GHG Emissions: Agriculture sector

Livestock & Soils

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Belize

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Outline

- Identify major processes leading to emissions in Agriculture sector
- Understand the methodological approaches for calculating GHG emissions and their data requirements
- Apply at least a Tier 1 methodology to calculate emissions from the Agriculture sector

AFOLU Sector Structure

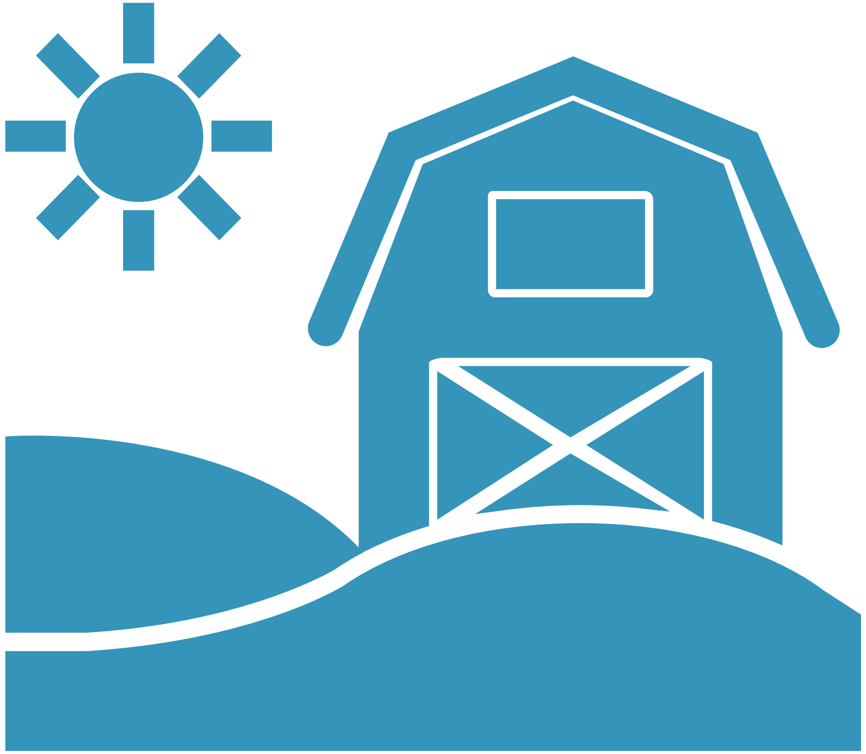
- AFOLU = **A**griculture, **F**orestry and **O**ther **L**and **U**se

3 Agriculture, Forestry and Other Land Use (AFOLU)

- 3A Livestock
  - 3A1 Enteric fermentation
  - 3A2 Manure management
- 3B Land
  - 3B1 Forest land
  - 3B2 Cropland
  - 3B3 Grassland
  - 3B4 Wetlands
  - 3B5 Settlements
  - 3B6 Other lands
- 3C Aggregated and non-CO_2 emission sources on land
  - 3C1 Biomass burning
  - 3C2 Liming
  - 3C3 Urea application
  - 3C4 Direct N_2O from managed soils
  - 3C5 Indirect N_2O from managed soils
  - 3C6 Indirect N_2O from manure management
  - 3C7 Rice cultivation
- 3D Other
  - 3D1 Harvested wood products

AGRICULTURE

Agriculture Sector: Emission Sources



- CH_4 emissions from enteric fermentation from all livestock categories (except poultry)
- Emissions of CH_4 and N_2O (direct and indirect) from manure management practices of all livestock manure (including poultry)

- Emissions (CO_2, CH_4, N_2O, CO, NO_x) from biomass burning which includes crop residue burning
- Emissions of CO_2 from lime and urea application to fields

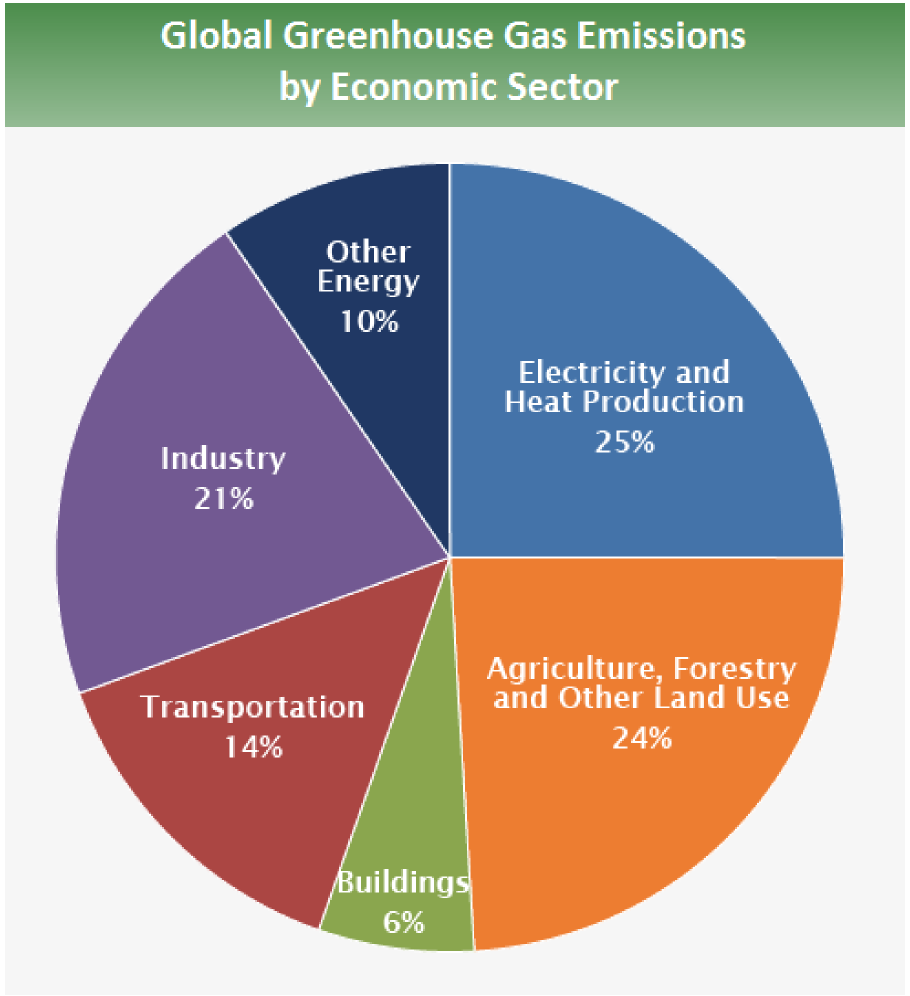
- Direct and indirect emissions of N_2O from application of nitrogen (organic and inorganic) to managed soils
- CH_4 emissions from rice production

AFOLU emissions

- Agriculture
  - Livestock (CH_4)
  - Manure (CH_4; N_2O)
  - Agricultural soils (N_2O; CO_2)
    - Synthetic fertilisers
    - Crop residues
    - Lime/urea application
  - Crop burning (CH_4; N_2O; CO_2)
  - Rice cultivation (CH_4)
- Forestry and other LU emissions (CO_2)
  - Forest lands (including deforestation)
  - Croplands
  - Grasslands
  - Wetlands
  - Settlements

Introduction

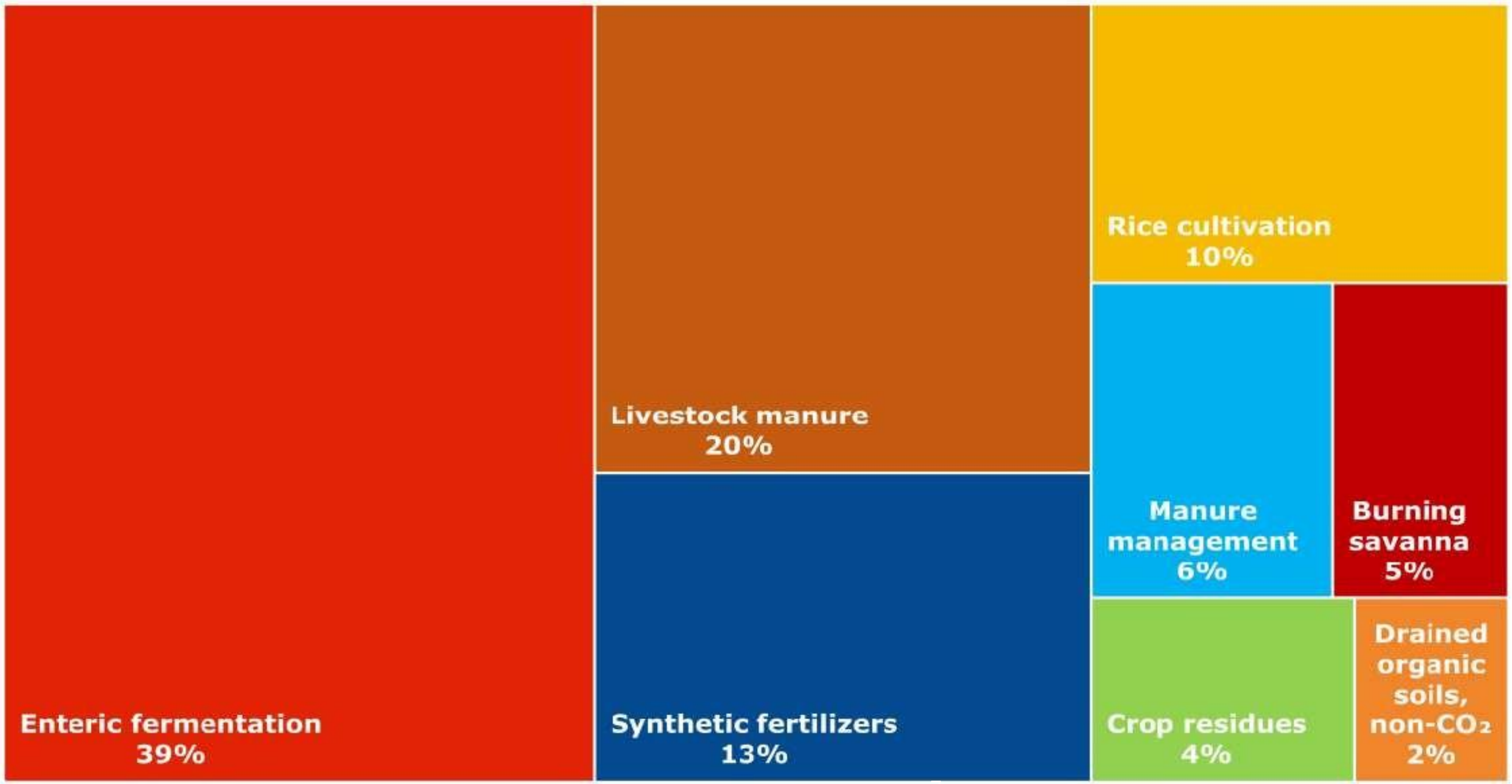
- Human activities - Land use change and management have a significant influence on the greenhouse gas concentrations in the atmosphere.
- Processes accounting for GHG emissions and removals include photosynthesis, respiration, decomposition, nitrification/de-nitrification, enteric fermentation, and combustion that are driven by the biological activity and physical processes.
- **AFOLU represents 20-24%** of net anthropogenic emissions, largest emission sector after energy.
- Mainly from deforestation, agricultural emissions from soil and nutrient management and livestock.



Source: IPCC, 2014

Global agriculture emissions

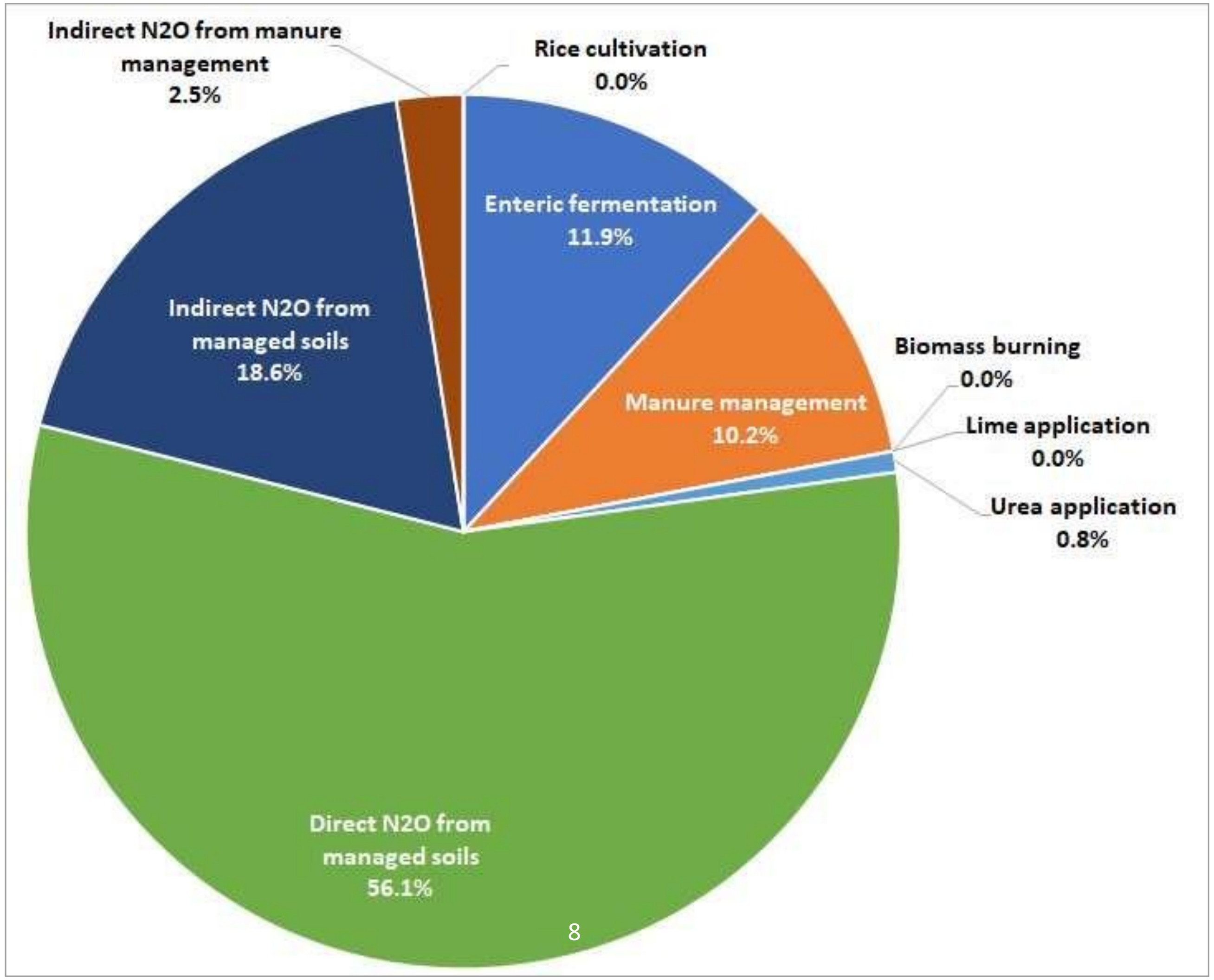
- Contribution of crops and livestock activities to total global non-CO_2 emissions from agriculture in 2018 (5.3 Gt CO_2eq)



FAOSTAT Analytical brief 18, 2020

Agriculture emissions in the Caribbean

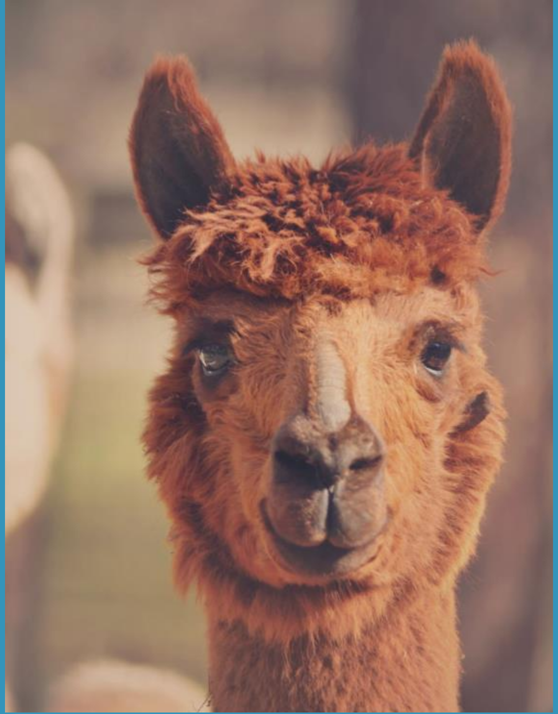
- Agriculture emissions across the 9 Caribbean countries:
  - Bahamas, Belize, Dominica, Haiti, Saint Lucia, St Kitts and Nevis, St Vincent and The Grenadines, Suriname, Trinidad and Tobago
  - Approximately 9.5% of economy wide emissions



Agricultural soils are important - *already being actively managed, and so amenable to implementation of improved practices*

Exclusions from agriculture

- Agriculture in the inventory includes production emissions, i.e., on farm emissions, and does not extend to activities beyond the farm gate
- Agriculture emissions do not include emissions from off-road vehicles used for agriculture production
  - These are dealt with under Transport in the Energy Sector
- CO_2 emissions from biomass burning can either be included under Biomass burning in Agriculture (3C) or as disturbance losses under Land (3B)
  - All other non-CO_2 gases from biomass burning fall under 3C

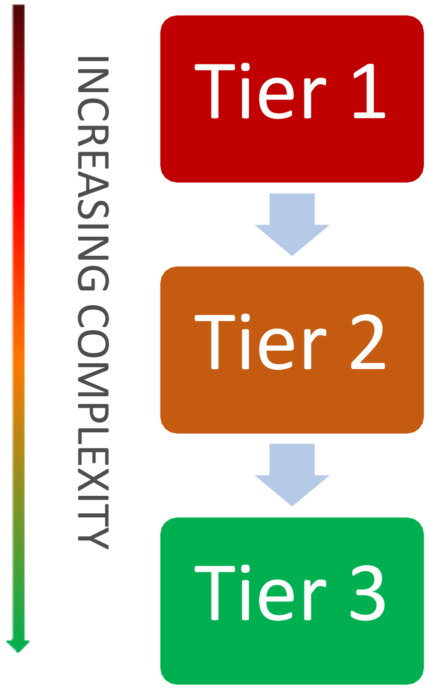



Basic methods and concepts

Basic concepts: Methodology for estimating emissions

- For all gases the basic methodology is:

- Increasing the tier level increases the data requirements and complexity of the equation



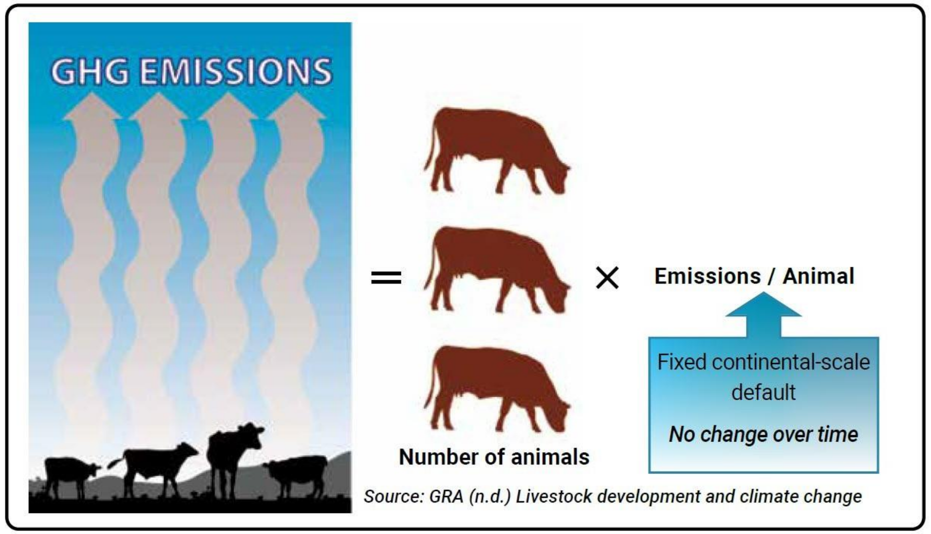
Methods are the simplest, require least effort and data, can provide default emission factors but tend to be the most uncertain.

Simple method but with more country specific data included.

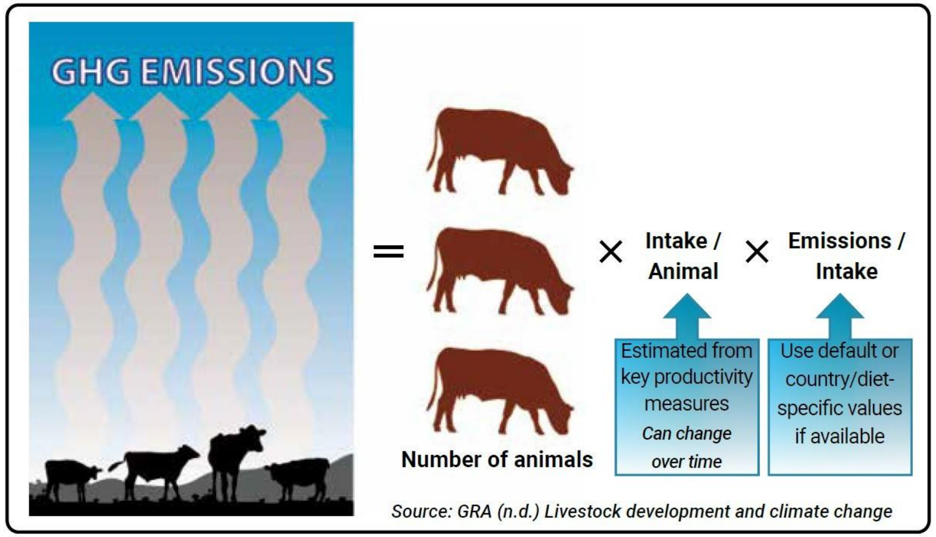
The most complex (often models), attempt to reduce uncertainties the most but need country specific data and more effort to compile).

Basic concepts: Importance of higher Tier level methods

- **Tier 1 uses default emission factors which:**
  - Provide a good first estimate
  - May be over or underestimates
  - Large uncertainties
  - Don't allow for any annual changes



- **Tier 2 uses more detailed country specific data which:**
  - Provide more accurate estimates for a country
  - Allow for emission factor variation
    - makes it easier to track policy impacts and emission reductions



Basic concepts: Livestock population characterisation

- **Basic livestock characterisation** (Tier 1):
  - Cattle
    - Dairy
    - Other
  - Buffalo
  - Sheep
  - Goats
  - Camels
  - Horses
  - Mules & asses
  - Swine
    - Market
    - Breeding
  - Poultry
    - Chickens:
      - Layers
      - Broilers
    - Turkeys/ducks
  - Other

- **Enhanced livestock characterisation** (Tier 2):

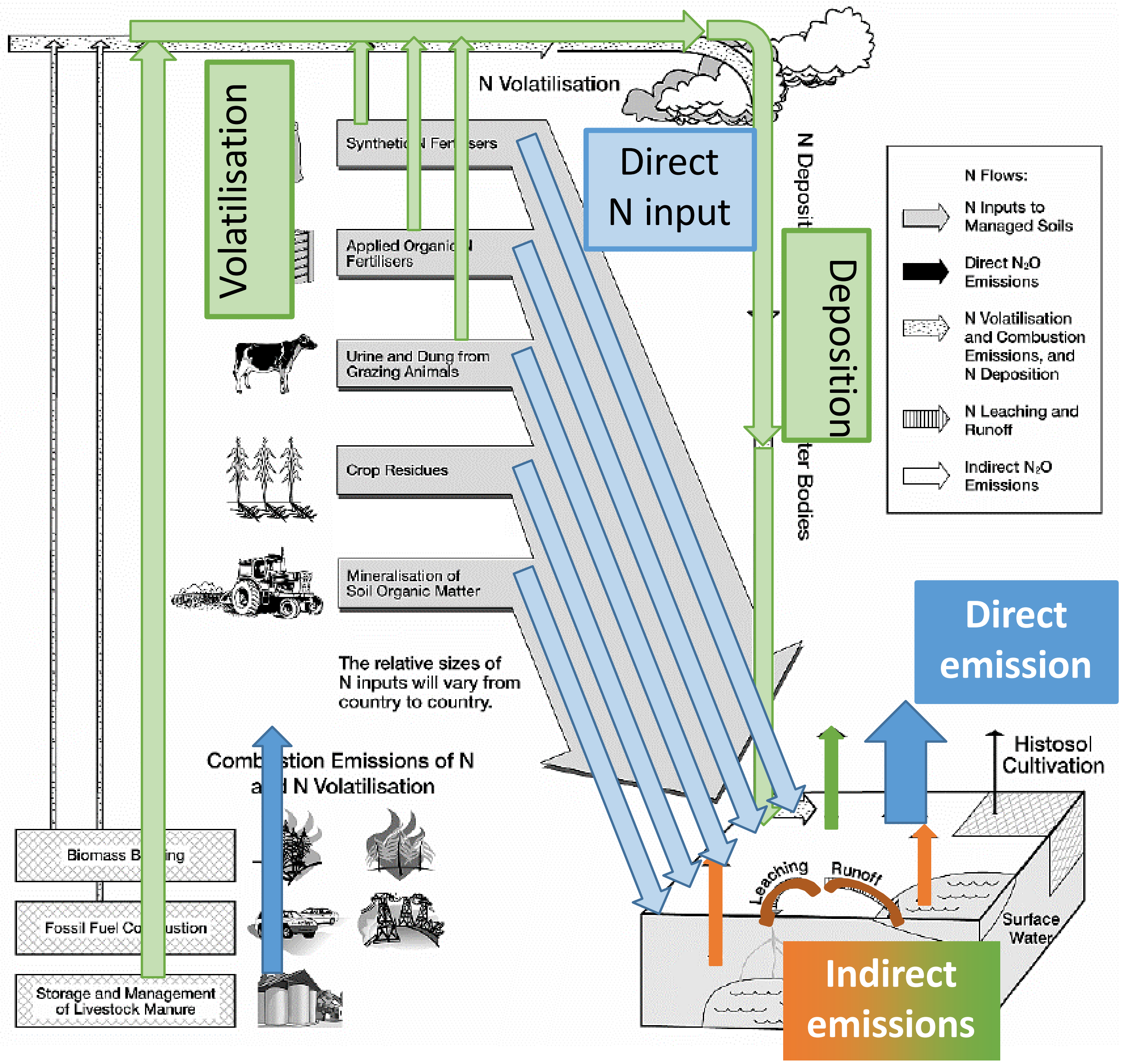
Main category	Subcategories
Mature dairy cow or Mature dairy Buffalo	• High-producing cows that are principally used for milk production • Low-producing cows that are principally used for milk production
Other mature cattle or Mature non-dairy buffalo	Females • Cows used to produce offspring for meat • 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 • Feedlot-fed cattle on diets containing >90% 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 (>1yr)	
Growing lambs	• Intact males • Castrates • Females
Mature swine	• Sows in gestation • Sows which l • Boars that ar
Growing swine	• Nursery • Finishing • Gilts that wil • Growing boars that will be used for breeding purposes
Chickens	• Broiler chickens grown for producing meat • Layer chickens for producing eggs, where manure is managed in dry systems • Layer chickens for producing eggs, where manure is managed in wet systems • Chickens under free-range conditions for egg or meat production

IPCC 2006, Vol 4, Chapter 10, Table 10.1

A finding from the 2018 voluntary peer review was to develop an enhanced characterization

Basic concepts: Direct and indirect N_2O emissions

- Occurs for both manure management and managed soils
- **Direct emissions**:
  - Directly from the soil to which the N is added/released
- Indirect emissions
  - N is transported from agricultural systems (i.e., not where N was applied):
    - Via water through ground water (**leaching**) and surface waters (**runoff**) and
    - Via air where NH_3 and NO_x are **volatilised** and subsequently **redeposited**
  - These result in further N_2O emissions at these deposition sites



Basic concepts: Global warming potentials

- Dealing with non-CO_2 gases so GWP are important
- This converts the non-CO_2 emission to a CO_2 equivalent so that values can be compared across categories and sectors

Industrial designation or common name	Chemical formula	GWP values for 100-year time horizon		
		Second Assessment Report (SAR)	Fourth Assessment Report (AR4)	Fifth Assessment Report (AR5)
Carbon dioxide	CO_2	1	1	1
Methane	CH_4	21	25	28
Nitrous oxide	N_2O	310	298	265
Substances controlled by the Montreal Protocol				
CFC-11	CCl_3F	3,800	4,750	4,660
CFC-12	CCl_2F_2	8,100	10,900	10,200
CFC-13	$CClF_3$		14,400	13,900
CFC-113	CCl_2FCClF_2	4,800	6,130	5,820
CFC-114	$CClF_2CClF_2$		10,000	8,590
CFC-115	$CClF_2CF_3$		7,370	7,670
Halon-1301	$CBrF_3$	5,400	7,140	6,290
Halon-1211	$CBrClF_2$		1,890	1,750
Halon-2402	$CBrF_2CBrF_2$		1,640	1,470
Carbon tetrachloride	CCl_4	1,400	1,400	1,730
Methyl bromide	CH_3Br		5	2
Methyl chloroform	CH_3CCl_3	100	146	160

Quiz

- Which of the following activities are covered under the AFOLU sector?
- Select one or more:
  A. Emissions from storing and composting manure
  B. Emissions from land conversions
  C. Fuel consumption in agricultural equipment
  D. Emissions from burning manure for fuel
  E. Crop residue burning for harvesting and clearing
  F. Agroprocessing emissions

ANSWER

Quiz

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E. Crop residue burning for harvesting and clearing
F. Agroprocessing emissions

ANSWER

Quiz

- Which of the following emissions are covered under the Agriculture sector?
- Select one or more:
  A. CH_4 from enteric fermentation
  B. CO_2 emissions due to decomposition
  C. CO_2 emissions from tractors
  D. N_2O emissions from urine and dung
  E. CH_4 emissions from rice cultivation
  F. CO_2 emissions from harvesting crops
  G. N_2O emissions from urea application

ANSWER

Quiz

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F. CO_2 emissions from harvesting crops
G. N_2O emissions from urea application

ANSWER

Quiz

- What do you multiply your CH_4 emission estimates by to convert it to CO_2 equivalents?
  A. Molecular mass of CO_2
  B. Molecular mass of CH_4
  C. Global warming potential

ANSWER

Quiz

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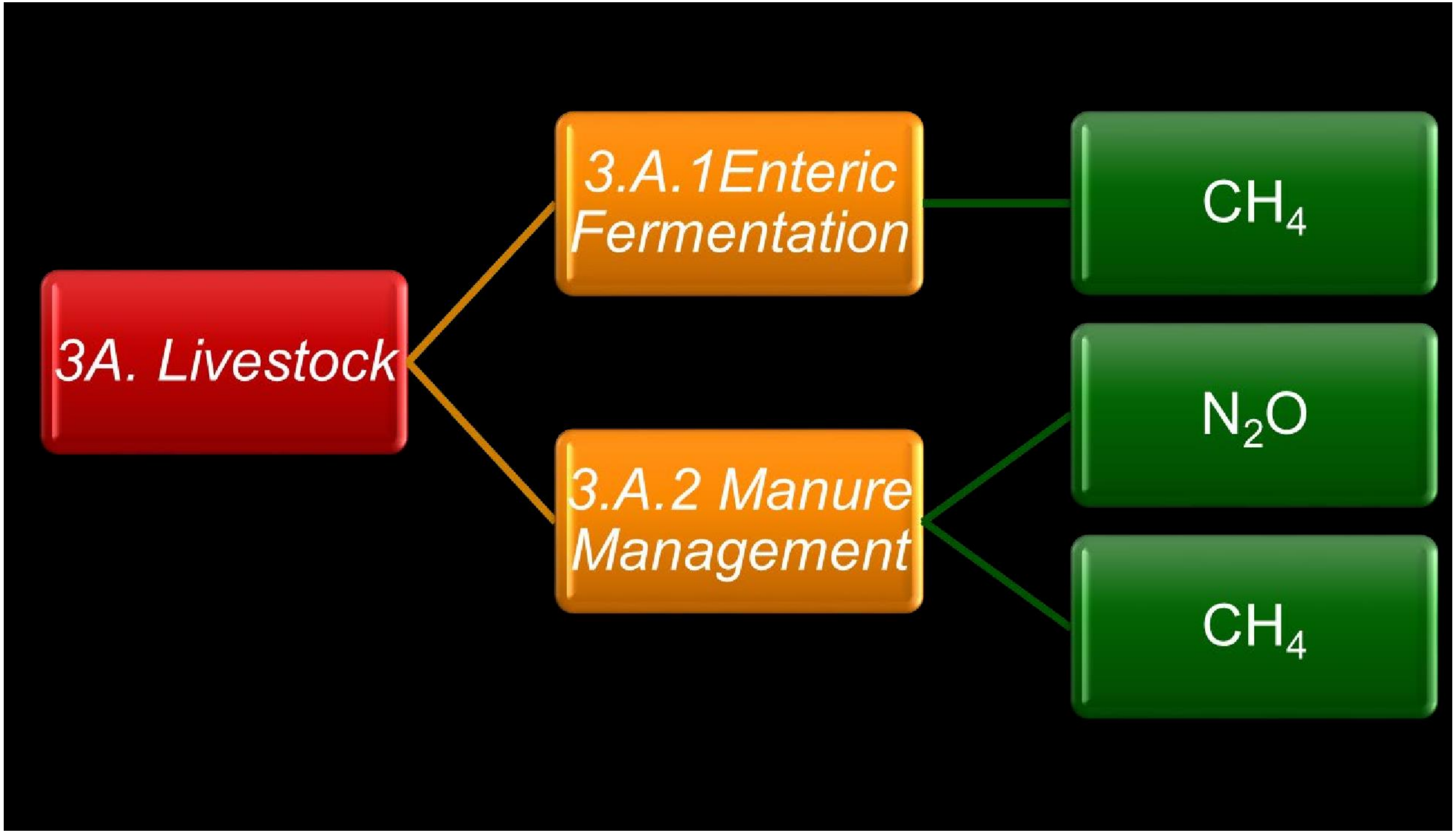
    A. Molecular mass of CO_2
    B. Molecular mass of CH_4
    C. Global warming potential

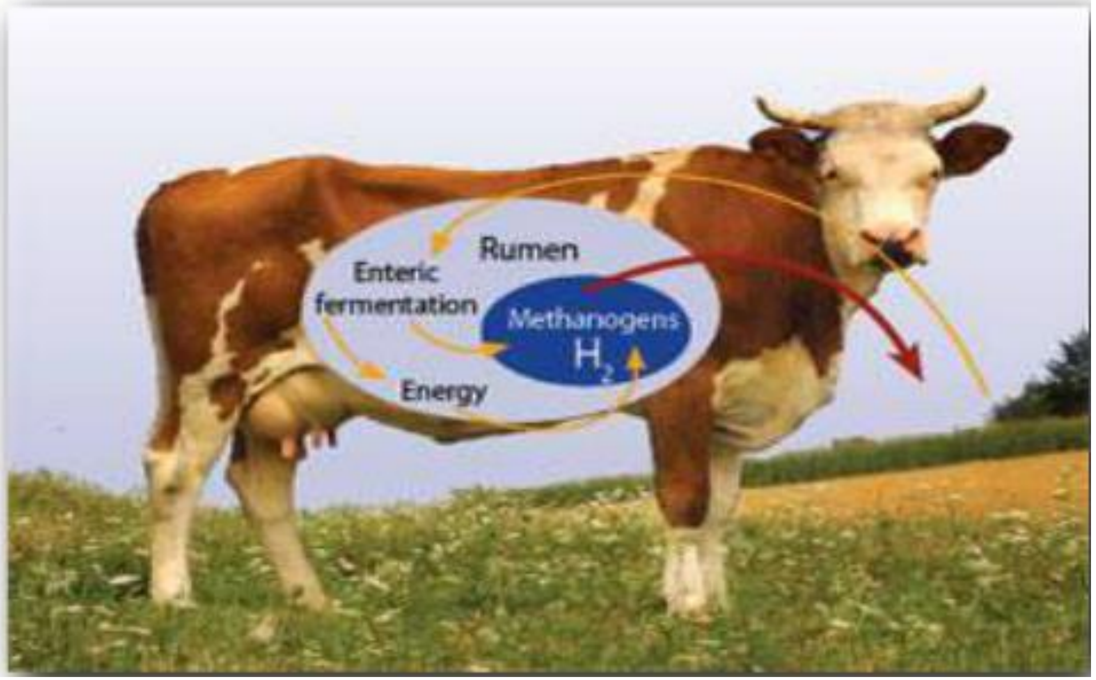
ANSWER

Emissions from Livestock



Enteric fermentation

Enteric fermentation: Introduction



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

Ruminants

Examples of ruminants

- Cattle
- Buffalo
- Goats
- Sheep
- Deer
- Camels

Non-ruminants

Examples of non-ruminant livestock

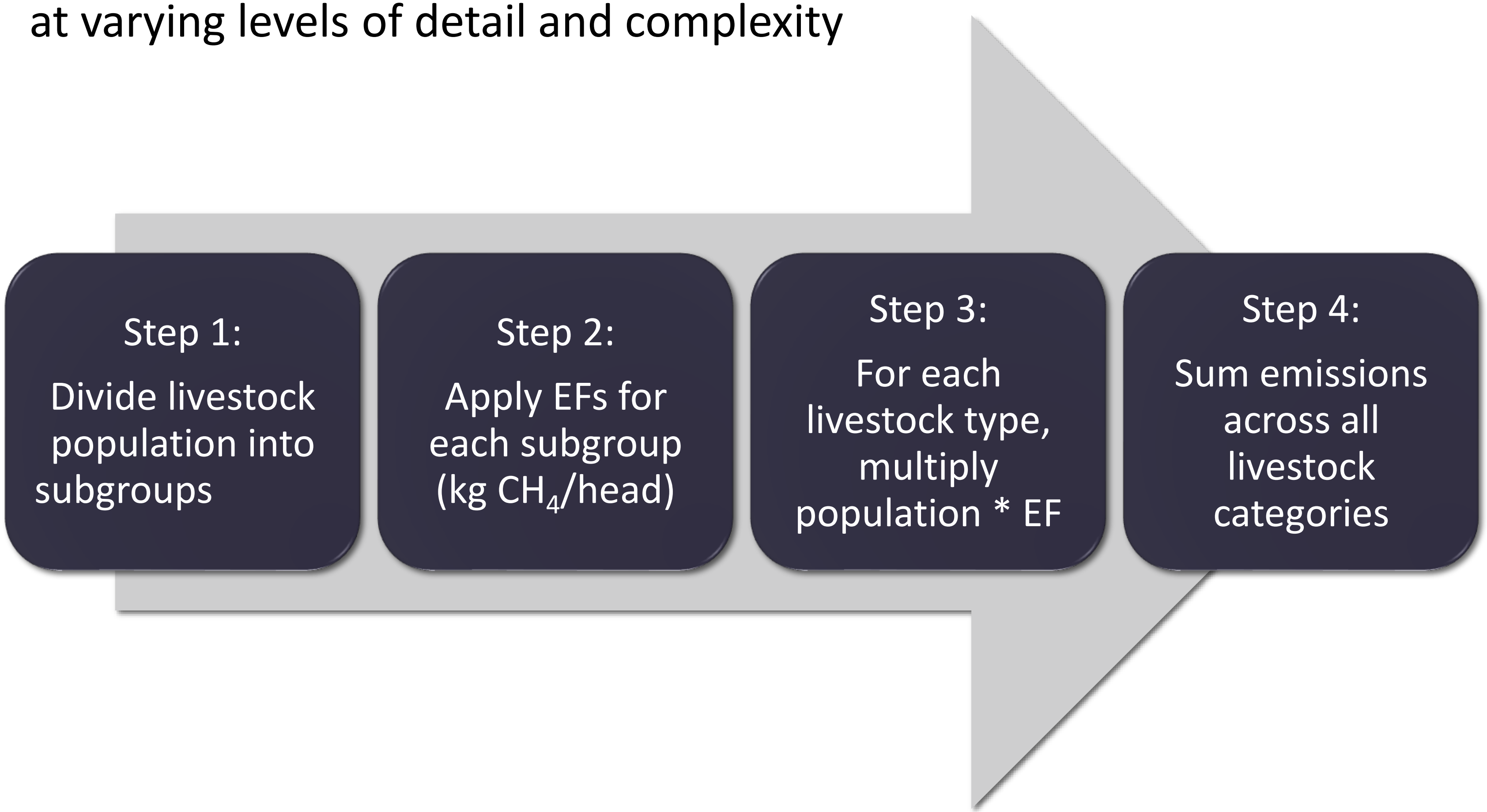
- Horses
- Mules
- Asses
- Swine

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



Estimating enteric fermentation emissions

Emissions = **Activity Data (AD)** X **Emission Factor (EF)**

(Livestock population)

EQUATION 10.19
ENTERIC FERMENTATION EMISSIONS FROM A LIVESTOCK CATEGORY

$$Emissions = EF_{(T)} \bullet \left(\frac{N_{(T)}}{10^6} \right)$$

Conversion factor

Where:

Emissions = methane emissions from Enteric Fermentation, 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

For each livestock type (T)

EQUATION 10.20
TOTAL EMISSIONS FROM LIVESTOCK ENTERIC FERMENTATION

$$Total\ CH_{4_{Enteric}} = \sum_i E_i$$

Where:

Total $CH_{4_{Enteric}}$ = total methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}

E_i = is the emissions for the i^{th} livestock categories and subcategories

Sum for each livestock type

Enteric fermentation: Activity data

$$Emissions = EF_{(T)} * \left[\frac{N_{(T)}}{10^6}\right]$$

- ***Population data*** is the activity data
- Basic (Tier 1) or enhanced (Tier 2) livestock categories
- Poultry not included – enteric fermentation emissions are insignificant
- Note that the emission factor unit is kg CH_4 per head **<u>per year</u>**
  - Assumes population is alive for 365 days
- This is not true for short lived (<1 year) livestock, such as poultry
  - In this case we need to calculate the annual average population

Annual average population =
(Number of livestock produced in a year/365) * number of days alive

- For example:
  - If we have 365 chickens produced in a year
  - Divide by 365 days in a year which gives us 1 chicken per day per year
  - However, each chicken lives for say 45 day
  - This means that we multiply the 1 chicken per day by 45 to get the number of chickens alive on any one day in that year
  - Now this can be multiplied by the emission factor

Example for broiler chickens:
For broiler chickens if 1 500 000 chickens are produced in a year this does not mean on every day there are 1 500 000 chickens

If the chickens live for 45 days then the average number of chickens alive on any 1 day in a year = (1 500 000/365) * 45 = 184 932 chickens

Enteric Fermentation: Emission factors

- **Tier 1** - requires <u>default</u> EFs (**$EF_{(T)}$**) for the livestock subcategories according to the basic characterization
    - IPCC 2006 guidelines

$$Emissions = EF_{(T)} * \left[\frac{N_{(T)}}{10^6}\right]$$

- **Tier 2** - requires <u>country-specific</u> EFs (**$EF_{(T)}$**) estimated for each animal category based on the gross energy intake estimated using the detailed data on:
    - Average daily feed intake (MJ per day or kg per day of dry matter)
    - Methane conversion factor (% of feed energy converted to CH_4)

EQUATION 10.21

CH_4 EMISSION FACTORS FOR ENTERIC FERMENTATION FROM A LIVESTOCK CATEGORY

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

Where:

EF = emission factor, kg CH_4 head^{-1} yr^{-1}

GE = gross energy intake, MJ head^{-1} day^{-1}

Y_m = methane conversion factor, per cent of gross energy in feed converted to methane

The factor 55.65 (MJ/kg CH_4) is the energy content of methane

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

Enteric fermentation: Gross energy intake (Tier 2)

$$Emissions = EF_{(T)} * \left[\frac{N_{(T)}}{10^6}\right]$$

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

- Animal performance and diet data are used to estimate feed intake, wh amount of Gross Energy (MJ/day) an animal needs for maintenance and for activities such as growth, lactation, and pregnancy
- The feed intake in kg day^{-1} should be calculated by converting from GE in energy units to dry matter intake (DMI), by dividing GE by the energy density of the feed

DMI (kg DM/day) = GE (MJ/day)/Energy density of feed (MJ/kg DM)
DMI = GE/18.45

Quality check: DMI should be about 2% to 3% of body weight of mature or growing animals. In high producing milk cows, it can be as much as 4%

Enteric fermentation: Gross energy intake calculation

$$Emissions = EF_{(T)} * \left[\frac{N_{(T)}}{10^6}\right]$$

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

EQUATION 10.16
GROSS ENERGY FOR CATTLE/BUFFALO AND SHEEP

$$GE = \left[\frac{\left(\frac{NE_m + NE_a + NE_l + NE_{work} + NE_p}{REM}\right) + \left(\frac{NE_g + NE_{wool}}{REG}\right)}{\frac{DE\%}{100}}\right]$$

Where:

GE = gross energy, MJ day^{-1}

NE_m = net energy required by the animal for maintenance (Equation 10.3), MJ day^{-1}

NE_a = net energy for animal activity (Equations 10.4 and 10.5), MJ day^{-1}

NE_l = net energy for lactation (Equations 10.8, 10.9, and 10.10), MJ day^{-1}

NE_{work} = net energy for work (Equation 10.11), MJ day^{-1}

NE_p = net energy required for pregnancy (Equation 10.13), MJ day^{-1}

REM = ratio of net energy available in a diet for maintenance to digestible energy consumed (Equation 10.14)

NE_g = net energy needed for growth (Equations 10.6 and 10.7), MJ day^{-1}

NE_{wool} = net energy required to produce a year of wool (Equation 10.12), MJ day^{-1}

REG = ratio of net energy available for growth in a diet to digestible energy consumed (Equation 10.15)

DE%= digestible energy expressed as a percentage of gross energy

Enteric fermentation: CH_4 conversion factor

TABLE 10.12
CATTLE/BUFFALO CH_4 CONVERSION FACTORS (Y_M)

Livestock category	Y_m [b]
Feedlot fed Cattle [a]	3.0% ± 1.0%
Dairy Cows (Cattle and Buffalo) and their young	6.5% ± 1.0%
Other Cattle and Buffaloes that are primarily fed low quality crop residues and by-products	6.5% ± 1.0%
Other Cattle or Buffalo – grazing	6.5% ± 1.0%

[a] When fed diets contain 90 percent or more concentrates.

[b] The ± values represent the range.

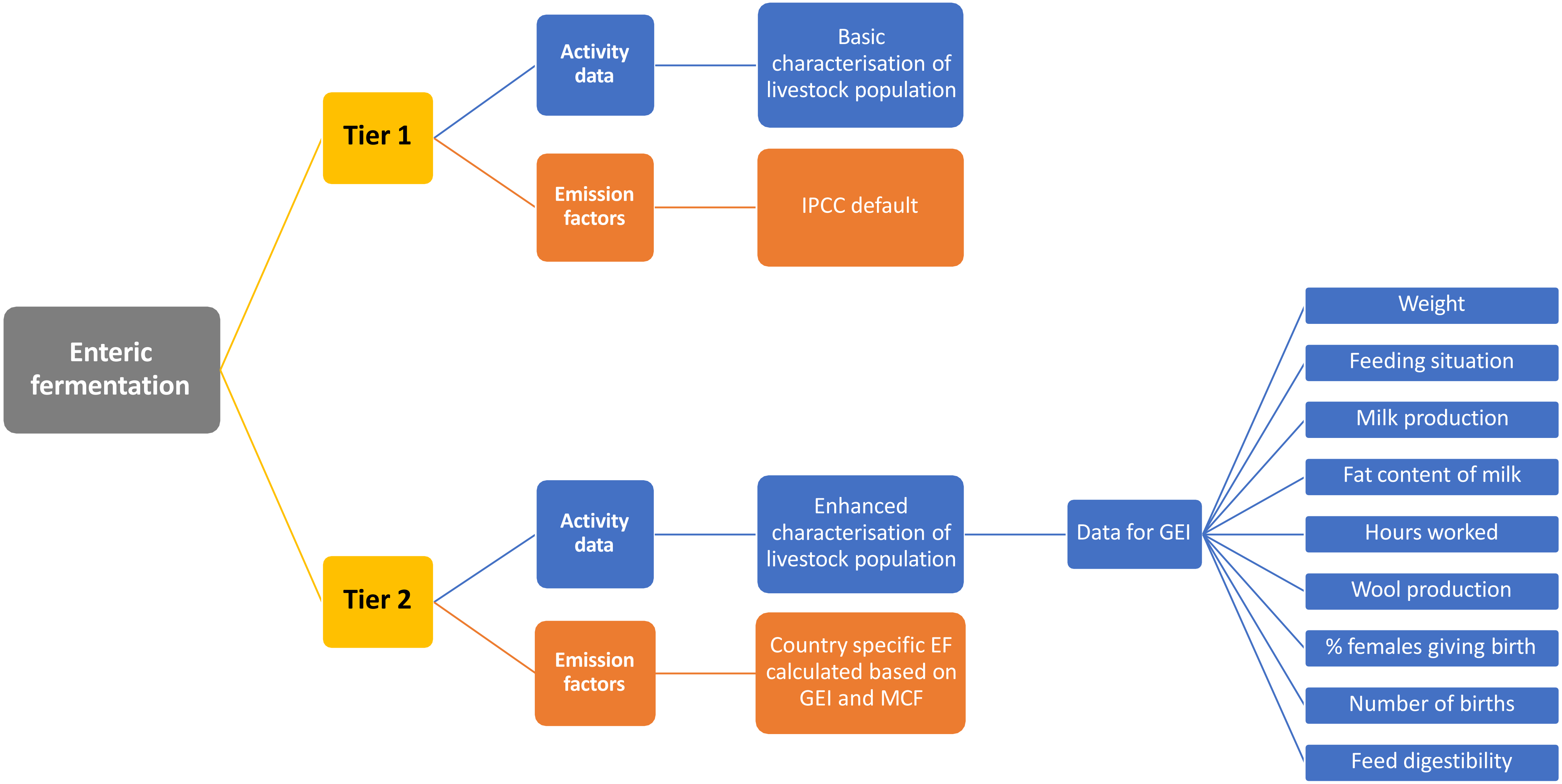
Source: IPCC Expert Group.

$$Emissions = EF_{(T)} * \left[\frac{N_{(T)}}{10^6}\right]$$

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

1. Y_m = extent to which feed energy is converted to CH_4
2. High digestibility/ high energy feed = use lower bounds; poorer feed use higher bounds
3. Y_m = 0 for all animals consuming only milk (e.g., lambs and calves)

Enteric fermentation method summary



Questions?

Exercise 1 – Calculate CH_4 emissions

$$Emissions = EF_{(T)} \bullet \left(\frac{N_{(T)}}{10^6} \right)$$

IPCC Equation – 10.19

How much $GgCH_4$ will be emitted by 1345 dairy cows in a year?

Given EF = 68 $kgCH_4$ /head/year

Exercise 1 – CH_4 emissions - Answer

$$Emissions = EF_{(T)} \bullet \left(\frac{N_{(T)}}{10^6} \right)$$

Emissions = 68 * 1345/1000000
= 91460/1000000
= 0.09146

Emissions from Dairy Cows = 0.09146 GgCH_4/year

Exercise 2 - Estimate CO_2 equivalent of CH_4 Emissions

$$Emissions = EF_{(T)} \bullet \left(\frac{N_{(T)}}{10^6} \right)$$

Equation – 10.19

- How much CO_2 eq will be emitted by have 6,295 buffalos in a year?

  - **$N_{(T)}$** = 6,295
  - **$EF_{(T)}$** = 55kg CH_4 /head/yr
  - **GWP** of Methane = 28

- Report your emissions in Gg CO_2 eq.

Exercise 2 – Estimate CO_2 equivalent of CH_4 Emissions Answer

$$Emissions = EF_{(T)} \bullet \left(\frac{N_{(T)}}{10^6} \right)$$

Emissions = 55 * 6295/1000000

= 346225/1000000

= 0.346225 $GgCH_4$/yr

Emissions = 0.346 * 28 = 9.69 $GgCO_2$ eq.

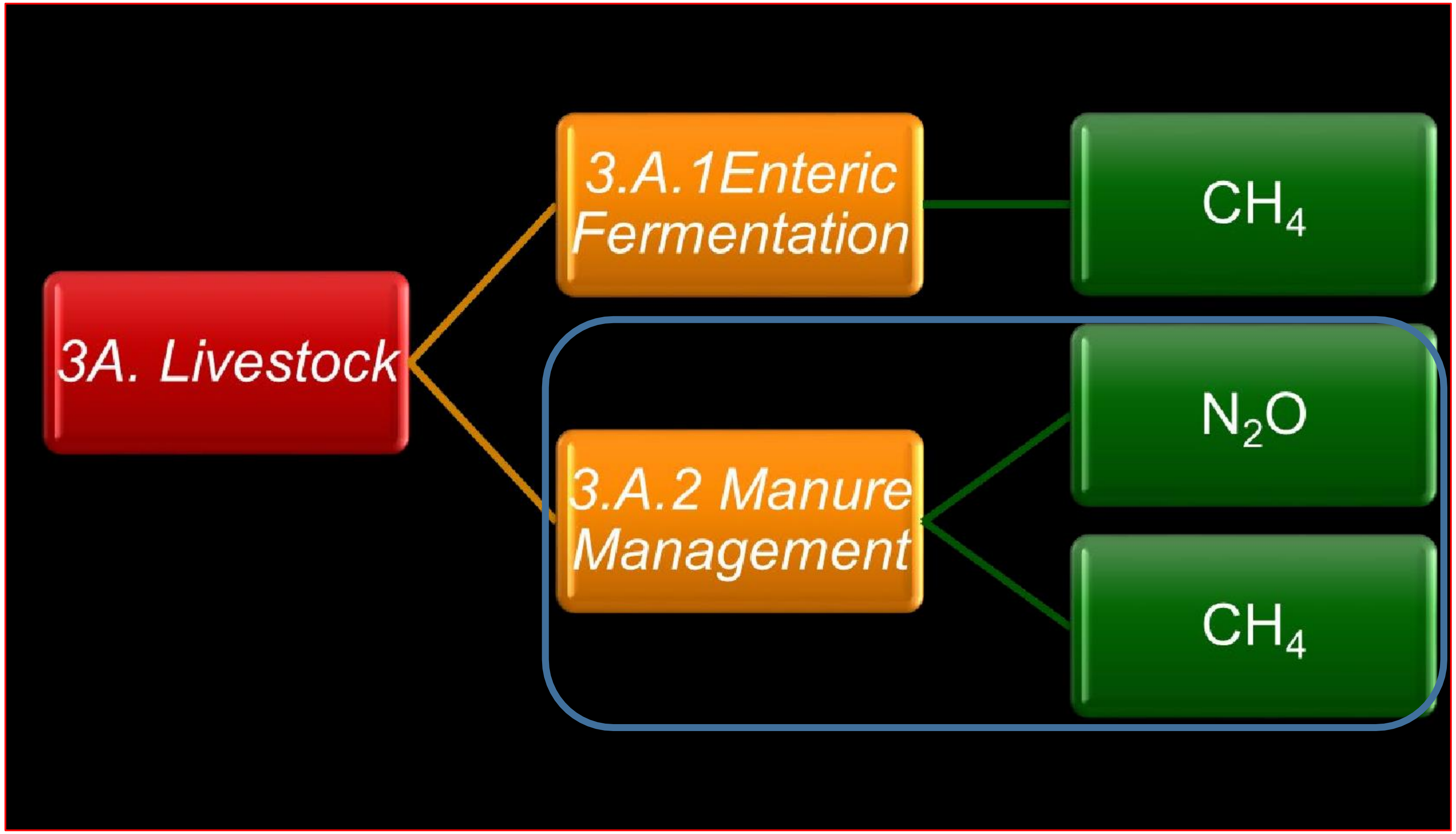
CO_2 eq. Emissions from Buffalos = 9.69 $GgCO_2$/year

Dairy cattle manure management lagoon in Louisiana, USA

Manure pile in Austria

Manure Management

Emissions from Livestock

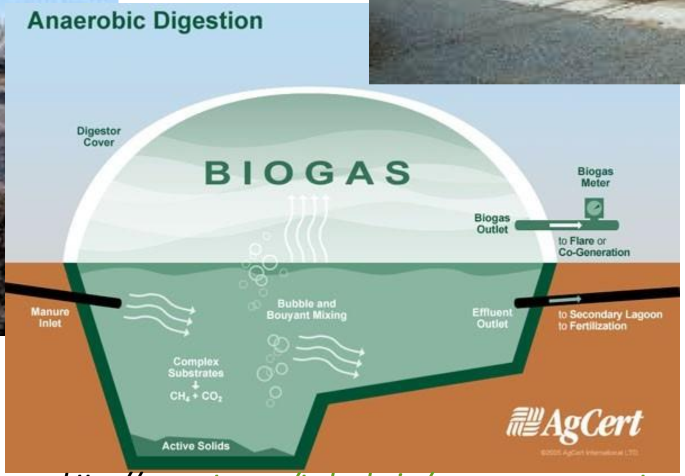


How do manure management systems produce GHGs?

- Manure management refers to the capture, storage, treatment, and utilization of manure
- CH_4 and N_2O are produced directly from Manure Management systems (MMS) due to manure decomposition
- N can also leach or be volatized from MMS leading to indirect N_2O emissions
- Key MMS emission determinants:
  - Aerobic vs anaerobic
  - Liquid vs solid
  - Temperature and storage time

Manure Management Systems (MMS)

- 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
- Composter
- Managed with or without litter (for poultry)
- Aerobically treated



https://www.ctc-n.org/technologies/manure-management

Manure Management: CH_4 emissions

Emissions = **Activity Data (AD)** X **Emission Factor (EF)**

(Livestock population)

Each livestock type

EQUATION 10.22

CH_4 EMISSIONS FROM MANURE MANAGEMENT

$$CH_{4Manure} = \sum_{(T)} \frac{EF_{(T)} \bullet N_{(T)}}{10^6}$$

Sum each livestock emissions for total emissions

Conversion factor

Where:

$CH_{4Manure}$ = 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): Emission factors

- **Tier 1:**
  - Relies on default methane emission factors for manure management by livestock category or subcategory
    - Default emission factors represent the range in manure volatile solids content and manure management practices used in each region
- **Tier 2:**
  - Relies on two primary input parameters that affect the selection of methane emission factors from manure
    - Manure characteristics and
    - Manure management system (MMS) usage

Manure Management (CH_4): Tier 2 EF

- Need: Manure characteristics (volatile solids; CH4 producing capacity)

ACTIVITY DATA

EQUATION 10.23
CH4 EMISSION FACTOR FROM MANURE MANAGEMENT

$$EF_{(T)} = \left(VS_{(T)} \bullet 365\right) \bullet \left[B_{o(T)} \bullet 0.67\,kg/m^3 \bullet \sum_{S,k} \frac{MCF_{S,k}}{100} \bullet MS_{(T,S,k)}\right]$$

Where:

$EF_{(T)}$ = annual CH_4 emission factor for livestock category T, kg CH_4 animal^{-1} yr^{-1}

$VS_{(T)}$ = daily volatile solid excreted for livestock category T, kg dry matter animal^{-1} day^{-1}

365 = basis for calculating annual VS production, days yr^{-1}

$B_{o(T)}$ = maximum methane producing capacity for manure produced by livestock category T, m^3 CH_4 kg^{-1} of VS excreted

0.67 = conversion factor of m^3 CH_4 to kilograms CH_4

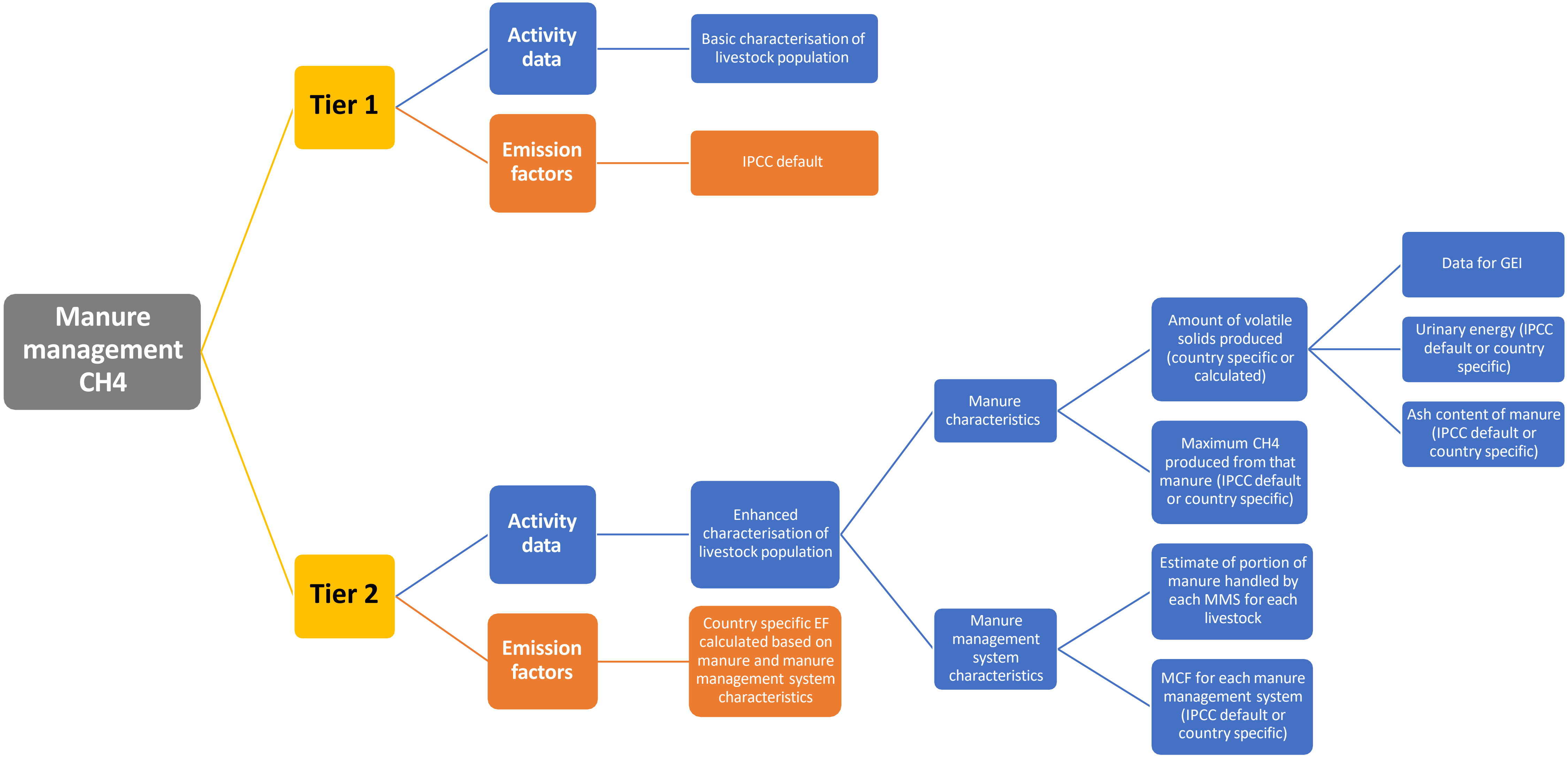
$MCF_{(S,k)}$ = methane conversion factors for each manure management system S by climate region k, %

$MS_{(T,S,k)}$ = fraction of livestock category T's manure handled using manure management system S in climate region k, dimensionless

- Need: MMS usage data (*portion of manure managed in each MMS for each representative animal species*)

ACTIVITY DATA

Manure management CH_4 method summary



Quiz

- If you wanted to improve the Tier level for manure management which factors would you focus on?

  A. Activity data

  B. Emission factors

ANSWER

Quiz

- If you wanted to improve the Tier level for manure management which factors would you focus on?

  A. Activity data

  B. Emission factors

ANSWER

Questions?

Manure Management (N_2O)

N_2O Emissions from Manure Management

Direct N_2O emissions

- Result from nitrification / denitrification of nitrogen in the manure
- N_2O emissions affected by:
  - Amount of manure produced
  - Nitrogen content of manure
  - Manure management system
  - Duration of the storage

Indirect N_2O 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 N_2O emissions also through leaching and run-off ; however, 2006 GL provide only Tier 2 method

What is not included under Manure Management?

- The following N_2O emissions are included under agricultural soils, not manure management
  - Manure applied to soils as organic fertilizer
  - Manure deposited on fields from animals on pasture, range and paddock

GREENHOUSE GAS SOURCE AND SINK CATEGORIES
a. Direct N_2O emissions from managed soils
1. Inorganic N fertilizers(3)
2. Organic N fertilizers(3)
a. Animal manure applied to soils
b. Sewage sludge applied to soils
c. Other organic fertilizers applied to soils
3. Urine and dung deposited by grazing animals
4. Crop residues
5. Mineralization/immobilization associated with loss/gain of soil organic matter (4)(5)

Direct N_2O 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 N_2O EFs for each MMS
- **Step 5:** For each MMS multiply EF * nitrogen managed in that system

Direct N_2O from Manure Management

EQUATION 10.25
DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)} \right) \right] \bullet EF_{3(S)} \right] \bullet \frac{44}{28}$$

Where:

$N_2O_{D(mm)}$ = Direct N_2O emissions from Manure Management in the country, kg N_2O yr^{-1}

$N_{(T)}$ = number of animals/category *T* in the country

$N_{ex(T)}$ = annual average N excretion/head of species/category *T*, kg N $animal^{-1}$ yr^{-1}

$MS_{(T,S)}$ = fraction of total annual N excretion for each livestock species/category T that is managed in manure management system *S*

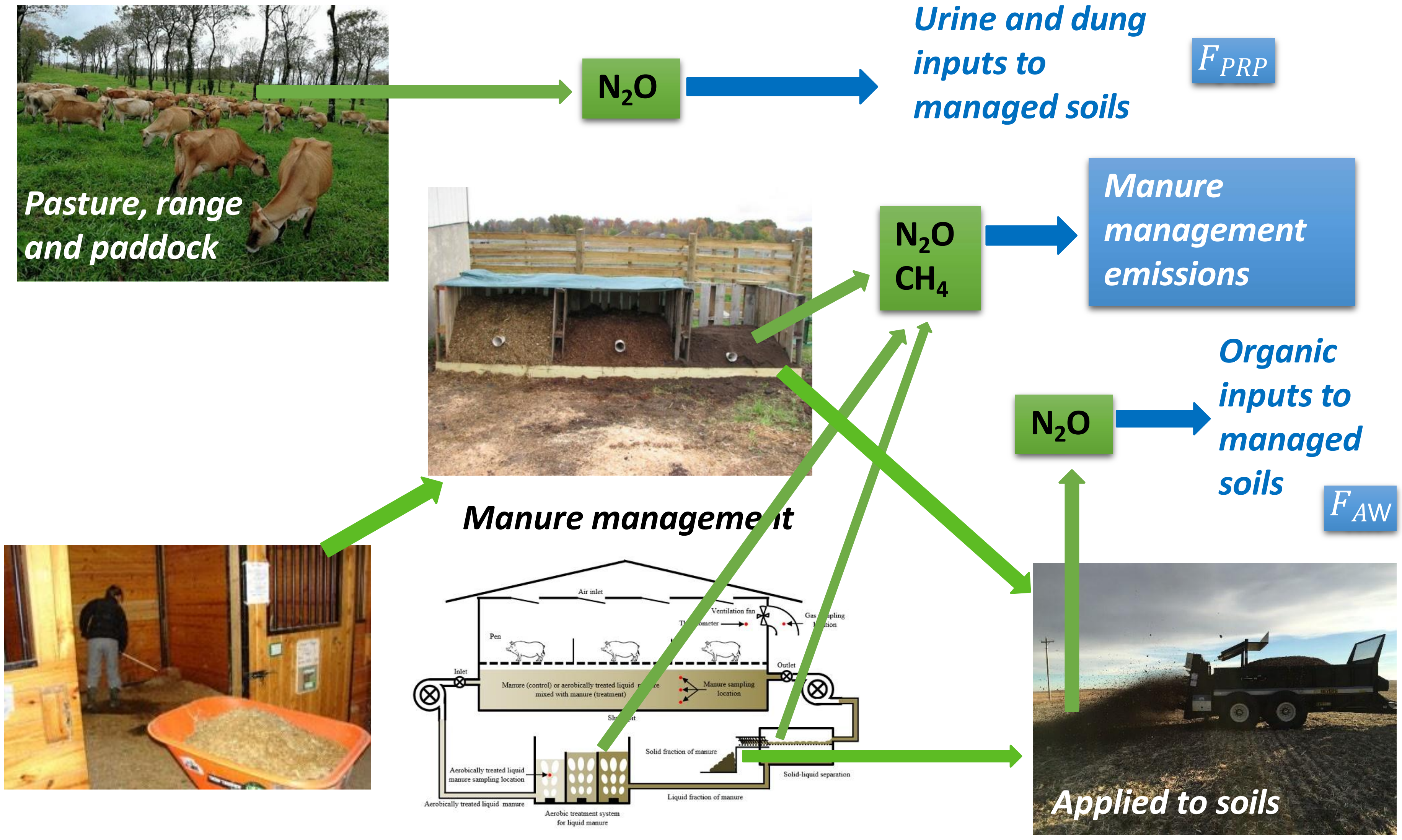
$EF_{3(S)}$ = Emission factor for direct N_2O emissions from manure management system *S* in the country, kg N_2O-N/kg N in manure management system *S*

S = manure management system

T = species/category of livestock

44/28 = conversion of (N_2O-N)(mm) emissions to N_2O(mm) emissions

Manure Management N_2O: Manure allocation



Manure Management N_2O: Direct emissions

Emissions = **Activity Data (AD)** X **Emission Factor (EF)**

(Population, N excretion rate, manure management data)

EQUATION 10.25

DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)} \right) \right] \bullet EF_{3(S)} \right] \bullet \frac{44}{28}$$

Conversion factor

Where:

$N_2O_{D(mm)}$ = direct N_2O emissions from Manure Management in the country, kg N_2O yr^{-1}

$N_{(T)}$ = number of head of livestock species/category *T* in the country

$Nex_{(T)}$ = annual average N excretion per head of species/category *T* in the country, kg N $animal^{-1}$ yr^{-1}

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless

$EF_{3(S)}$ = emission factor for direct N_2O emissions from manure management system *S* in the country, kg N_2O-N/kg N in manure management system *S*

S = manure management system

T = species/category of livestock

44/28 = conversion of $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$ emissions

N_2O Conversion note

Note on conversion factor

- Calculations give output as N_2O-N and this needs to be converted to N_2O

$$N_2O = N_2O - N \ * \frac{CC}{28}$$

- Applies to all N_2O emission equations

Manure Management Direct N_2O: Activity data (T1)

$$Emissions = \left\{ \sum_{S} \left[\sum_{T} \left(N_{(T)} * Nex_{(T)} * MS_{(T,S)} \right) \right] * EF_{3(S)} \right\} * \frac{44}{28}$$

- **Tier 1**
  - Animal population data according to basic characterization
  - Default or country specific manure management system usage data
  - Annual nitrogen excretion rates which can be calculated from:
    - Default daily N excretion rate
    - Default or country specific **typical animal mass**

EQUATION 10.30
ANNUAL N EXCRETION RATES

$$Nex_{(T)} = N_{rate(T)} \bullet \frac{TAM}{1000} \bullet 365$$

IPCC default

Where:

$Nex_{(T)}$ = annual N excretion for livestock category T, kg N animal^{-1} yr^{-1}

$N_{rate(T)}$ = default N excretion rate, kg N (1000 kg animal mass)$^{-1}$ day^{-1} (see Table 10.19)

$TAM_{(T)}$ = typical animal mass for livestock category T, kg animal^{-1}

Manure Management Direct N_2O: Activity data (T2)

- **Tier 2**
  - Animal population data according to enhanced characterization
  - Country-specific manure management system usage data from national statistics or independent survey
  - Country specific nitrogen excretion defined by the livestock population characterisation based on total annual N intake and total annual N retention data of animals.

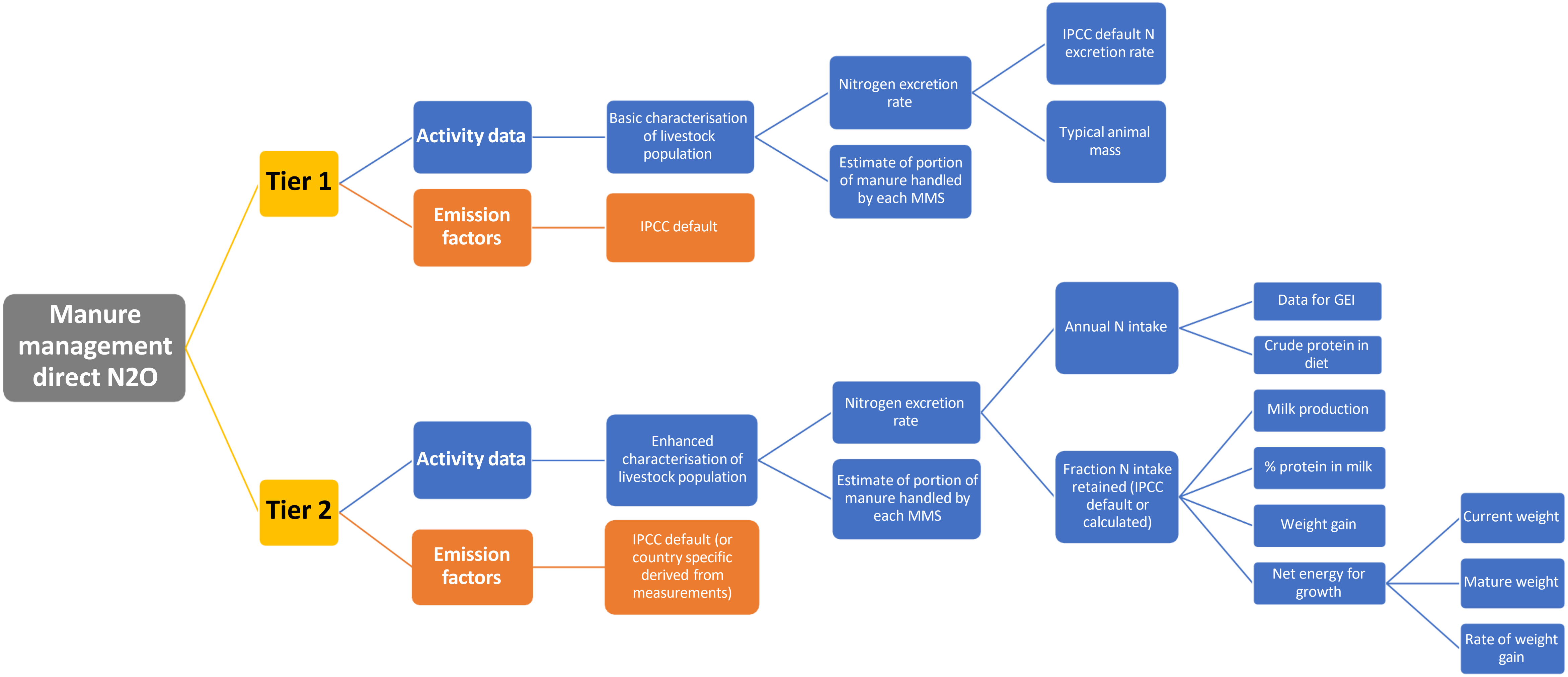
$$Emissions = \left\{ \sum_{S} \left[\sum_{T} \left(N_{(T)} * Nex_{(T)} * MS_{(T,S)} \right) \right] * EF_{3(S)} \right\} * \frac{44}{28}$$

Manure Management Direct N_2O: Emission factors

$$Emissions = \left\{ \sum_{S} \left[\sum_{T} \left(N_{(T)} * Nex_{(T)} * MS_{(T,S)} \right) \right] * EF_{33(S)} \right\} * \frac{44}{28}$$

- **Tier 1**
  - Default emission factor from IPCC Guidelines
  - Emissions factors are per MMS not per livestock
- **Tier 2**
  - Country specific emission factor (***measured***)

Manure management direct N_2O method summary



Indirect N_2O from manure management

Manure Management Indirect N_2O: Volatilisation (Tier 1)

Emissions = **Activity Data (AD)** X **Emission Factor (EF)**

EQUATION 10.27

INDIRECT N_2O EMISSIONS DUE TO VOLATILISATION OF N FROM MANURE MANAGEMENT

$$N_2O_{G(mm)} = \left(N_{volatilization-MMS} \bullet EF_4\right) \bullet \frac{44}{28}$$

Conversion factor

EQUATION 10.26

N LOSSES DUE TO VOLATILISATION FROM MANURE MANAGEMENT

$$N_{volatilization-MMS} = \sum_S \left[\sum_T \left[\left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)}\right) \bullet \left(\frac{Frac_{GasMS}}{100}\right)_{(T,S)} \right] \right]$$

IPCC default values

Calculate weighted N loss per head

Where:

$N_{volatilization\text{-}MMS}$ = amount of manure nitrogen that is lost due to volatilisation of NH_3 and NO_x, kg N yr^{-1}

$N_{(T)}$ = number of head of livestock species/category T in the country

$Nex_{(T)}$ = annual average N excretion per head of species/category T in the country, kg N $animal^{-1}$ yr^{-1}

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless

$Frac_{GasMS}$ = percent of managed manure nitrogen for livestock category T that volatilises as NH_3 and NO_x in the manure management system S, %

EQUATION 10.25

DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)}\right) \right] \bullet EF_{3(S)} \right] \bullet \frac{44}{28}$$

Direct N_2O

Manure Management Indirect N_2O: Volatilisation (Tier 1)

ACTIVITY DATA

$Frac_{GasMS}$ = percent of managed manure nitrogen for livestock category *T* that volatilises as NH_3 and NO_x in the manure management system *S*, %

EMISSION FACTOR

EF = 0.01 kg N_2O-N for all MMS (see equation 10.27 of 2006 GL)

TABLE 10.22
DEFAULT VALUES FOR NITROGEN LOSS DUE TO VOLATILISATION OF NH_3 AND NO_x FROM MANURE MANAGEMENT

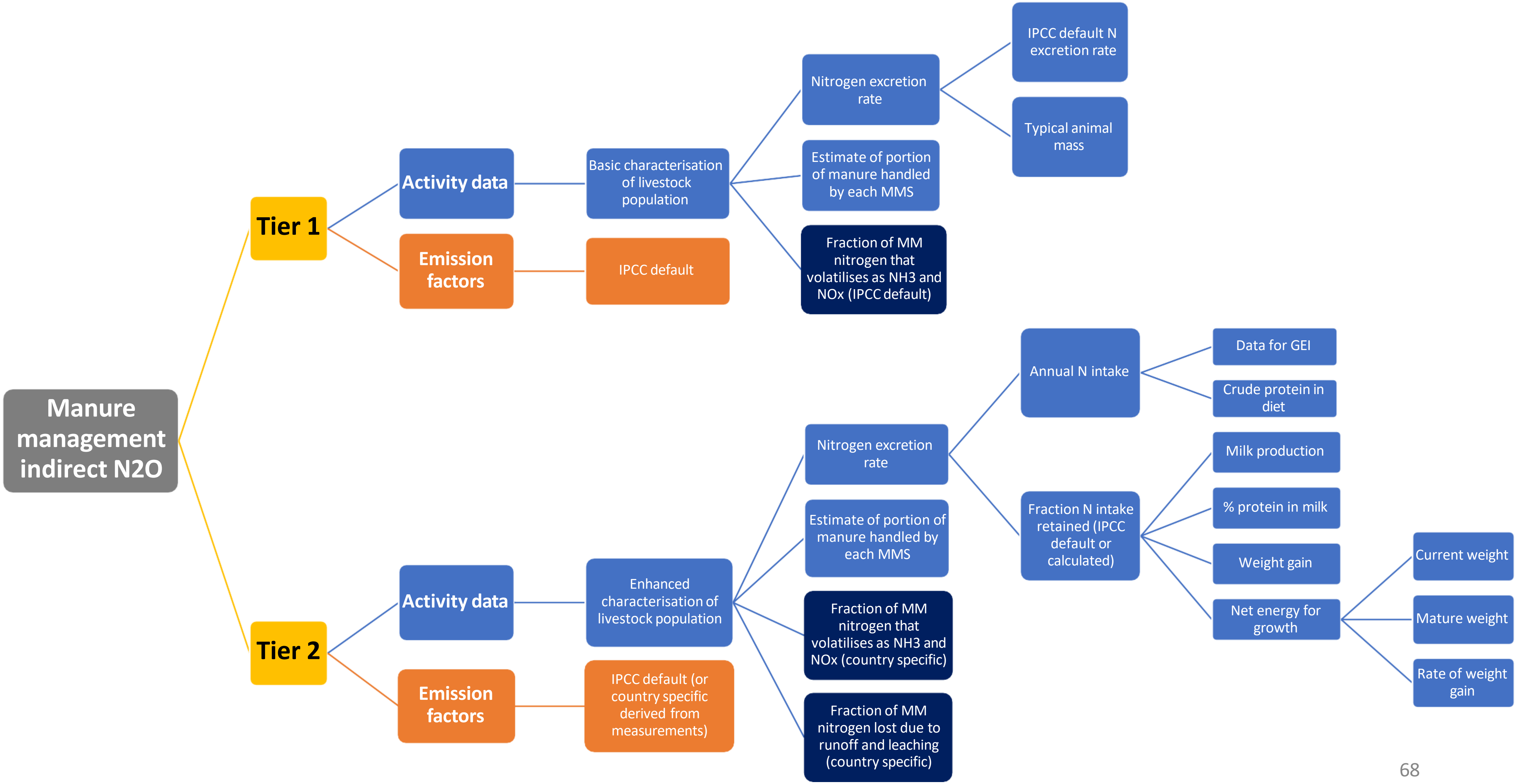
Animal type	Manure management system (MMS) [a]	N loss from MMS due to volatilisation of N-NH_3 and N-NO_x (%) [b] $Frac_{GasMS}$ (Range of $Frac_{GasMS}$)
Swine	Anaerobic lagoon	40% (25 – 75)
	Pit storage	25% (15 – 30)
	Deep bedding	40% (10 – 60)
	Liquid/slurry	48% (15 – 60)
	Solid storage	45% (10 – 65)
Dairy Cow	Anaerobic lagoon	35% (20 – 80)
	Liquid/Slurry	40% (15 – 45)
	Pit storage	28% (10 – 40)
	Dry lot	20% (10 – 35)
	Solid storage	30% (10 – 40)
	Daily spread	7% (5 – 60)
Poultry	Poultry without litter	55% (40 – 70)
	Anaerobic lagoon	40% (25 – 75)
	Poultry with litter	40% (10 – 60)
Other Cattle	Dry lot	30% (20 – 50)
	Solid storage	45% (10 – 65)
	Deep bedding	30% (20 – 40)
Other [c]	Deep bedding	25% (10 – 30)
	Solid storage	12% (5 – 20)

Manure Management Indirect N_2O: Volatilisation (Tier 2)

- Follow the same equation as for Tier 1 but include country specific data for some of the variables, such as:
  - Nitrogen excretion rates
  - NH_3 emissions from an NH_3 inventory (if a country has one)

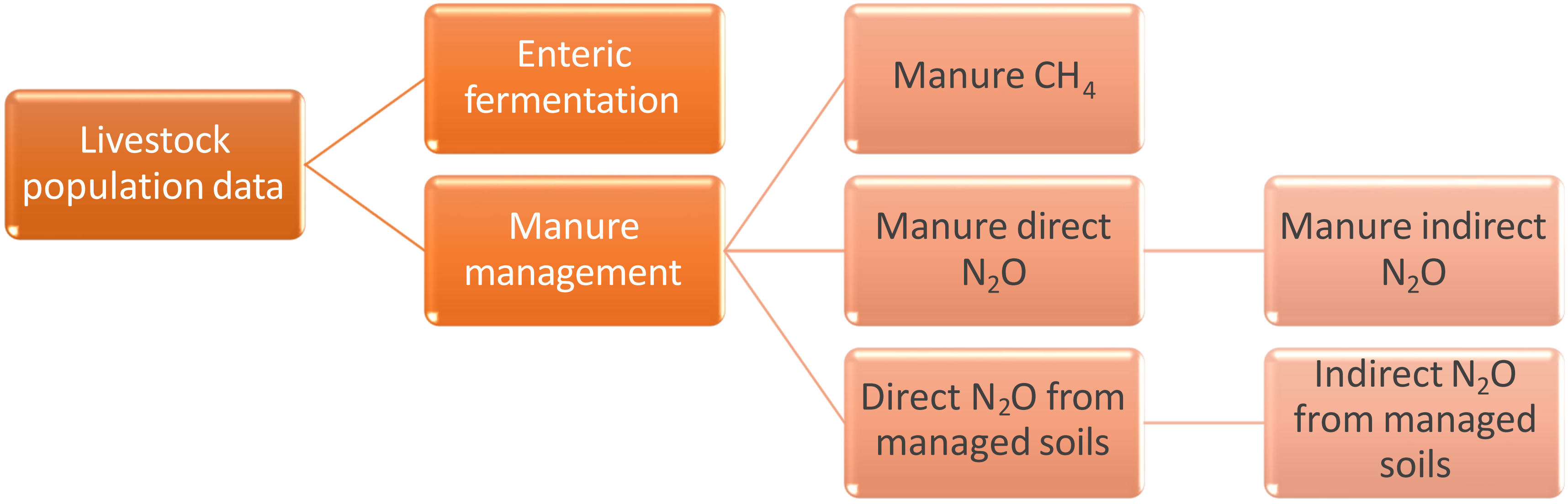
- Requires a detailed characterisation of the flow of nitrogen throughout the animal housing and manure management systems

Manure management indirect N_2O method summary



Quiz

- Why is it particularly important to improve the accuracy of livestock population and manure management usage data?



Questions?

Data collection template for the Agriculture sector

	A	B	C	D	E	F	G	H	I	J
1	IPCC Classification		IPCC Sub category	Category species characterization	Typical Animal Mass (kg/head)	Nitrogen excretion rate	2006		2007	
2	Livestock Enteric Fermentation	Livestock Manure Management					Annual Activity Data If not estimated write NE or if not occuring (NO).		Annual Activity D If not estimated write if not occuring (N	
3			Source: 2006 IPCC Guidelines	Source: List of species assigned to IPCC category, per the country's basic characterization of livestock	Source: Default IPCC values for Typical Animal Mass (TAM) are built into the IPCC software. If TAM is known, report it here. If not known apply default.	Source: Default IPCC values for Nitrogen excretion (Nex) rate per animal per year are built into the IPCC software. If Nex is known, report it here. If not known apply default.	Annual average number of head	Type of manure management system Select from list below, source: 2006 IPCC Guidelines, Table 10.18). (Add rows as necessary for multiple MMS per livestock type)	Annual average number of head	Type of manu management Select from li below, source IPCC Guidelin Table 10.18). rows as neces for multiple M per livestock
4	3.A									
5	3.A.1	3.A.2								
6	3.A.1.a	3.A.2.a	Cattle							
7	3.A.1.a.i	3.A.2.a.i	Dairy Cows							
8	3.A.1.a.ii	3.A.2.a.ii	Other Cattle							
9	3.A.1.b	3.A.2.b	Buffalo							
10	3.A.1.c	3.A.2.c	Sheep							
11	3.A.1.d	3.A.2.d	Goats							
12	3.A.1.e	3.A.2.e	Camels							
13	3.A.1.f	3.A.2.f	Horses							
14	3.A.1.g	3.A.2.g	Mules and Asses							
15	3.A.1.h	3.A.2.h	Swine							
16	Not applicable	3.A.2.i	Poultry							
17	3.A.1.j	3.A.2.j	Other (please specify)							
18										
19	Manure Mangement System		Description of manure management system							
20	**Pature/Range/Paddock**		The manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed							
21	**Daily spread**		Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion							
			The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to stacked due to							

... Livestock & Manure Management | Biomass burning | Soils | Rice cultivation | Harvested Wood Product | Supplement-Croplan ...

Ready 110%



Agricultural soils/ Managed soils



Source of Direct and Indirect N_2O Emissions

- N_2O is produced naturally in soils through the processes of nitrification and denitrification.

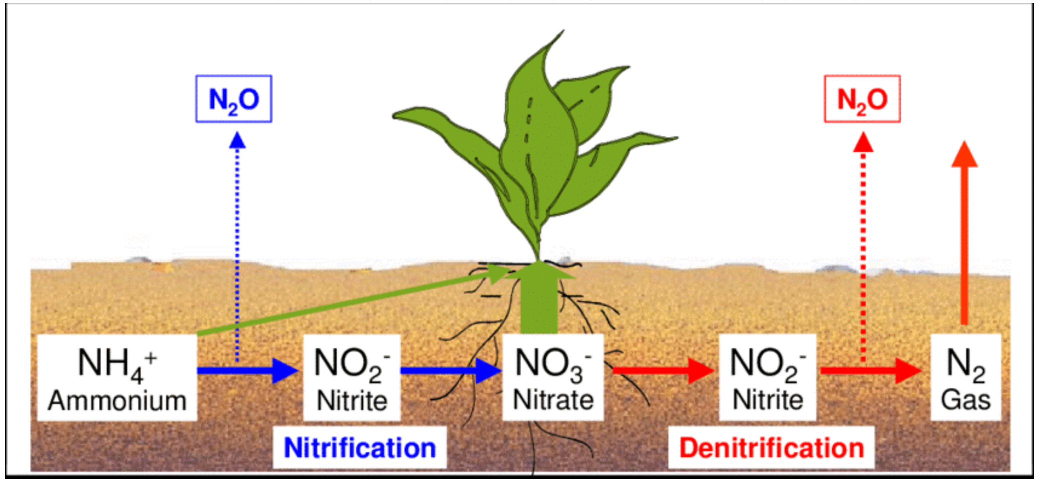
- N_2O emissions a function of the availability of inorganic N in the soil.

- Direct N_2O emissions are from human-induced net N additions to soils (e.g. synthetic or organic fertilizers, deposited manure, crop residues, sewage sludge), or of mineralisation of N in soil organic matter following drainage/management of mineral soils, or cultivation on organic soils.

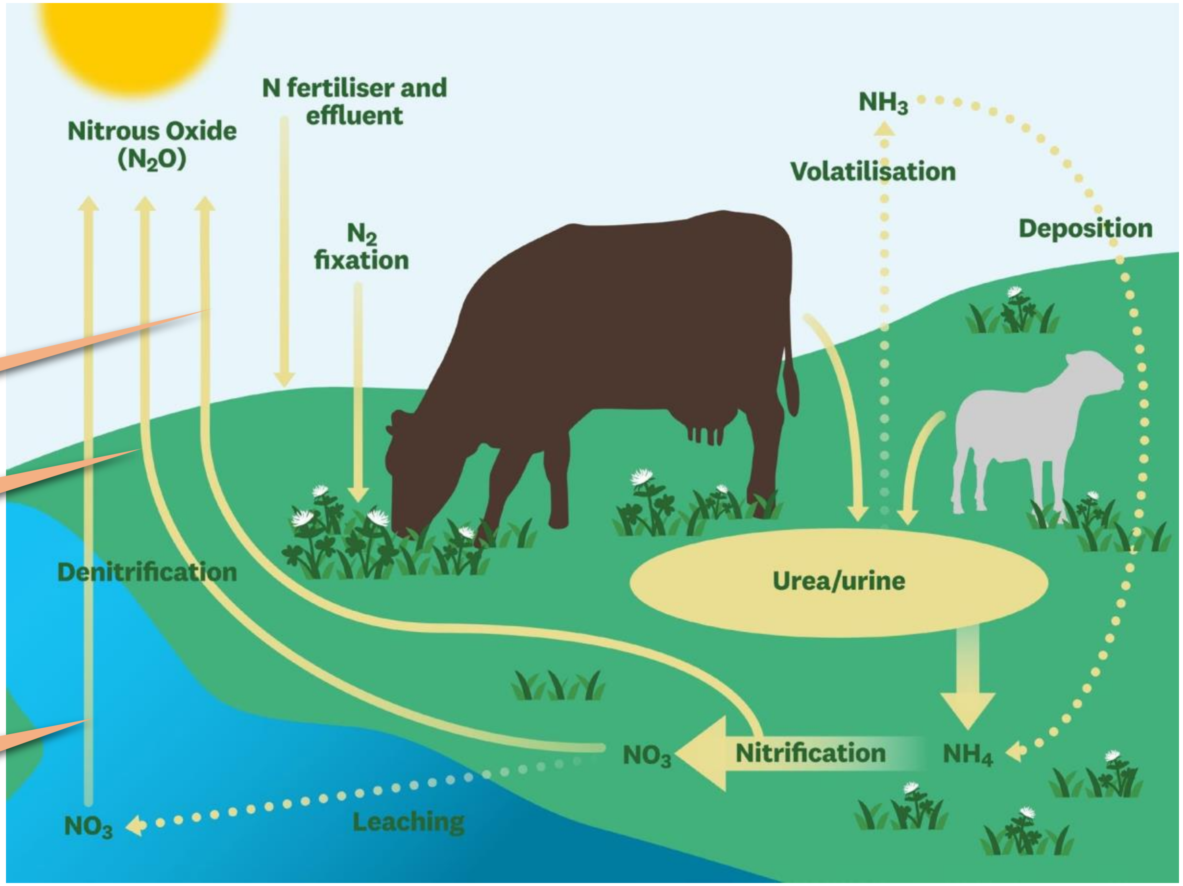
- Indirect N_2O emissions from volatilization and leaching and runoff.

Managed soils: Introduction

N_2O produced through the processes of nitrification and denitrification



Direct and indirect N_2O emissions



Emissions occur **directly** from the soils where the N is applied

Emissions occur **indirectly** through volatilisation of NH_3 and NO_x in the atmosphere and the subsequent deposition of N to soils and waterbodies

Emissions occur **indirectly** through leaching and runoff of N, mainly as NO_3^-, to groundwater and surface water

Source: De Klein CAM, Pinares-Patino C, Waghorn GC (2008). Greenhouse gas emissions. Book chapter. Environmental Impacts of Pasture-Based Farming, pg 1-32

Managed soils: Nitrogen inputs

- Synthetic fertilisers (F_{SN})
- Organic fertilisers (F_{ON})
- Manure left on pasture, range and paddocks (F_{PRP})
- Crop residues (F_{CR})
- Mineral soils (F_{SOM})
- Managed organic soils (F_{OS})

Managed soils: Direct N_2O

EQUATION 11.1
DIRECT N_2O EMISSIONS FROM MANAGED SOILS (TIER 1)

$$N_2O_{Direct}\text{–}N = N_2O\text{–}N_{N\,inputs} + N_2O\text{–}N_{OS} + N_2O\text{–}N_{PRP}$$

N_2O_{Direct} –N = annual direct N_2O–N emissions produced from agricultural soils, kg N_2O–N yr^{-1}
N_2O–$N_{Ninputs}$ = annual direct N2O–N emissions from N inputs to agricultural soils, kg N2O–N yr^{-1}
N_2O–N_{OS} = annual direct N_2O–N emissions from agricultural organic soils, kg N_2O–N yr^{-1}
N_2O–N_{PRP} = annual direct N_2O–N emissions from urine and dung inputs to grazed soils, kg N2O–N yr^{-1}

- Calculations give output as N_2O-N and this needs to be converted to N_2O

$$N_2O = N_2O - N \ * \frac{44}{28}$$

Managed soils direct N_2O: Nitrogen inputs Tier 2

$$N_2O_{Direct} - N = N_2O\_N_{N\,inputs} + N_2O\_N_{OS} + N_2O\_N_{PRP}$$

- For a Tier 2 of N inputs more detailed activity and emission factor data are required:
  - There are different emission factors for:
    - *Synthetic and organic fertilisers and*
    - *Crop residues and SOM*

EQUATION 11.2

DIRECT N_2O EMISSIONS FROM MANAGED SOILS (TIER 2)

$$N_2O_{Direct}\text{–}N = \sum_i \left(F_{SN} + F_{ON}\right)_i \bullet EF_{1i} + \left(F_{CR} + F_{SOM}\right) \bullet EF_1 + N_2O\text{–}N_{OS} + N_2O\text{–}N_{PRP}$$

Managed soils direct N_2O: N-input emission factors

- IPCC default values are provided

$$N_2O_{Dre} - N = N_2O\_N_{N\,in} + N_2O\_N_{OS} + N_2O\_N_{PRP}$$

$$NNO - N_{N\,p} = [(F_{SN} + F_{ON} + F_{CR} + F_{SOOM}) * EF_{11}] + [(F_{SN} + F_{OON} + F_{CR} + F_{SOOM})_{FR} * EF_{11FR}]$$

TABLE 11.1
DEFAULT EMISSION FACTORS TO ESTIMATE DIRECT N_2O EMISSIONS FROM MANAGED SOILS

Emission factor	Default value	Uncertainty range
EF_1 for N additions from mineral fertilisers, organic amendments and crop residues, and N mineralised from mineral soil as a result of loss of soil carbon [kg N_2O–N (kg N)$^{-1}$]	0.01	0.003 - 0.03
EF_{1FR} for flooded rice fields [kg N_2O–N (kg N)$^{-1}$]	0.003	0.000 - 0.006
$EF_{2\,CG,\,Temp}$ for temperate organic crop and grassland soils (kg N_2O–N ha^{-1})	8	2 - 24
$EF_{2\,CG,\,Trop}$ for tropical organic crop and grassland soils (kg N_2O–N ha^{-1})	16	5 - 48
$EF_{2F,\,Temp,\,Org,\,R}$ for temperate and boreal organic nutrient rich forest soils (kg N_2O–N ha^{-1})	0.6	0.16 - 2.4
$EF_{2F,\,Temp,\,Org,\,P}$ for temperate and boreal organic nutrient poor forest soils (kg N_2O–N ha^{-1})	0.1	0.02 - 0.3
$EF_{2F,\,Trop}$ for tropical organic forest soils (kg N_2O–N ha^{-1})	8	0 - 24
$EF_{3PRP,\,CPP}$ for cattle (dairy, non-dairy and buffalo), poultry and pigs [kg N_2O–N (kg N)$^{-1}$]	0.02	0.007 - 0.06
$EF_{3PRP,\,SO}$ for sheep and 'other animals' [kg N_2O–N (kg N)$^{-1}$]	0.01	0.003 - 0.03

Sources:
EF_1: Bouwman et al. 2002a,b; Stehfest & Bouwman, 2006; Novoa & Tejeda, 2006 in press; EF_{1FR}: Akiyama *et al.*, 2005; $EF_{2CG,\,Temp}$. $EF_{2CG,\,Trop}$, $EF_{2F,\,Trop}$: Klemedtsson *et al.*, 1999, IPCC Good Practice Guidance, 2000; $EF_{2F,\,Temp}$: Alm *et al.*, 1999; Laine *et al.*, 1996; Martikainen *et al.*, 1995; Minkkinen *et al.*, 2002: Regina *et al.*, 1996; Klemedtsson *et al.*, 2002; $EF_{3,\,CPP}$, $EF_{3,\,SO}$: de Klein, 2004.

Managed soils direct N_2O: N-input activity data summary

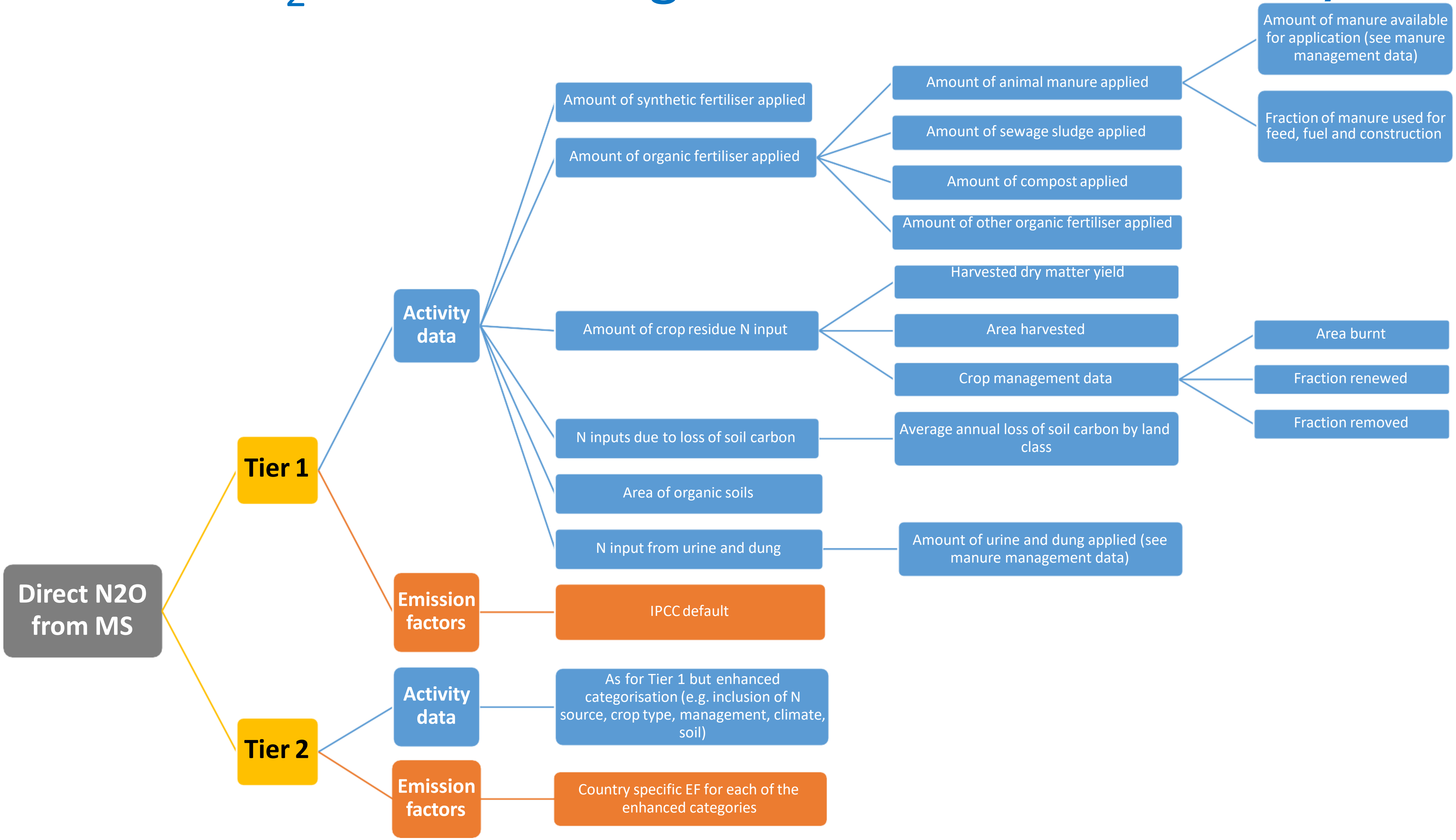
- Activity data:
  - F_{SN}
    - Amount of synthetic N fertiliser applied to soils
  - F_{ON}
    - Animal manure inputs (from livestock manure management)
    - Amount of sewage sludge N applied to soils
    - Amount of compost N applied to soils
    - Amount of other organic N inputs to the soils
  - F_{CR}
    - Harvested dry matter
    - Total annual area harvested
    - Crop residue management
  - F_{SOM}
    - Change in soil carbon due to land management

Synthetic fertiliser consumption data (F_{SN}) should be collected from official statistics (e.g. national bureaux of statistics) or International Fertiliser Industry Association (IFIA), FAO

F_{CR} from crop production data (national or FAO) and IPCC default fractions

For soils and flooded rice

Direct N_2O from managed soils method summary



Indirect N_2O from managed soils

Managed soils indirect N_2O: Introduction

- Synthetic fertilisers (F_{SN})
- Organic fertilisers (F_{ON})
- Manure left on pasture, range and paddocks (F_{PRP})
- Crop residues (F_{CR})
- Mineral soils (F_{SOM})
- Managed organic soils (F_{OS})

Indirect due to volatilisation (synthetic fertilisers, organic fertilisers, manure left on pasture, range and paddocks)

Indirect due to leaching and runoff (synthetic fertilisers, organic fertilisers, manure left on pasture, range and paddocks, crop residues, mineral soils)

Managed soils indirect N_2O: Volatilisation

Collected for direct N_2O emission estimates

Emissions = **Activity Data (AD)** X **Emission Factor (EF)**

EQUATION 11.9

N_2O FROM ATMOSPHERIC DEPOSITION OF N VOLATILISED FROM MANAGED SOILS (TIER 1)

$$N_2O_{(ATD)}-N = \left[\left(F_{SN} \bullet Frac_{GASF}\right) + \left(\left(F_{ON} + F_{PRP}\right) \bullet Frac_{GASM}\right)\right] \bullet EF_4$$

IPCC default values

Managed soils indirect N_2O: Leaching and runoff

Collected for direct N_2O emission estimates

Emissions = **Activity Data (AD)** X **Emission Factor (EF)**

EQUATION 11.10
N_2O FROM N LEACHING/RUNOFF FROM MANAGED SOILS IN REGIONS WHERE LEACHING/RUNOFF OCCURS (TIER 1)

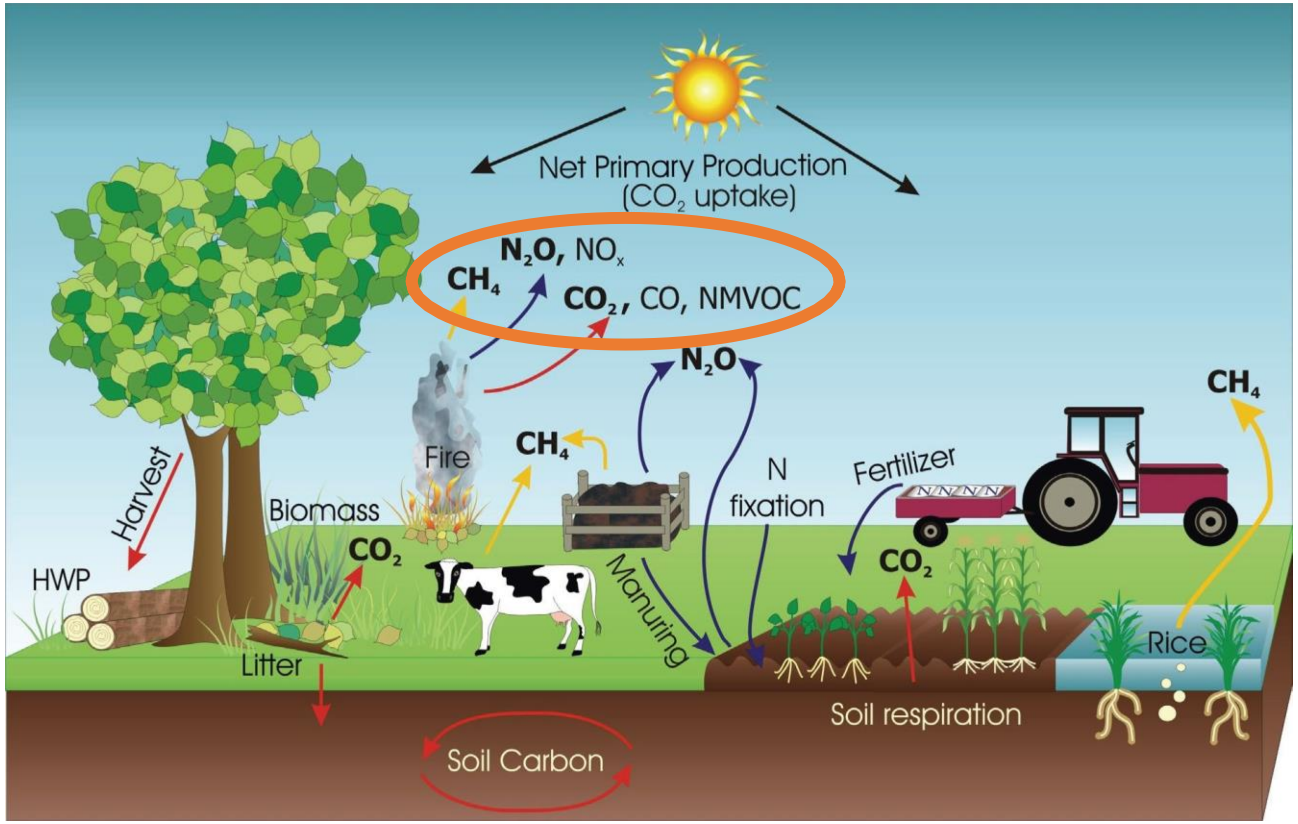
$$N_2O_{(L)}-N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \bullet Frac_{LEACH-(H)} \bullet EF_5$$

IPCC default values


Biomass Burning

Biomass burning: Introduction

- Includes the emissions of gases from burning due to:
  - Crop harvesting or clearing
    - Crop residue burning
  - Wild and controlled fires
    - From all land classes (Forest lands, croplands, grasslands, wetlands)
- Does not include emissions from burning biomass as a fuel
  - This is reported under energy



Biomass burning: Methodology

Emissions = **Activity Data (AD)** X **Emission Factor (EF)**

EQUATION 2.27

ESTIMATION OF GREENHOUSE GAS EMISSIONS FROM FIRE

$$L_{fire} = A \bullet M_B \bullet C_f \bullet G_{ef} \bullet 10^{-3}$$

Biomass consumption

L_{fire} = amount of greenhouse gas emissions from fire, tonnes of each GHG e.g., CH_4, N_2O, etc.

A = area burnt, ha

M_B = mass of fuel available for combustion, tonnes ha^{-1}. This includes biomass, ground litter and dead wood. When Tier 1 methods are used then litter and dead wood pools are assumed zero, except where there is a land-use change (see Section 2.3.2.2).

C_f = combustion factor, dimensionless (default values in Table 2.6)

G_{ef} = emission factor, g kg^{-1} dry matter burnt (default values in Table 2.5)

Note: Where data for M_B and C_f are not available, a default value for the amount of fuel actually burnt (the product of M_B and C_f) can be used (Table 2.4) under Tier 1 methodology.

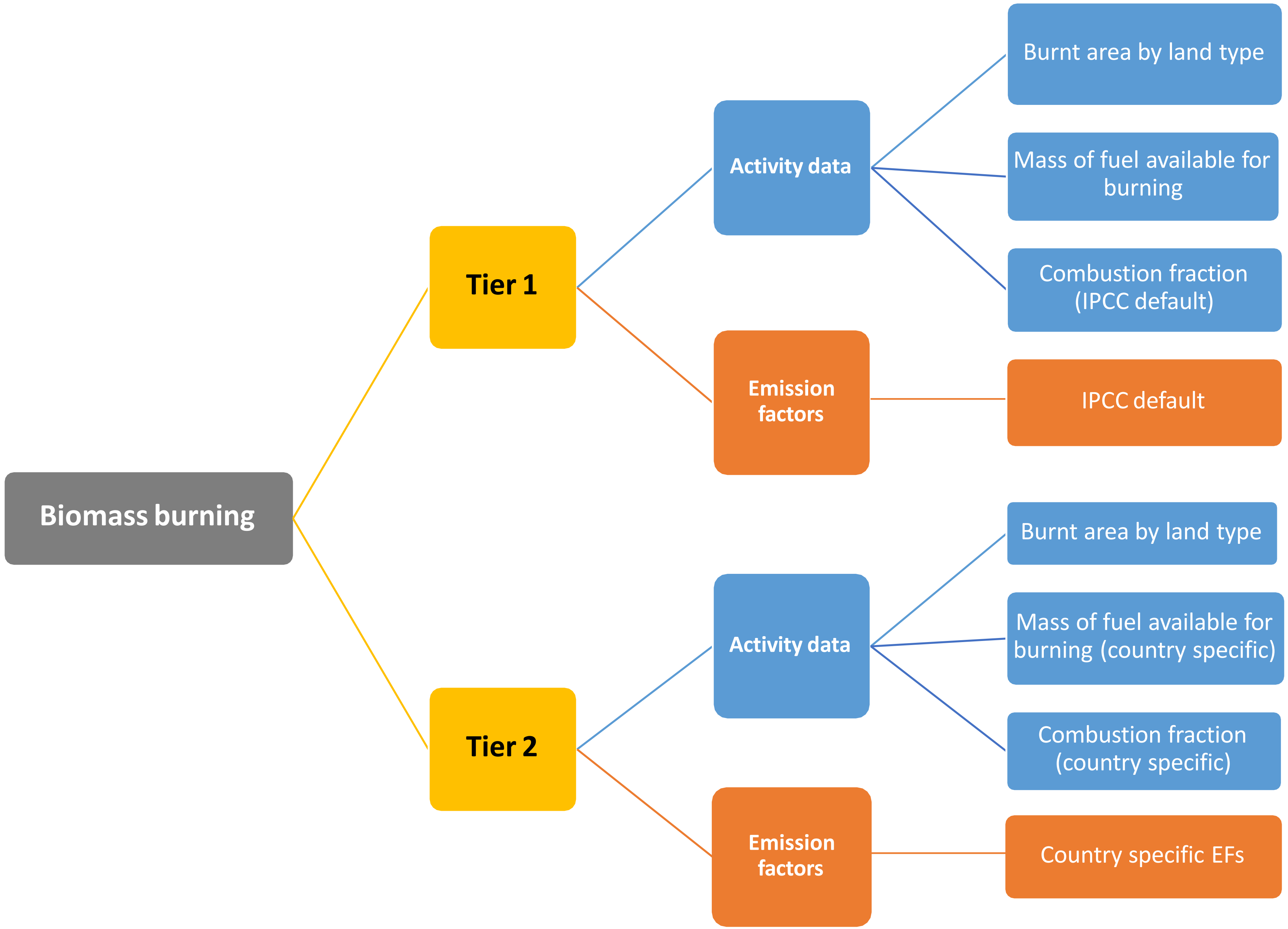
Biomass burning: Activity data

- Area burnt:
  - Data often obtained from satellite data (such as MODIS)
    - Wildfires and controlled fires together
    - Need burnt area per land type and, if available, per land conversion
  - Controlled fire data often difficult to separate out
    - Satellite data often too course for this
    - Ground-based data such as from forest inventories, plantation companies, croplands
  - Report wildfire and controlled fires separately if possible
- Mass of fuel available for combustion
  - Includes biomass and DOM
    - IPCC default biomass data
    - Country-specific data (Tier 2) – co-ordinate with land sector compiler
  - For crop residues only residues burn therefore need data on residue ratios
- Combustion factors
  - Defaults provided by IPCC
  - Country-specific values (Tier 2)

Biomass burning: Emission factors

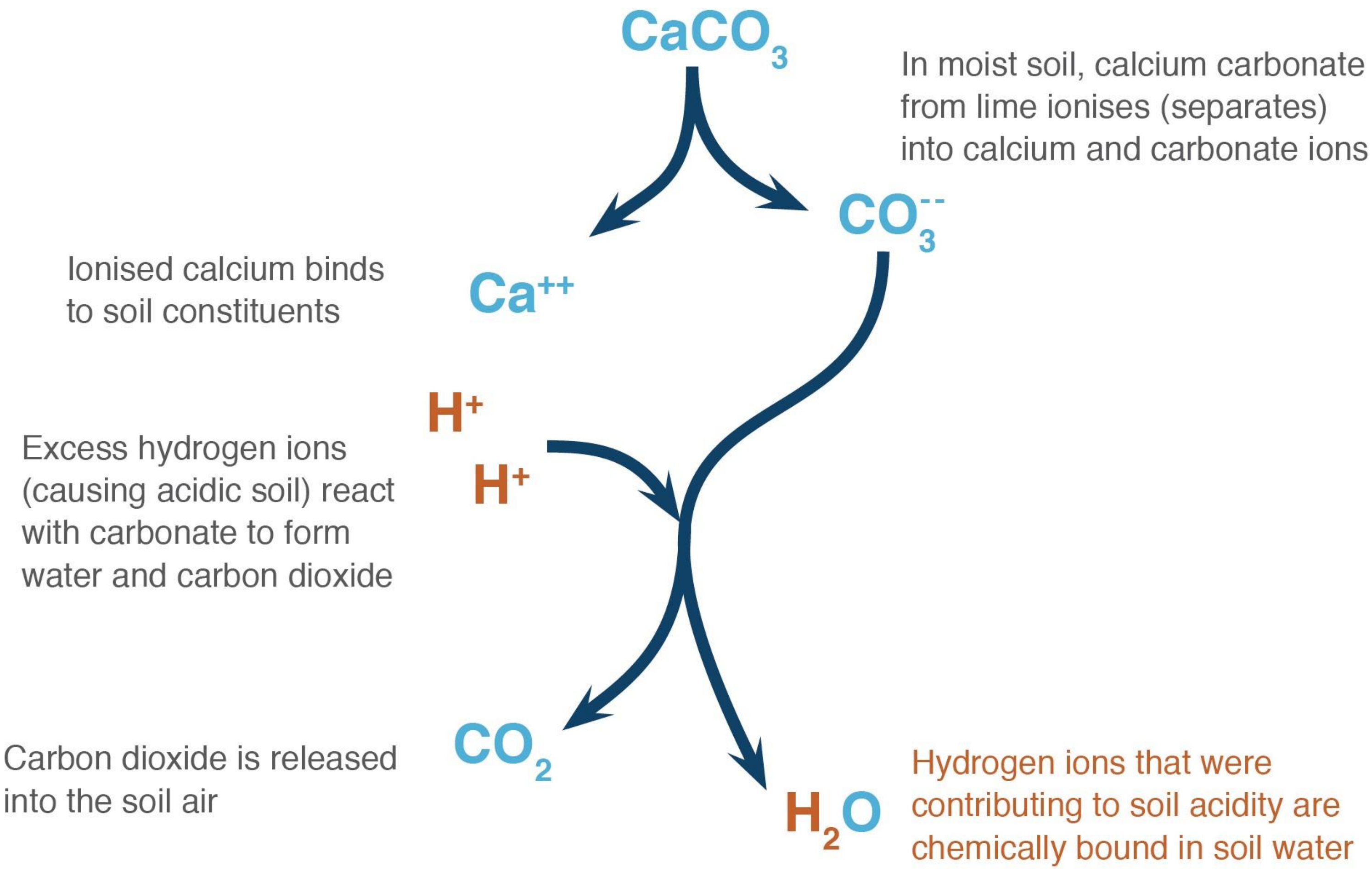
- IPCC provides default emission factors
  - Country-specific emissions factors can be applied for a Tier 2 approach

Biomass burning method summary



CO_2 from lime and urea application

Lime application: Introduction



Lime application: Methodology

Emissions = **Activity Data (AD)** X **Emission Factor (EF)**

(Lime consumption) ***(IPCC default factors)***

EQUATION 11.12

ANNUAL CO_2 EMISSIONS FROM LIME APPLICATION

$$CO_2\text{–}C\ Emission = \left(M_{Limestone} \bullet EF_{Limestone}\right) + \left(M_{Dolomite} \bullet EF_{Dolomite}\right)$$

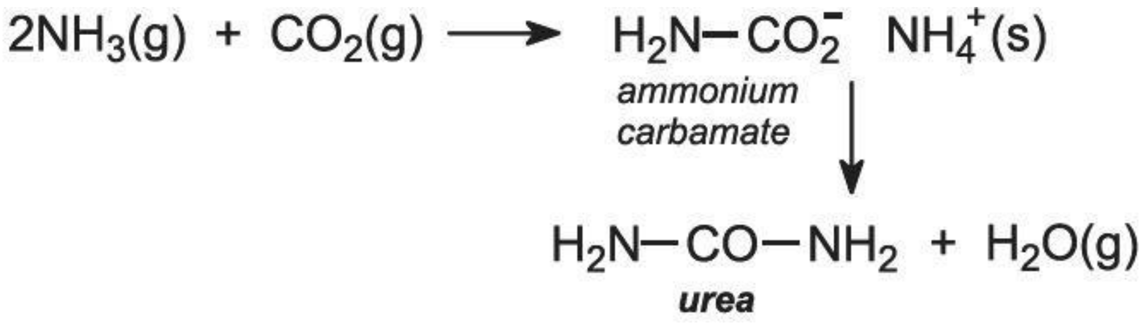
CO_2–C Emission = annual C emissions from lime application, tonnes C yr^{-1}

M = annual amount of calcic limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$), tonnes yr^{-1}

EF = emission factor, tonne of C (tonne of limestone or dolomite) $^{-1}$

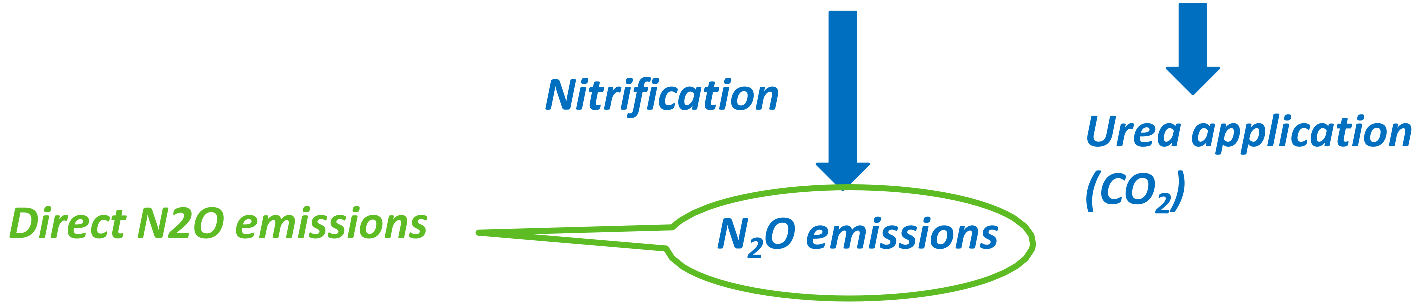
Urea application: Introduction

Urea production : CO_2 is fixed during the production



Urea application to soil : CO_2 released when water applied

$$\underset{\text{urea}}{NH_2CONH_2} + \underset{\text{water}}{H_2O} + \text{heat} \longrightarrow \underset{\text{ammonia}}{2NH_3} + \underset{\text{carbon dioxide}}{CO_2}$$



Urea application: Methodology (CO_2)

Emissions = **Activity Data (AD)** X **Emission Factor (EF)**

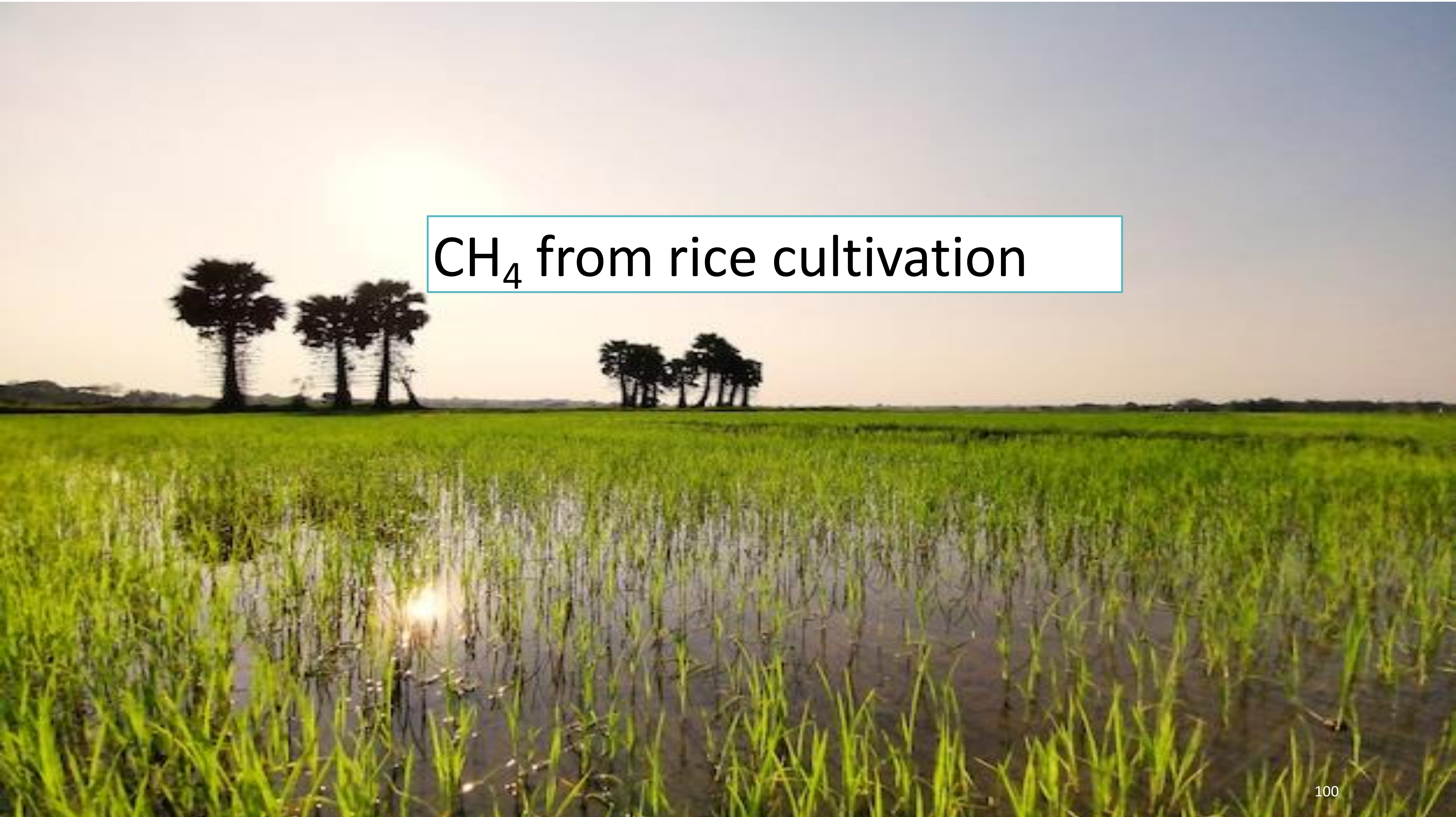
(Urea consumption) ***(IPCC default factors)***

EQUATION 11.13
ANNUAL CO_2 EMISSIONS FROM UREA APPLICATION

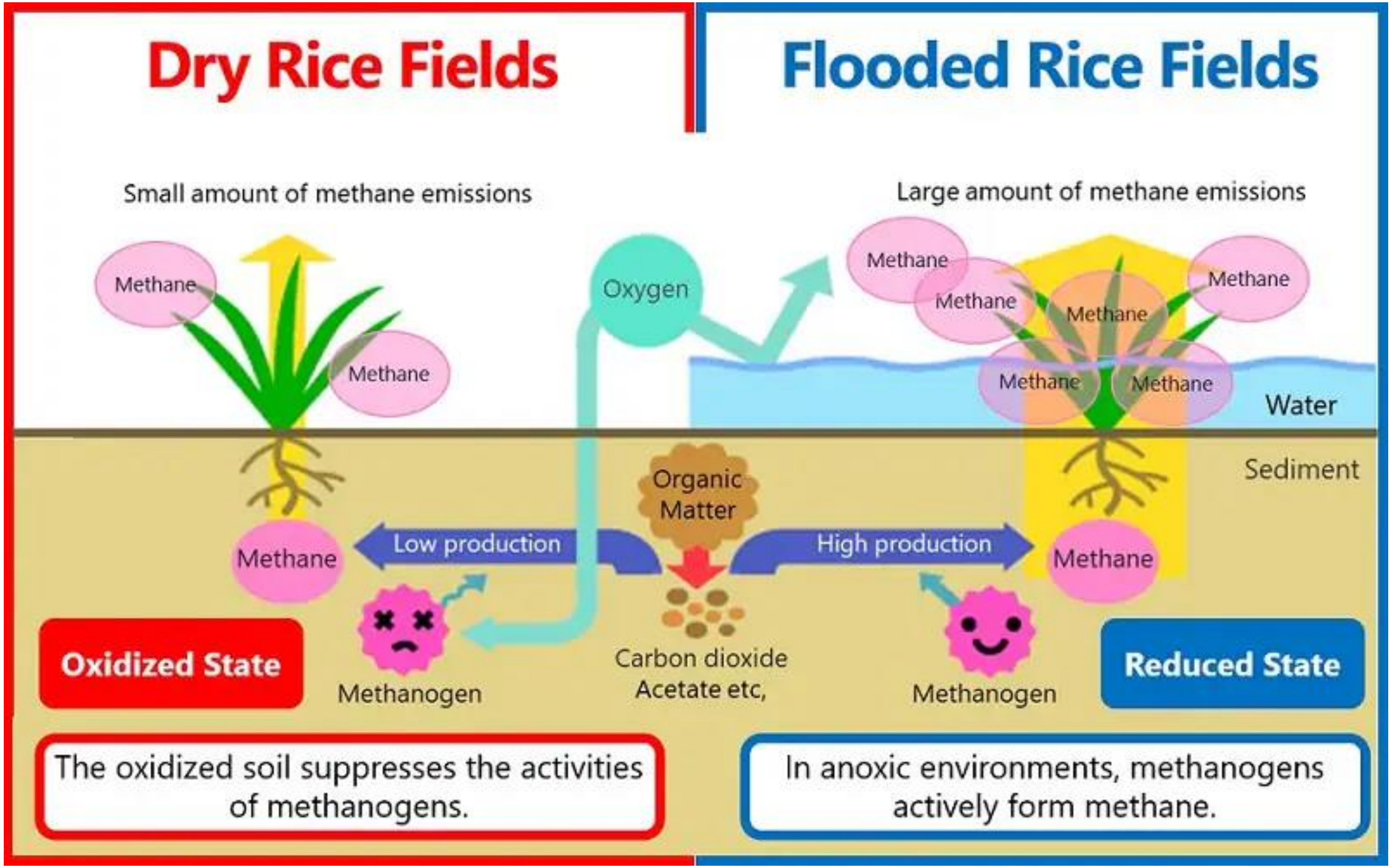
$$CO_2\text{–}C\ Emission = M \bullet EF$$

CO_2–C Emission = annual C emissions from urea application, tonnes C yr^{-1}
M = annual amount of urea fertilisation, tonnes urea yr^{-1}
EF = emission factor, tonne of C (tonne of urea)$^{-1}$

CH_4 from rice cultivation



Rice cultivation emissions: Introduction



Rice cultivation: Methodology (T1 & T2)

Emissions = **Activity Data (AD)** X **Emission Factor (EF)**

(Harvested area, cultivation period)

EQUATION 5.1

CH_4 EMISSIONS FROM RICE CULTIVATION

$$CH_{4\ Rice} = \sum_{i,j,k} \left(EF_{i,j,k} \bullet t_{i,j,k} \bullet A_{i,j,k} \bullet 10^{-6} \right)$$

$CH_{4\ Rice}$ = annual methane emissions from rice cultivation, Gg CH_4 yr^{-1}

EF_{ijk} = a daily emission factor for *i*, *j*, and *k* conditions, kg CH_4 ha^{-1} day^{-1}

t_{ijk} = cultivation period of rice for *i*, *j*, and *k* conditions, day

A_{ijk} = annual harvested area of rice for *i*, *j*, and *k* conditions, ha yr^{-1}

i, *j*, and *k* = represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary

Rice cultivation: Area divisions

$$CH_{4\ RDDce} = \sum_{ii,jj,k}(EF_{ii,jj,k} * t_{ii,jj,k} * A_{ii,jj,k} * 10^{-6})$$

- Classify the rice land area into its various types:
- For Tier 1 should be split into at least 3 baseline water regimes:
  - Irrigated
  - Rainfed
  - Upland
- Encouraged to include as many of the cultivation characteristics as possible:
  - Regional differences in rice cropping practices
  - Multiple crops
  - Water regime:
    - *Ecosystem type*
    - *Flooding pattern*
  - Organic amendments to soils
  - Other conditions:
    - *Soil type*
    - *Rice cultivar*
    - *Sulphate containing amendments*

Rice cultivation: Activity data

$$CH_{4\,Rice} = \sum_{i,j,k} \left(EF_{i,j,k} * t_{i,j,k} * A_{i,j,k} * 10^{-6} \right)$$

- Once area has been divided into the various categories, activity data is required for each of these areas:
  - Harvested area
  - Cultivation period

- Also need to collect data for EF adjustments:
  - Amount of organic amendment applied

- Note: Remember that nitrogen input data will also be required in the estimation of direct and indirect emission calculations
  - *calculation component specific for flooded rice*

Rice cultivation: Emission factors

$$CH_{4\ RDDœ} = \sum_{DDjjk} (EF_{ii,jj,k} * t_{DDjjk} * A_{DDjjk} * 10^{-6})$$

EQUATION 5.2

ADJUSTED DAILY EMISSION FACTOR

$$EF_i = EF_c \bullet SF_w \bullet SF_p \bullet SF_o \bullet SF_{s,r}$$

EF_i = adjusted daily emission factor for a particular harvested area

EF_c = baseline emission factor for continuously flooded fields without organic amendments

SF_w = scaling factor to account for the differences in water regime during the cultivation period (from Table 5.12)

SF_p = scaling factor to account for the differences in water regime in the pre-season before the cultivation period (from Table 5.13)

SF_o = scaling factor should vary for both type and amount of organic amendment applied (from Equation 5.3 and Table 5.14)

$SF_{s,r}$ = scaling factor for soil type, rice cultivar, etc., if available

Rice cultivation: Emission factors

$$CH_{4\ RDDœ} = \sum_{DDjjk}\left(EF_{ii,jj,k} * t_{DDjjk} * A_{DDjjk} * 10^{-6}\right)$$

EQUATION 5.2

ADJUSTED DAILY EMISSION FACTOR

$$EF_i = EF_c \bullet SF_w \bullet SF_p \bullet SF_o \bullet SF_{s,r}$$

IPCC defaults are provided

No default values: Include if data available

EQUATION 5.3

ADJUSTED CH_4 EMISSION SCALING FACTORS FOR ORGANIC AMENDMENTS

$$SF_o = \left(1 + \sum_i ROA_i \bullet CFOA_i\right)^{0.59}$$

SF_o = scaling factor for both type and amount of organic amendment applied

ROA_i = application rate of organic amendment *i*, in dry weight for straw and fresh weight for others, tonne ha^{-1}

$CFOA_i$ = conversion factor for organic amendment *i* (in terms of its relative effect with respect to straw applied shortly before cultivation) as shown in Table 5.14.

Thank You!

Questions?