is managed in wet systems (e.g., laying)  
• Chickens under free-range conditions for egg or meat production  |

**Basic**

- Dairy Cows
- Other Cattle
- Buffalo
- Sheep
- Goats
- Camels
- Horses
- Mules and Asses
- Swine
- Poultry
- Other
IPCC Software and Livestock Manager
The amount of CH$_4$ emitted from enteric fermentation also depends on:

- **Animal age**: Older animals tend to emit less CH$_4$
- **Animal weight**: Heavier animals tend to emit more CH$_4$
- **Quality of feed consumed**: Lower quality feed consumed tends to result in greater CH$_4$ emissions
- **Quantity of feed consumed**: Higher quantities of feed consumed tend to result in greater emissions
## Enteric Fermentation Introduction

<table>
<thead>
<tr>
<th>Ruminants</th>
<th>Non-ruminants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Examples of ruminants</strong></td>
<td><strong>Examples of non-ruminant livestock</strong></td>
</tr>
<tr>
<td>• Cattle</td>
<td>• Horses</td>
</tr>
<tr>
<td>• Buffalo</td>
<td>• Mules</td>
</tr>
<tr>
<td>• Goats</td>
<td>• Asses</td>
</tr>
<tr>
<td>• Sheep</td>
<td>• Swine</td>
</tr>
<tr>
<td>• Deer</td>
<td></td>
</tr>
<tr>
<td>• Camels</td>
<td></td>
</tr>
</tbody>
</table>

**More methane**

**Less methane**
Enteric: General Approach

General approach applies to all methodological tiers and can be performed at varying levels of detail and complexity

Step 1: Divide livestock population into subgroups

Step 2: Apply EFs for each subgroup (kg CH₄/head)

Step 3: For each livestock type, multiply population * EF

Step 4: Sum emissions across all livestock categories
Enteric Fermentation: Methodological Choice

Tier 1:
Number of heads and Application of default EFs

Tier 2:
EF requires data on gross energy intake and methane conversion factors

Tier 3:
Additional country specific information
May use models, consider diet composition, seasonal variation in population
Experimental data
CH$_4$ Emissions from Enteric Fermentation: Tier 1 Method

**Equation 10.19**

ENTERIC FERMENTATION EMISSIONS FROM A LIVESTOCK CATEGORY

\[
\text{Emissions} = \text{EF}(\gamma) \cdot \left( \frac{N(\gamma)}{10^6} \right)
\]

Where:
- Emissions = methane emissions from Enteric Fermentation, Gg CH$_4$ yr$^{-1}$
- EF(\gamma) = emission factor for the defined livestock population, kg CH$_4$ head$^{-1}$ yr$^{-1}$
- N(\gamma) = the number of head of livestock species / category $T$ in the country
- $T$ = species/category of livestock

**Equation 10.20**

TOTAL EMISSIONS FROM LIVESTOCK ENTERIC FERMENTATION

\[
\text{Total CH}_4\text{Enterc} = \sum_{i} E_i
\]

Where:
- Total CH$_4$\text{Enterc} = total methane emissions from Enteric Fermentation, Gg CH$_4$ yr$^{-1}$
- $E_i$ = is the emissions for the $i^{th}$ livestock categories and subcategories
IPCC Software: Enteric Fermentation
CH$_4$ Emissions from Manure Management

CH$_4$ emissions affected by:

- Amount of manure produced
  - Number of animals
  - Waste production / animal
- Portion that decomposes anaerobically
  - System in which manure is managed (liquid systems yield more methane)
  - Temperature
  - Retention time

Main manure management systems

Manure may be:
- Spread daily on croplands or pastures
- Stored as a solid in stacks
- Stored on a dry lot
- Managed as a liquid or slurry in tanks or ponds
- Managed in an uncovered anaerobic lagoon
- Stored in pits below animal confinements
- Managed in an anaerobic digester
- Burned for fuel
- Composted
- For poultry, managed with or without litter
- Aerobically treated
**N₂O Emissions from Manure Management**

**Direct N₂O emissions**
- Result from nitrification / denitrification of nitrogen in the manure
- N₂O emissions affected by:
  - Amount of manure produced
  - Nitrogen content of manure
  - Manure management system
  - Duration of the storage

**Indirect N₂O emissions**
- Result from volatilization of nitrogen in the form of ammonia and NOx
- The amount of volatilization is a function of storage time and to a lesser extent, temperature
- Indirect N₂O emissions also through leaching and run-off; however 2006 GL provide only Tier 2 method
Manure CH$_4$: Methodological Choice

Tier 1:
Livestock population by region
IPCC default EFs

Tier 2:
Enhanced livestock characteristics
More detailed manure management practices

Tier 3:
Country-specific methods, including measurement based
CH$_4$ Emissions from Manure Management: Tier 1 Method

Equation 10.22 shows how to calculate CH$_4$ emissions from manure management:

**EQUATION 10.22**

CH$_4$ EMISSIONS FROM MANURE MANAGEMENT

\[ CH_{4_{\text{Manure}}} = \sum_{(T)} \left( \frac{EF_{(T)} \cdot N_{(T)}}{10^6} \right) \]

Where:

- $CH_{4_{\text{Manure}}}$ = CH$_4$ emissions from manure management, for a defined population, Gg CH$_4$ yr$^{-1}$
- $EF_{(T)}$ = emission factor for the defined livestock population, kg CH$_4$ head$^{-1}$ yr$^{-1}$
- $N_{(T)}$ = the number of head of livestock species/category $T$ in the country
- $T$ = species/category of livestock
Manure Management CH$_4$: Collection of AD

- Collect livestock data (refer to livestock characterization)
- Collect fraction of manure treated in different systems, by livestock and specifies region if applicable.

<table>
<thead>
<tr>
<th>System</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture/Range/Paddock</td>
<td>The manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed.</td>
</tr>
<tr>
<td>Daily spread</td>
<td>Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.</td>
</tr>
<tr>
<td>Solid storage</td>
<td>The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.</td>
</tr>
<tr>
<td>Dry lot</td>
<td>A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically.</td>
</tr>
<tr>
<td>Liquid/Shurry</td>
<td>Manure is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the animal housing, usually for periods less than one year.</td>
</tr>
<tr>
<td>Uncovered anaerobic lagoon</td>
<td>A type of liquid storage system designed and operated to combine waste stabilization and storage. Lagoon supernate is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The water from the lagoon may be recycled as flush water or used to irrigate and fertilize fields.</td>
</tr>
<tr>
<td>Pit storage below animal confinement</td>
<td>Collection and storage of manure usually with little or no added water typically below a slanted floor in an enclosed animal confinement facility, usually for periods less than one year.</td>
</tr>
<tr>
<td>Anaerobic digester</td>
<td>Animal excreta with or without straw are collected and anaerobically digested in a large containment vessel or covered lagoon. Digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to CO$_2$ and CH$_4$, which is captured and flared or used as a fuel.</td>
</tr>
<tr>
<td>Burned for fuel</td>
<td>The dung and urine are excreted on fields. The sun-dried dung cakes are burned for fuel.</td>
</tr>
<tr>
<td>Castle and Swine deep bedding</td>
<td>As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 8 to 12 months. This manure management system also is known as a bedded pack manure management system and may be combined with a dry lot or pasture.</td>
</tr>
</tbody>
</table>

Note: This table is an extract from the 2006 GL; refer to the GL for the full table.
Manure Management CH$_4$- Tier 1 EFs

- Be sure to select an appropriate temperature region
- The annex 10A.2 in the 2006 GL describes how factors were selected, if characteristics not representative, adjust.
- If multiple temperature zones, estimate a weighted average EF.
Adding CH₄ from Manure Management to IPCC software

• Go to Livestock manager under “Administrate”

  • Add relevant livestock data, manure management system and regional data to Livestock Manager.

  Under manure management, select the animal type, then the drop down under “Region”

  • Open the button next to the region; select your animal type. Data from the Livestock Manager will automatically populate. Select screen for CH₄ emissions

  Select EF from drop down and select save. You may overwrite a country-specific value.
$\text{CH}_4$ from Manure Management: Output of IPCC software
Direct \( \text{N}_2\text{O} \) Emissions from Manure Management: General Approach

- **General approach** applies to all methodological tiers and can be performed at varying levels of detail and complexity

**Step 1:** Divide livestock population into subgroups

**Step 2:** Apply default or CS values for nitrogen excretion rate/head for each subgroup

**Step 3:** Use default values or determine fraction of total Nitrogen excretion for each livestock in each manure mgmt. system (MMS)

**Step 4:** Use default values or develop \( \text{N}_2\text{O} \) EFs for each MMS

**Step 5:** For each MMS multiply EF * nitrogen managed in that system
Manure Direct $N_2O$: Methodological Choice

Tier 1:
Multiply default nitrogen excretion by livestock category/region by default MMS regions and EFs

Tier 2:
Same as tier 1 but with use of some country-specific data (e.g. NEx rate)

Tier 3:
Country-specific methods, including process- or mass-balanced based
Adding Direct $\text{N}_2\text{O}$ Emissions from Manure Management to IPCC software

1-2 You have already entered basic data under the Livestock Manager
3. Enter each type of MMS and the fractions (taken from annex tables 10.A.4- 10.A.9)
4. Enter fraction of manure in each MMS
5. I have selected at this point the fraction of $\text{N}$ loss, but that is for calculating indirect $\text{N}_2\text{O}$
6. Don’t forget to save!
7. Toggle to the “Direct $\text{N}_2\text{O}$ emissions” tab
8 and 9. Enter default or country specific $\text{EF}$ for the respective MMS; note that there is an exclamation point until you enter the relevant data.
10. Calculation of $\text{N}_2\text{O}$ emissions
Indirect N$_2$O Emissions Volatilization from Manure Management: IPCC Software

1. Select the first tab for indirect emissions from volatilization
2. Data on the total nitrogen in each MMS was already available from direct N$_2$O calculations
3. Default fractions of the amount of N that volatilizes is in Table 10.22 of the 2006 GL
4. The IPCC default EFs for all MMS = 0.01 kg N2O-N
5. Calculation of indirect N$_2$O emissions
THANK YOU!

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