AGRICULTURE SECTOR INVENTORY

DISCLAIMER

PREPARED UNDER

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ABBREVIATION AND ACRONYMS

AD	Activity Data
AAP	Annual Average Population
CH_4	Methane
DOCC	Department of Climate Change
EF	Emission Factor
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
MALFFB	Ministry of Agriculture, Livestock, Forestry, Fisheries and Biosecurity
NAPA	Number of Animal Produced Annually
N_2O	Nitrous Oxide
N_2	Dinitrogen
QA/QC	Quality Assurance/Quality Control
RTI	Right to Information
TAM	Typical Animal Mass
VBoS	Vanuatu Bureau of Statistics

3.1 CATEGORY OVERVIEW

3.1.1 Enteric Fermentation

Livestock production can result in CH_4 emissions from enteric fermentation and both CH_4 and nitrous oxide (N_2O) emissions from livestock manure management systems. Cattle are an important source of CH_4 in many countries because of their large population and high CH_4 emission rate due to their ruminant digestive system. Methane emissions from manure management tend to be smaller than enteric emissions, with the most substantial emissions associated with confined animal management operations where manure is handled in liquid-based systems. Nitrous oxide emissions from manure management vary significantly between the types of management system used and can also result in indirect emissions due to other forms of nitrogen loss from the system.

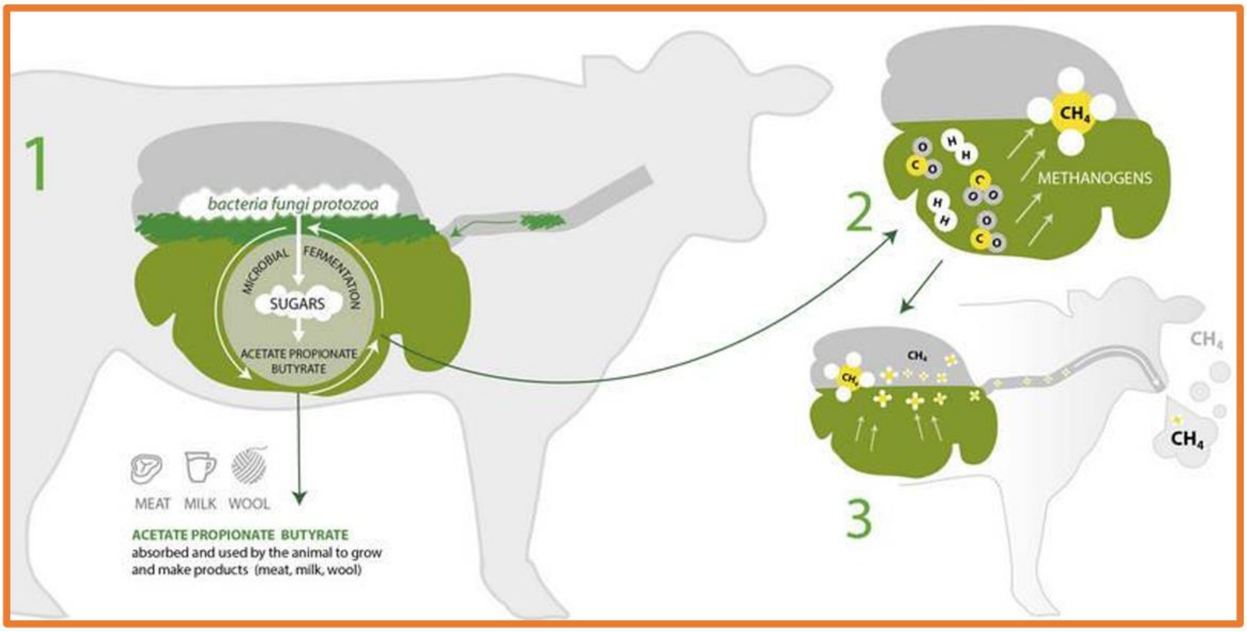


Figure 1. A representation of how Enteric fermentation works.

Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream. The amount of methane released depends on the type of digestive tract, age, and weight of the animal, and the quality and quantity of the feed consumed. Ruminant livestock (e.g., cattle, sheep) are major sources of methane with moderate amounts produced from non-ruminant livestock (e.g., pigs, horses). The ruminant gut structure fosters extensive enteric fermentation of their diet.

Natural wild ruminants are not considered in the derivation of a country's emission estimate. Emissions should only be considered from animals under domestic management (e.g., farmed deer, elk, and buffalo).[1]

3.1.2 Manure Management

The term 'manure' is used here collectively to include both dung and urine (i.e., the solids and the liquids) produced by livestock. The emissions associated with the burning of dung for fuel are to be reported under Volume 2 (Energy), or under Volume 5 (Waste) if burned without energy recovery.

[1] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch10_Livestock.pdf

When manure is used in the production of biogas, the emissions reported under the manure management category are those occurring on the farm site not resulting from combustion. These include, on-farm storage of the digestion input materials - pre-digestion, leakage during the digestion process and emissions from the storage and application of digestate to agricultural fields (included in Volume 4, Chapter 11, Section 11.2, Nitrous oxide emissions from managed Soils). Emissions from biogas combustion during the production of energy, whether on or off farm should be reported under Volume 2 “Energy”.

The decomposition of manure that occurs under anaerobic conditions (i.e., in the absence of oxygen), during storage and treatment, produces CH_4. These conditions occur most readily when large numbers of animals are managed in a confined area (e.g., dairy farms, beef feedlots, and swine and poultry farms), and where manure is disposed of in liquid-based systems. Emissions of CH_4 related to manure handling and storage are reported under ‘Manure Management.’ The main factors affecting CH_4 emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically. The former depends on the rate of waste production per animal and the number of animals, and the latter on how the manure is managed. When manure is stored or treated as a liquid (e.g., in lagoons, ponds, tanks, or pits), it decomposes anaerobically and can produce a significant quantity of CH_4. The temperature and the retention time of the storage unit greatly affect the amount of methane produced. When manure is handled as a solid (e.g., in stacks or piles) or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions and less CH_4 is produced.[2]

3.1.3 N_2O EMISSIONS

Direct N_2O emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. The emission of N_2O from manure during storage and treatment depends on the nitrogen and carbon content of manure, and on the duration of the storage and type of treatment. Nitrification (the oxidation of ammonia nitrogen to nitrate nitrogen) is a necessary prerequisite for the emission of N_2O from stored animal manures. Nitrification is likely to occur in stored animal manures provided there is a sufficient supply of oxygen. Nitrification does not occur under anaerobic conditions. Nitrites and nitrates are transformed to N_2O and dinitrogen (N_2) during the naturally occurring process of denitrification, an anaerobic process. There is general agreement in the scientific literature that the ratio of N_2O to N_2increases with increasing acidity, nitrate concentration, and reduced moisture. In summary, the production and emission of from managed manures requires the presence of either nitrites or nitrates in an anaerobic environment preceded by aerobic conditions necessary for the formation of these oxidized forms of nitrogen. In addition, conditions preventing reduction of N_2O to N_2, such as a low pH or limited moisture, must be present.

[2] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch10_Livestock.pdf

3.2 REFERENCE MANUAL

3.2.1. Data Collection

ENTERIC FERMENTATION

Tier 1 Activity Data (AD) requirements for Enteric Fermentation emissions of each livestock type.

To calculate the enteric fermentation emissions for each livestock type, the following AD are mandatory.

- Livestock Characterization – Animal types *(Refer to Annex, Table 2.2.1.1)*
- Population data
- Default CH_4 Emission Factor, kg CH_4 per head per year. *(Refer to Annex, Table 2.2.1.2a and Table 2.2.1.2b)*
- For cattle, where possible:
  - Average Milk Production
  - Typical Animal Mass (TAM- liveweight, kg)
- For other animal types: (TAM- Liveweight, kg)
- Region (Oceania)- to select appropriate default emission factors from tables 10.10 and 10.11. (*See 2006 IPCC Guideline, Volume 4, Chapter 10 EMISSIONS FROM LIVESTOCK AND MANURE MANAGEMENT, Section 10.3.2 Choice of emission factors*)
- Uncertainties
- Data Sources and time of sourcing
- Frequency of data recording; are the data provisional or actual?

MANURE MANAGEMENT

Tier 1 Activity Data (AD) requirement to estimate Methane (CH_4) in Manure Management

To calculate CH_4 emissions using Tier 1 in Manure management, the following AD are mandatory:

- Livestock population data according to basic characterization. (Same data for enteric fermentation should be used).
- Average annual temperature for the country or region to select the EFs (for Vanuatu it's ~25°C), the geographical zone (for Vanuatu = tropical moist).
- Default methane emission factors for manure management by livestock category or subcategory. The region is Oceania. *(Refer to Annex, Table 2.2.1.3a and Table 2.2.1.3b)*

Tier 1 Activity Data (AD) requirement to estimate manure management Direct Nitrous Oxide (N_2O) emissions

To calculate direct N_2O emission using Tier 1 in Manure Management, the following AD are required:

- Animal population data according to basic characterization
- Default or country specific manure management system usage data. *(Refer to Annex, Table 2.2.1.4a – Table 2.2.1.4d)*
- Annual nitrogen excretion rates which can be calculated from:
  - Default daily N excretion rate. (*Refer to Annex, Table 2.2.1.3c)*
  - Default or country specific typical animal mass (TAM).

- 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. (*Refer to Annex, Table 2.2.1.3d)*

(See 2006 IPCC Guideline, Volume 4, Chapter 10, Section 10.5.1, Equation 10.25)

Tier 1 Activity Data (AD) requirement to estimate manure management Indirect Nitrous Oxide (N_2O) emissions

To calculate Indirect N_2O emission using Tier 1 in Manure Management, the following AD are required:

- Number of head of livestock species/category T in the country
- Annual average N excretion per head of species/category T in the country, kg N animal-1 yr-1
- Fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless
- Percentage of managed manure nitrogen for livestock category T that volatilizes as NH_3 and NOx in the manure management system S, %. *(Refer to Annex, Table 2.2.1.3e)*

3.2.2. Data Sources (Departments, Stakeholders)

The country's specific data can be collected from the following departments/stakeholders/organization:

- Department of Livestock, Ministry of Agriculture, Livestock, Forestry, Fisheries and Biosecurity (MALFFB)
- Vanuatu Bureau of Statistics (VBoS)
- Livestock Farms
- Vanuatu Abattoir
- Department of Climate Change (DOCC)

Once a data set is selected, a more detailed formal specification of data should be created. A clear clarity of data requirements will allow data that is requested from the different departments/organizations to be delivered upon expectation (Goodwin, Woodfield, Ibnoaf, Koch, & Yan, 2006). The specification should include details such as:

- Definition of the data set (E.g. time series, sectors and sub-sector detail, national coverage, requirements for uncertainty data, emission factors and/or activity data units).
- The format (e.g., spreadsheet) and structure (e.g., what different tables are needed and their structure) of the data set,
- Description of any assumptions made regarding national coverage, the sectors included, representative year, technology/management level, and emission factors or uncertainty parameters.
- Identification of the routines and timescales for data collection activities (e.g., how often is the data set updated and what elements are updated).
- Reference to documentation and QA/QC procedures.
- Contact name and department/ organization.
- Date of availability

Flow chart 3.2.2.1: Details of access to data sources by Department of Climate Change (DOCC)

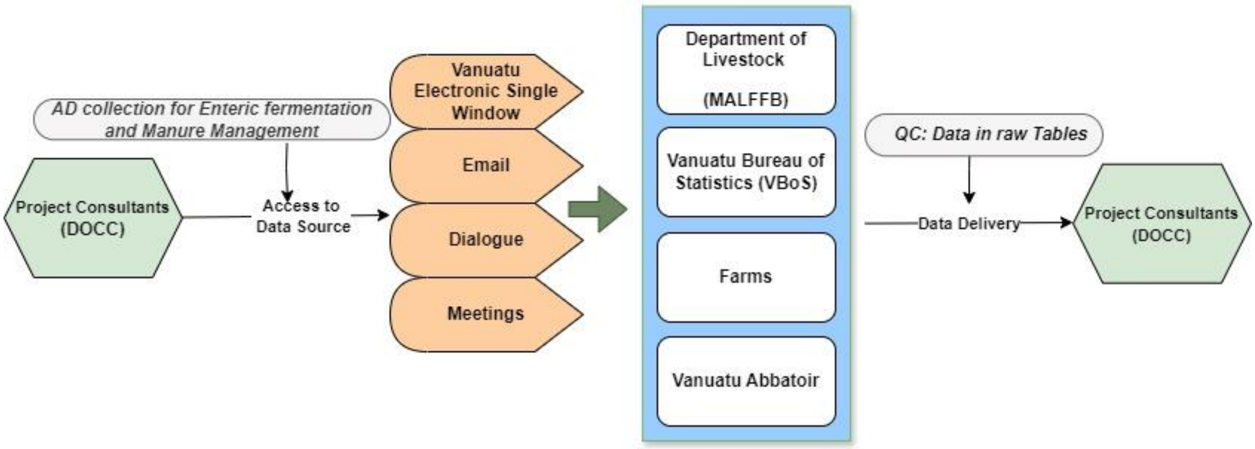


Table 1: Detailed Information of Collecting Activity Data from Sources.

Department/ Organization	**Roles and Responsibility**	**Dates**	**Relevant Governing Arrangement**	**Contact Person**	**Comments**
Department of Livestock (MALFFB)	It is responsible to provide data on livestock populations, management practices, and productivity	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between Department of Livestock and DOCC	Department of Livestock Sergio Email: Tel: Sylvia Email: Tel:	For significant information and data requirements, DOCC needs to send a prompt letter to the Department of livestock two months prior. A follow-up email or call is crucial as well.
Vanuatu Bureau of Statistics (VBoS)	VBoS is responsible for providing data relevant to greenhouse gas emissions estimation	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between VBoS and DOCC	KWARI Linda *Statistician - Agriculture (Economics)* Email: Tel: VBoS contact E-mail: stats@vanuatu.gov.vu	For significant information and data collection, DOCC needs to send a prompt letter to VBoS two months prior.

				Tel: (678) 22110 / 22111 / 33040	A follow-up email or call is crucial as well.
Vanuatu Abattoir	To provide data on livestock slaughter numbers and carcass weights. This information can be useful for estimating livestock populations and meat production, which are relevant factors in emissions calculations.	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between Abattoir and DOCC	Vanuatu Abattoir Tel: 7722961	For significant information and data collection, DOCC needs to send a prompt letter to Abattoir two months prior. A follow-up email or call is crucial as well.
Farm	To provide ground data related to livestock management practices and manure management. And to provide information on their livestock populations, feeding practices, and waste management methods.	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between the Farmers and DOCC		For significant information and data collection, DOCC needs to send a prompt letter to the farms two months prior. A follow-up email or call is crucial as well.
Department of Climate Change (DOCC)	DOCC is responsible to send a formal letter requesting relevant data and information on manure management and enteric fermentation to Department of	February – March every year	Provide a Memorandum of understanding or Right to Information (RTI) to the Department of livestock, VBoS, Vanuatu Abattoir and farms.	Name: Nelson Kalo Director of Climate Change Email: nekalo@vanuatu.gov.vu	DOCC is responsible for doing a follow-up to the departments or organization for the required data to be delivered upon schedule.

	livestock, VBoS, Vanuatu Abattoir and farms.				

3.2.3. Data Assumptions

The following assumptions have been made in deriving the tier 1 enteric fermentation emission factors for cattle1:

- Mature weights of animals have been used.
- Cows have been assumed to be non-lactating as lactation levels were low.
- The mix of bulls and castrates among "males" was undetermined as Cfi value for castrates was not specified.

Default EF for direct N_2O emissions from manure management in Daily Spread System:

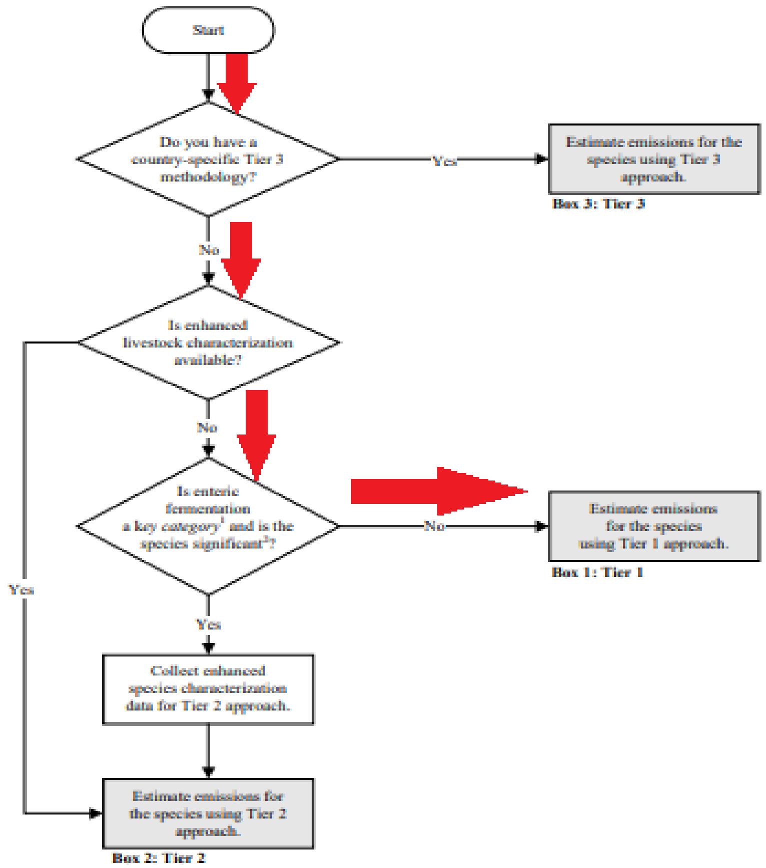
- N_2O emissions during storage and treatment are assumed to be **zero**.

3.3 CALCULATING GREENHOUSE GAS EMISSION

3.3.1 METHODOLOGY FOR ENTERIC FERMENTATION

Figure 2 Displays the decision tree employed for selecting the method approach for actual CH4 emissions from category 3.A.1-Enteric Fermentation. The Decisions implemented During this operation are indicated by the red arrows below.

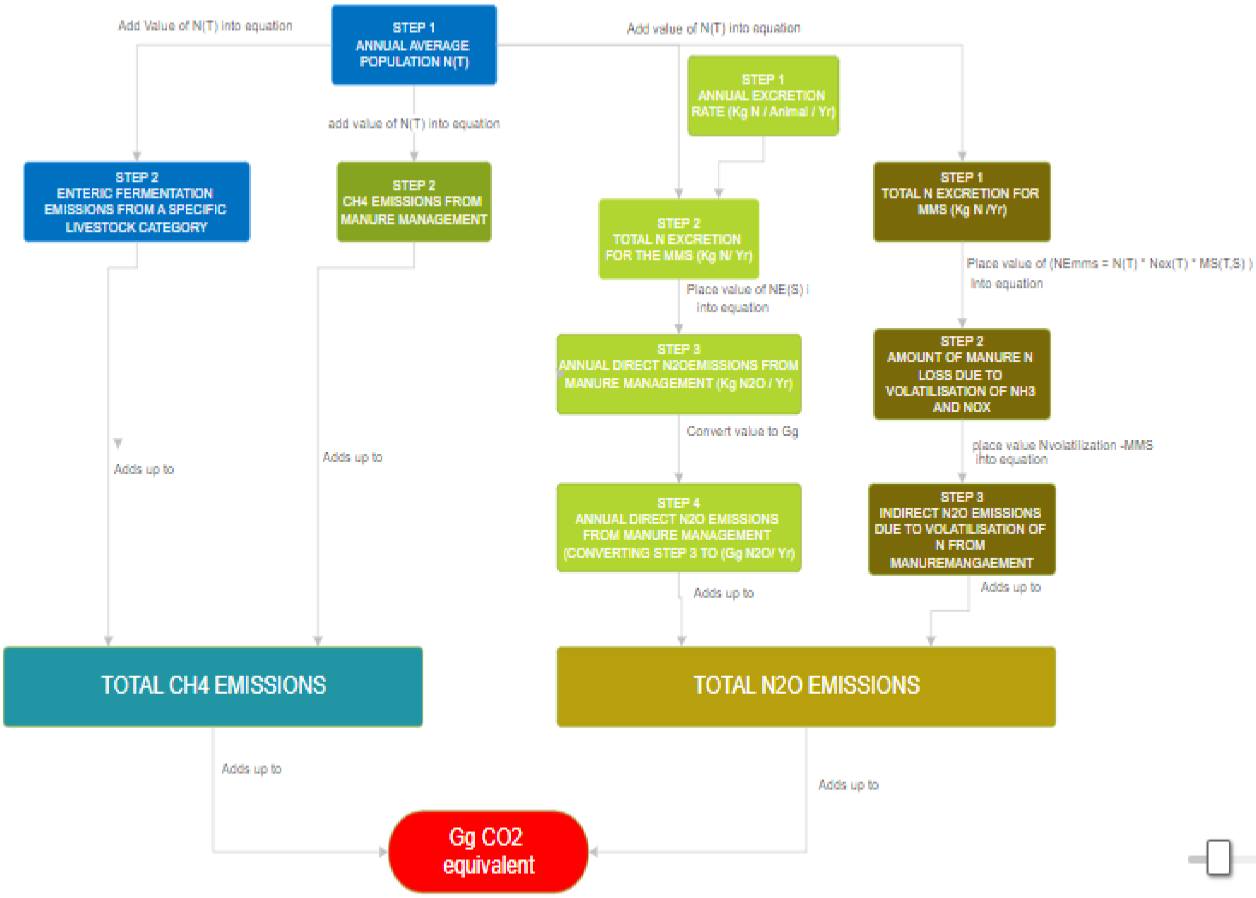
Figure 10.2 Decision Tree for CH_4 Emissions from Enteric Fermentation



(2006 IPCC Guidelines, Vol. 4, Ch. 10, Pg. 25, FIGURE 10.2)

NOTE: Due to national Circumstances (Lack of resources) Vanuatu does not have yet reliable country-specific emission factors and parameters and therefore, is applying the default parameters and Tier 1 method to estimate CH_4 emissions from the 3.A.1 category.

Figure 3: Depicts the logical processes required to calculate the emissions of CH4 from enteric fermentation, CH4, N2O from manure management, and indirect N2O



CH_4 EMISSIONS FROM ENTERIC FERMENTATION IN VANUATU USING TIER 1 APPROACH

STEP 1: FIND THE ANNUAL AVERAGE POPULATION OF LIVESTOCK

EQUATION 10.1

ANNUAL AVERAGE POPULATION

$$AAP = Days\_alive * \left(\frac{NAPA}{365}\right)$$

where:

AAP = annual average population (2006 IPCC Guidelines, Vol. 4, Ch. 10, EQUATION 10.1)

NAPA = number of animals produced annually (2006 IPCC Guidelines, Vol. 4, Ch. 10, EQUATION 10.1).

STEP 2: CH_4 EMISSIONS FROM ENTERIC FERMENTATION

Note: Take the annual average population from Equation 10.1 and place into the equation below to find the Enteric Fermentation for each of the Specific livestock categories.

EQUATION 10.19

ENTERIC FERMENTATION EMISSIONS FROM A SPECIFIC LIVESTOCK CATEGORY

$$CH_4 \text{ Emission} = EF_{(T)} \times [N_{(T)} / 10^6]$$

Where:

CH_4 Emissions = methane emissions from Enteric Fermentation, Gg CH4 yr-1 (See 2006 IPCC Guidelines, Vol. 4, Ch. 10, Pg. 28)

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH4 head-1 yr-1 (See 2006 IPCC Guidelines, Vol. 4, Ch. 10, Pg. 28).

$N_{(T)}$ = the number of heads of livestock species/category T in the country (See 2006 IPCC Guidelines, Vol. 4, Ch. 10, Pg. 28).

T = species/category of livestock (See 2006 IPCC Guidelines, Vol. 4, Ch. 10, Pg. 28).

CH_4 EMISSIONS FROM THE MANURE MANAGEMENT SYSTEM IN VANUATU USING THE TIER 1 APPROACH

STEP 1: CH_4 EMISSIONS FROM MANURE MANAGEMENT

Note: Use the standard value of $N_{(T)}$ from step 1 in CH_4 emissions from enteric fermentation in Vanuatu using tier 1 approach.

EQUATION 10.22

CH4 EMISSIONS FROM MANURE MANAGEMENT

$$\sum_{T} \frac{EF_{(T)}\ x\ N_{(T)}}{10^6}$$

Where:

CH_4 Manure = CH_4 emissions from manure management, for a defined population, Gg CH4 yr-1 (see 2006 IPCC Guidelines, Vol.4, Ch.10, Pg. 37, EQUATION 10.22).

$EF_{(T)}$ = Emission factor for the defined livestock population, kg CH4 head-1 yr-1 1 (see 2006 IPCC Guidelines, Vol.4, Ch.10, Pg. 37, EQUATION 10.22).

$N_{(T)}$ = The number of heads of livestock species/category T in the country 1 (see 2006 IPCC Guidelines, Vol.4, Ch.10, Pg. 37, EQUATION 10.22).

T = Species/category of livestock 1 (see 2006 IPCC Guidelines, Vol.4, Ch.10, Pg. 37, EQUATION 10.22).

N_2O EMISSIONS FROM THE MANURE MANAGEMENT SYSTEM IN VANUATU USING THE TIER 1

APPROACH

STEP 1: TOTAL N EXCRETION RATE FOR THE MMS (Kg N/Yr)

EQUATION 10.30

ANNUAL N EXCRETION RATES

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

$Nex_{(T)}$ = Annual N excretion for livestock category T, kg N animal-1 yr-1 (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg. 57, EQUATION 10.30)

$N_{rate(T)}$ = Default N excretion rate, kg N (1000 kg animal mass)$^{-1}$ day-1 (see Table 10.19) (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg. 57, EQUATION 10.30)

$TAM_{(T)}$ = Typical animal mass for livestock category T, kg animal-1 (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg. 57, EQUATION 10.30)

STEP 2: TOTAL N EXCRETION FOR THE MMS (Kg N/yr.)

TOTAL N EXCRETION FOR THE MMS (Kg N/ yr)

$$NE(S) = \sum MS_{(T,S)} * N_{(T)}$$

$NE_{(S)}$: Total N Excretion for the MMS (Kg N/ Year)

$MS_{(T, S)}$ = Fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless (2006, IPCC guidelines)

$N_{(T)}$ = Number of heads of livestock species/category T in the country. (2006, IPCC guidelines)

STEP 3: ANNUAL DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT (Kg N_2O /yr)

Note: take the value of $NE_{(S)}$: Total N Excretion for the MMS (Kg N/ Year) from step 2 above and place into the following equation.

ANNUAL DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT (Kg N_2O /yr)

$$N_2O_{(S)} = NE_{(S)} * EF3_{(S)} * 44/28$$

$N_2O_{(S)}$ = Annual direct N_2O emissions from manure management (kg N2O /yr) (2006, IPCC Guidelines)

$NE_{(S)}$: Total N Excretion for the MMS (Kg N/ Year) (2006, IPCC Guidelines)

$EF3_{(S)}$ = Emission factor for direct N_2O emissions from manure management system S in the country, kg N2O-N/kg N in manure management system (2006, IPCC guidelines).

44/28 = Conversion of (N_2O-N) (mm) emissions to N_2O(mm) emissions (2006, IPCC Guidelines).

STEP 4: ANNUAL DIRECT N_2O EMISISONS FROM MANURE MANAGEMENT

Note: convert the answer from step 3 above to kt/Gg by placing the answer from step 3 above into the equation below.

ANNUAL DIRECT N_2O EMISISONS FROM MANURE MANAGEMENT

$$\text{Gg of } N_2O_{(S)} = N_2O_{(S)} * 10^{-6}$$

Where:

$N_2O_{(S)}$ = Annual direct N_2O emissions from manure management (kg N2O /yr) (2006, IPCC Guidelines).

10^{-6} = conversion factor used to convert kg to Gg/Kt (2006, IPCC Guidelines)

ALTERNATIVE EQUATION

Note: Equation 10.25 below is a Summarized equation from step 1 to 3 to calculate the direct N_2O emissions from manure management.

EQUATION 10.25

DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT

$$N_2O_{D(mm)} = \sum\sum_S [\sum_{(T)}(N_{(T)} * Nex_{(T)} * MS_{(T,S)})] * EF_{3(S)}] * \frac{44}{28}$$

Where:

N_2O_D (mm) = Direct N2O emissions from Manure Management in the country, kg N2O yr-1 (2006 IPCC Guidelines, Vol. 4, Ch.10, Pg. 54, EQUATION 10.25).

$N_{(T)}$ = Number of heads of livestock species/category T in the country (2006 IPCC Guidelines, Vol. 4, Ch.10, Pg. 54, EQUATION 10.25).

$NEX_{(T)}$= Annual average N excretion per head of species/category T in the country, kg N animal-1 yr-1 (2006 IPCC Guidelines, Vol. 4, Ch.10, Pg. 54, EQUATION 10.25).

$MS_{(T,S)}$ = Fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless (2006 IPCC Guidelines, Vol. 4, Ch.10, Pg. 54, EQUATION 10.25).

$EF3_{(S)}$ = Emission factor for direct N2O emissions from manure management system S in the country, kg N2O-N/kg N in manure management system S (2006 IPCC Guidelines, Vol. 4, Ch.10, Pg. 54, EQUATION 10.25).

S = Manure management system (2006 IPCC Guidelines, Vol. 4, Ch.10, Pg. 54, EQUATION 10.25).

T = Species/category of livestock (2006 IPCC Guidelines, Vol. 4, Ch.10, Pg. 54, EQUATION 10.25).

44/28 = Conversion of (N2O-N) (mm) emissions to N2O(mm) emissions (2006 IPCC Guidelines, Vol. 4, Ch.10, Pg. 54, EQUATION 10.25).

INDIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT SYSTEM IN VANUATU USING TIER 1 APPROACH

STEP 1: TOTAL N EXCRETION FOR THE MMS (Kg N/YR)

TOTAL N EXCRETION FOR THE MMS (KG N/YR)

$$NEmms = N(T) * Nex_{(T)} * MS_{(T,S)}$$

Where:

N(T) = number of heads of livestock species/category T in the country (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26).

$Nex_{(T)}$ = annual average N excretion per head of species/category T in the country, kg N animal-1 yr^{-1} (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26).

$MS_{(T, S)}$ = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless(See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26)

STEP 2: AMOUNT OF MANURE N LOSS DUE TO VOLATILISATION OF NH_3 AND NO_X

NOTE: take the answer from step 1 ($NEmms = N_{(T)} * Nex_{(T)} * MS_{(T,S)}$) above and place into the equation 10.26 below.

EQUATION 10.26

N LOSSES DUE TO VOLATILIZATION FROM MANURE MANAGEMENT

$$N_{Volatilisation\text{-}MMS} = \sum_S [\sum_T [N_T * Nex_{(T)} * MS_{(T,S)}) * (\frac{Frac_{GASMS}}{100})_{(T,S)}]]$$

Volatilization-MMS = amount of manure nitrogen that is lost due to volatilization of NH3 and NOx, kg N yr^{-1} (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26).

N(T) = number of heads of livestock species/category T in the country (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26).

$Nex_{(T)}$ = annual average N excretion per head of species/category T in the country, kg N animal-1 yr^{-1} (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26).

$MS_{(T, S)}$ = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless(See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26)

$Frac_{GasMS}$ = percent of managed manure nitrogen for livestock category T that volatilises as NH3 and NOx in the manure management system S, % (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26)

STEP 3: THE INDIRECT N_2O EMISSIONS FROM VOLATILIZATION OF N IN FORMS OF NH_3 AND NO_x ($N_2O_{G\ (mm)}$

Note: take the answer from $N_{volatilization\ -MMS}$ and place into the equation below to find the $N_2O_{G(mm).}$

EQUATION 10.27

INDIRECT N_2O EMISSIONS DUE TO VOLATILISATION OF N FROM MANURE MANAGEMENT

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

$N_2O_{G\ (mm)}$ = indirect N2O emissions due to volatilization of N from Manure Management in the country, kg N2O yr^{-1} (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.56, EQUATION 10.27)

EF_4 = emission factor for N2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N_2O-N (kg NH3-N + NOx-N $volatilized)^{-1}$; default value is 0.01 kg N2O-N (kg NH_3-N + NO_x-N $volatilized)^{-1}$, given in Chapter 11, Table 11.3(see Annex). (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.56, EQUATION 10.27)

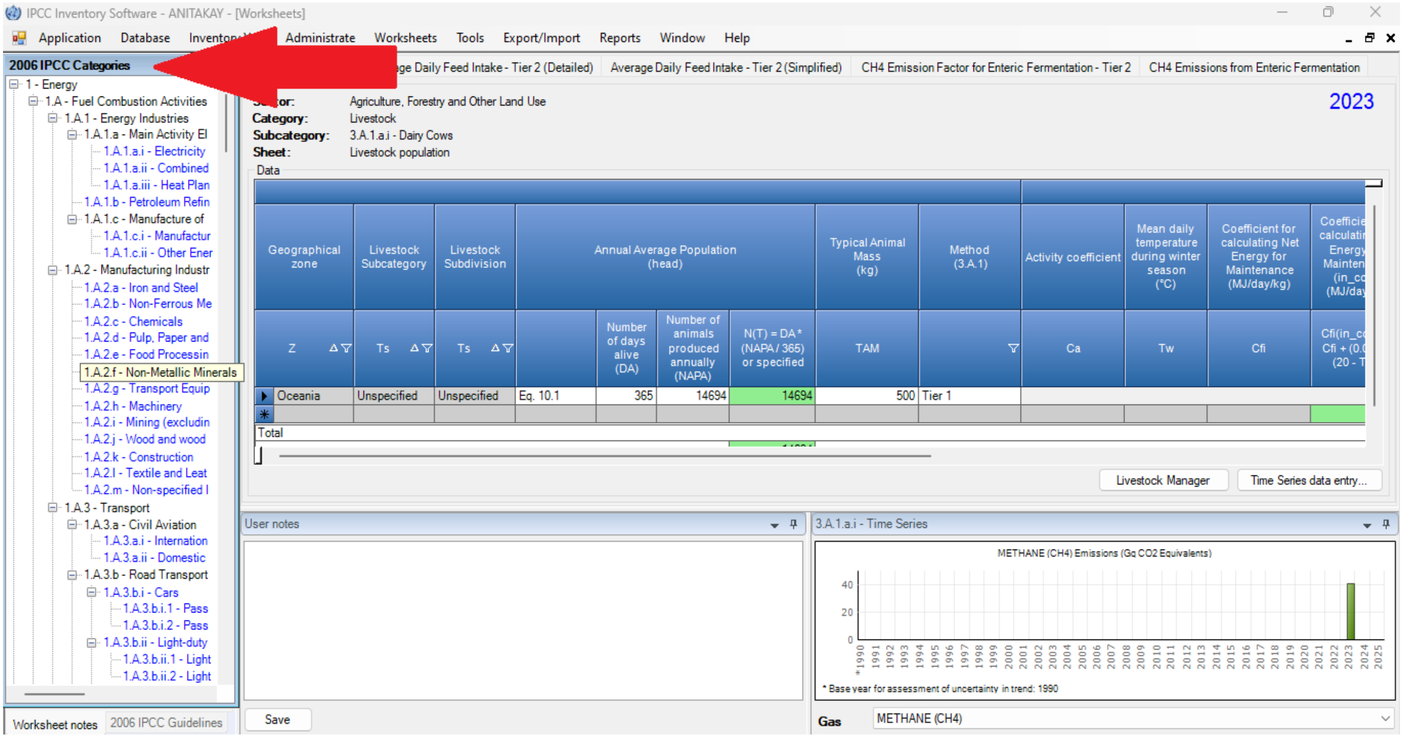
3.3.2 STEP- BY- STEP CALCULATION, DOCUMENTING RESOURCES USED

1.1 Launch the IPCC software ver. 2.901 IPCC Inventory software - 32bit for national GHG inventories.

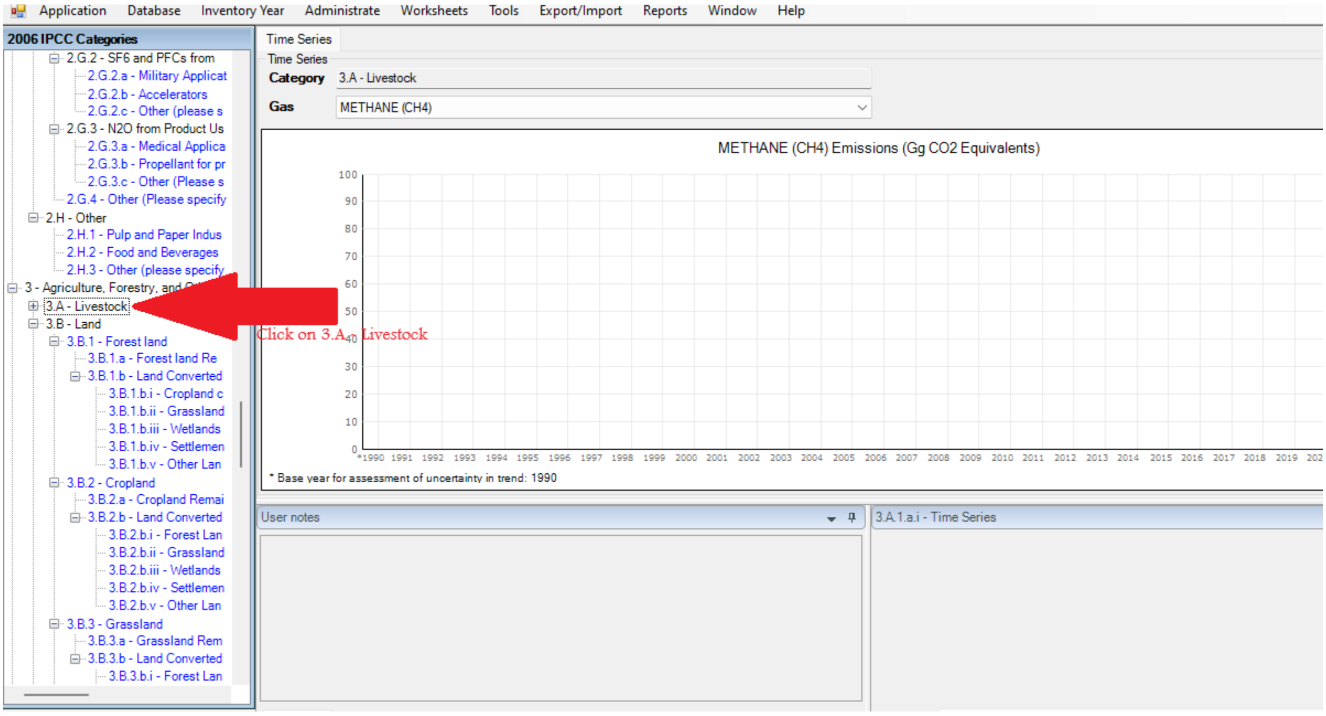
1.2 Type in your password and username.

1.3 Type in the year of your choosing or the current inventory year.

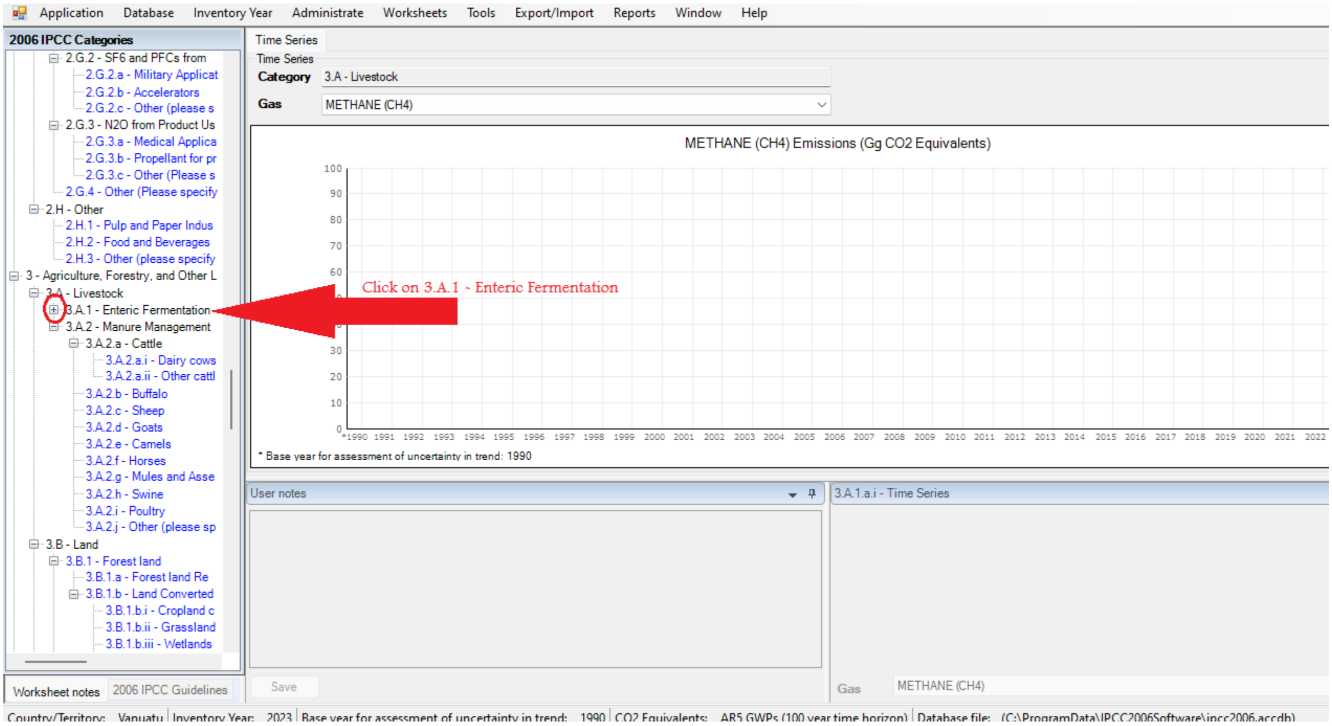
1.4 Locate the bar on the left-hand corner of the page labeled "2006 IPCC categories" (See illustration below)



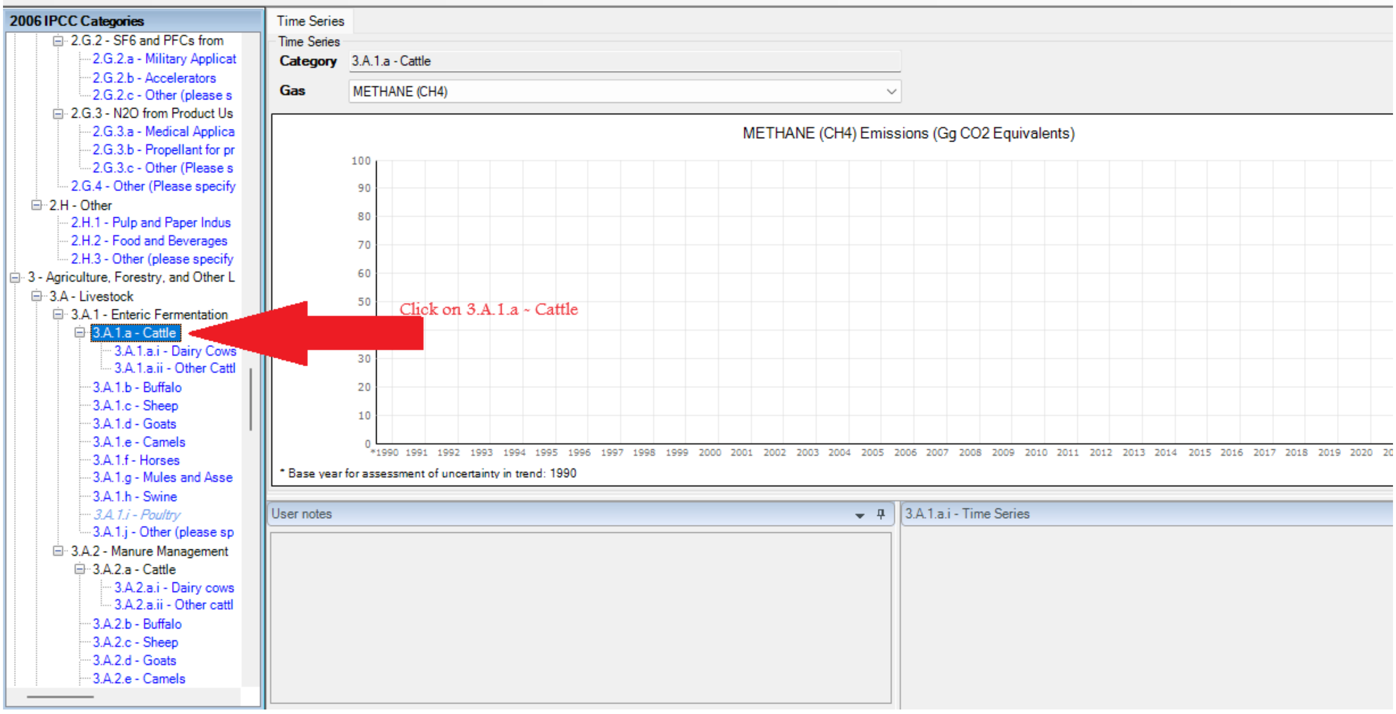
1.4 Scroll down "2006 IPCC categories" till you reach “3. A- Livestock” and then click on the (+) sign to reveal the sub-sectors (see illustration below).



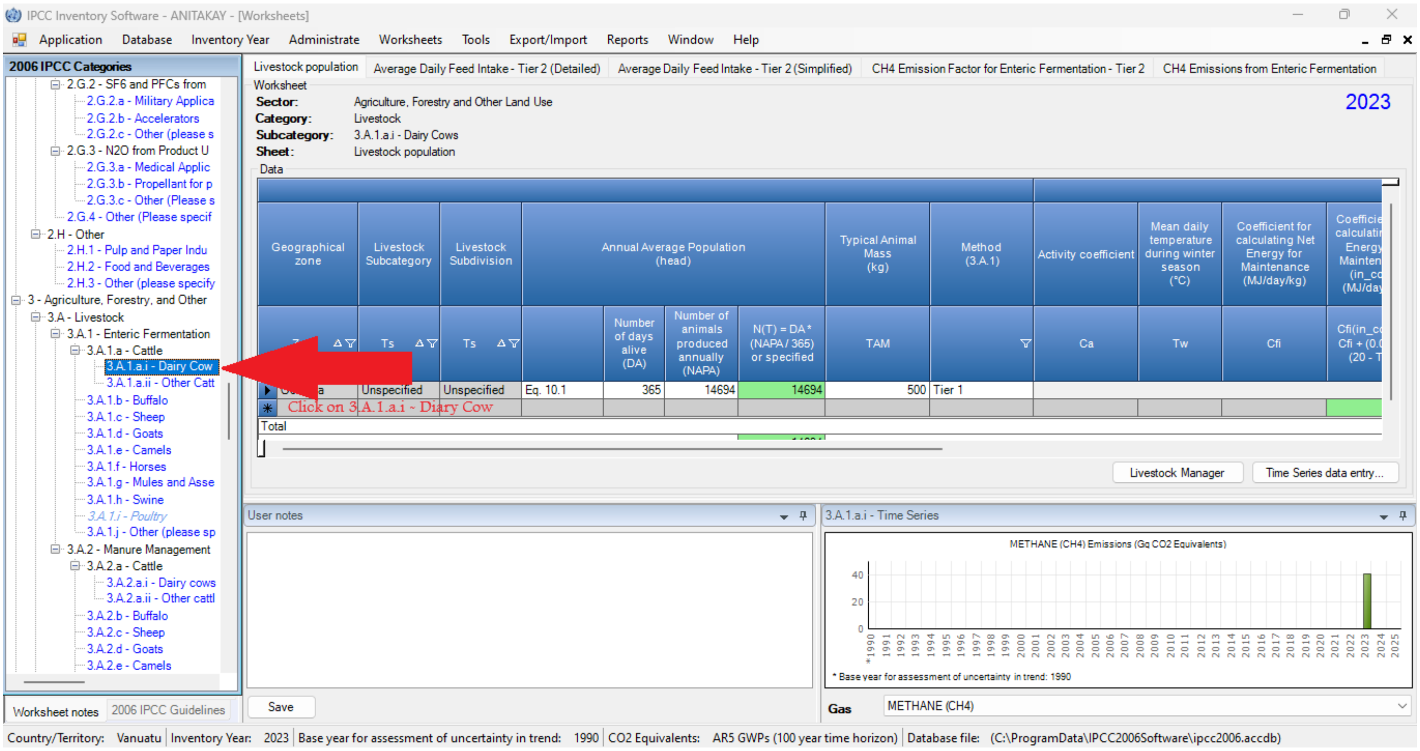
1.6 Click on the subsector 3.A.1 Enteric Fermentation (see illustration below).



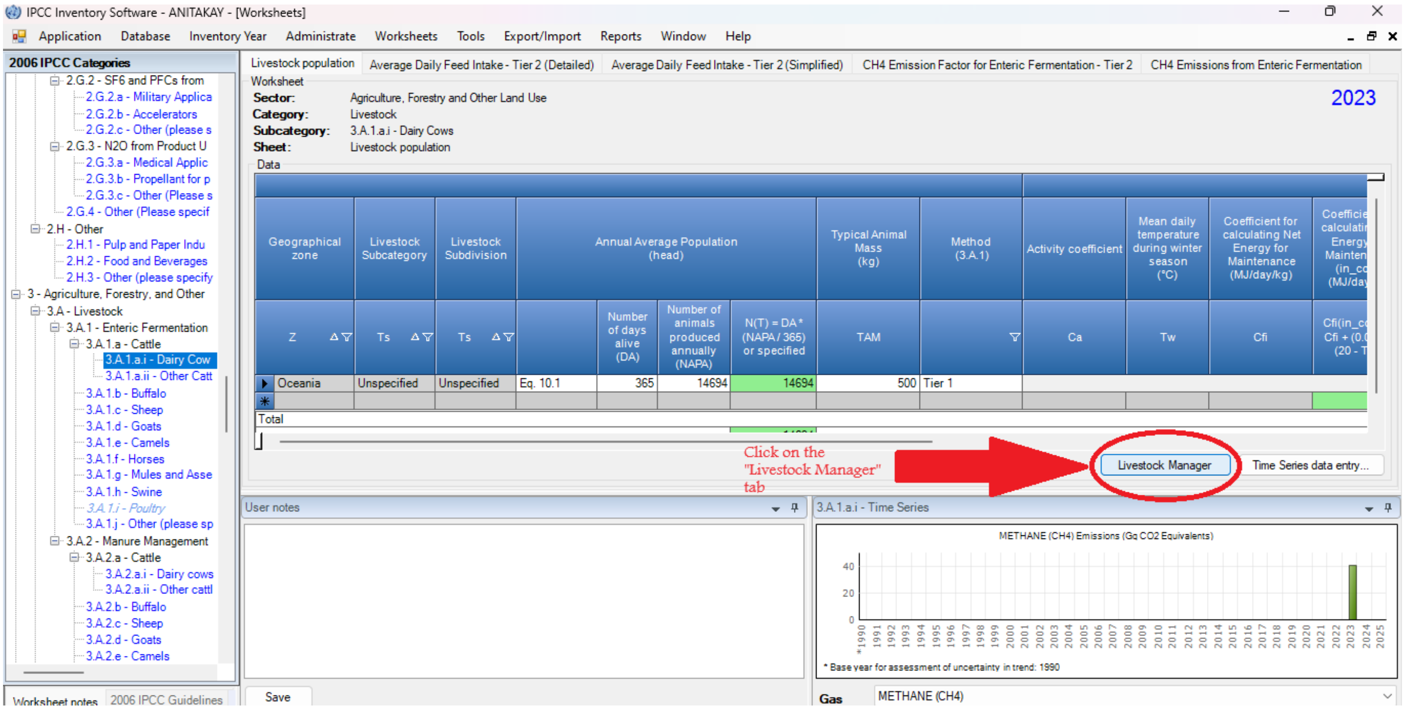
1.5 Click on (+) sign on the 3.A.1.a – Cattle (see illustration below)



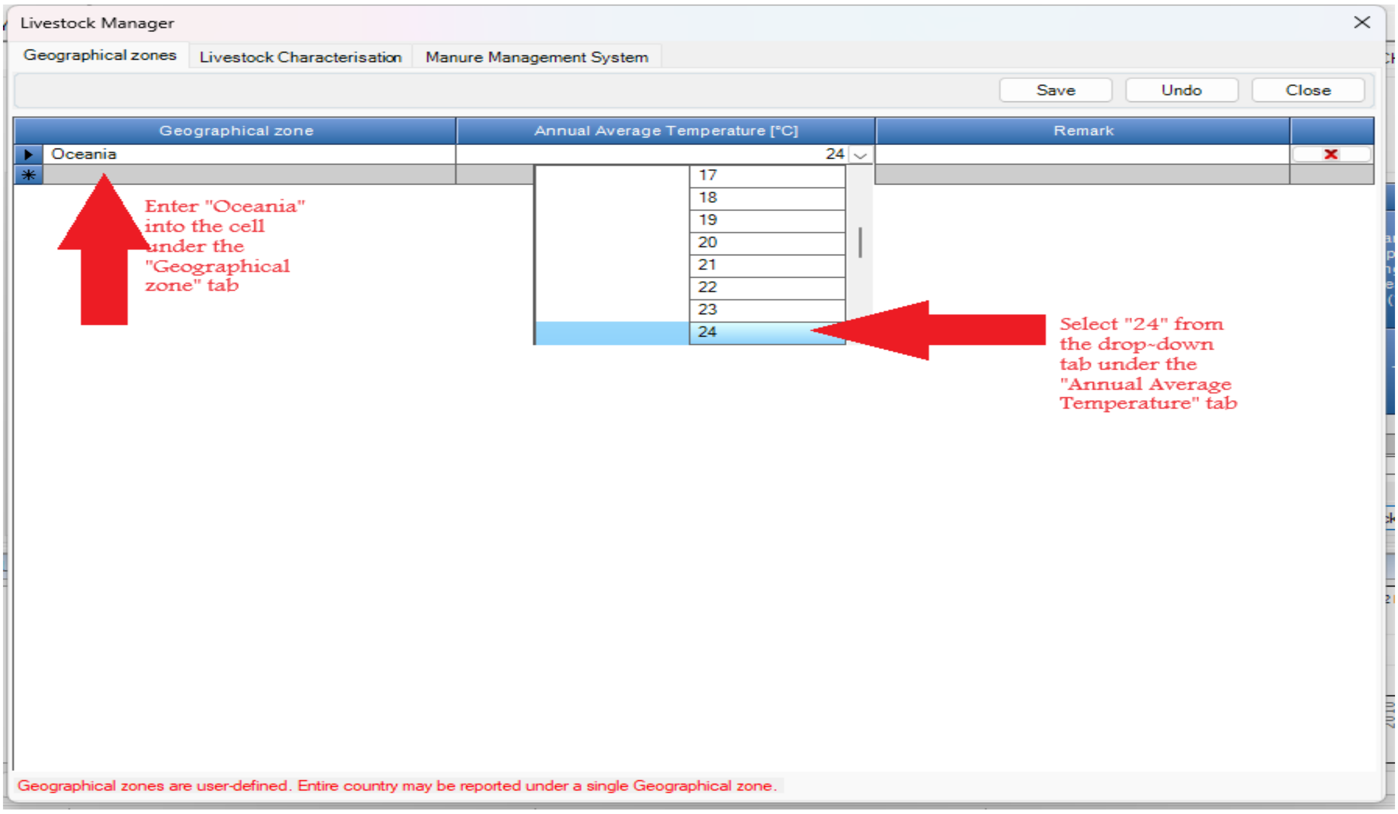
1.6 Click on "3.A.1.a.i – Diary Cow" (See illustration below).



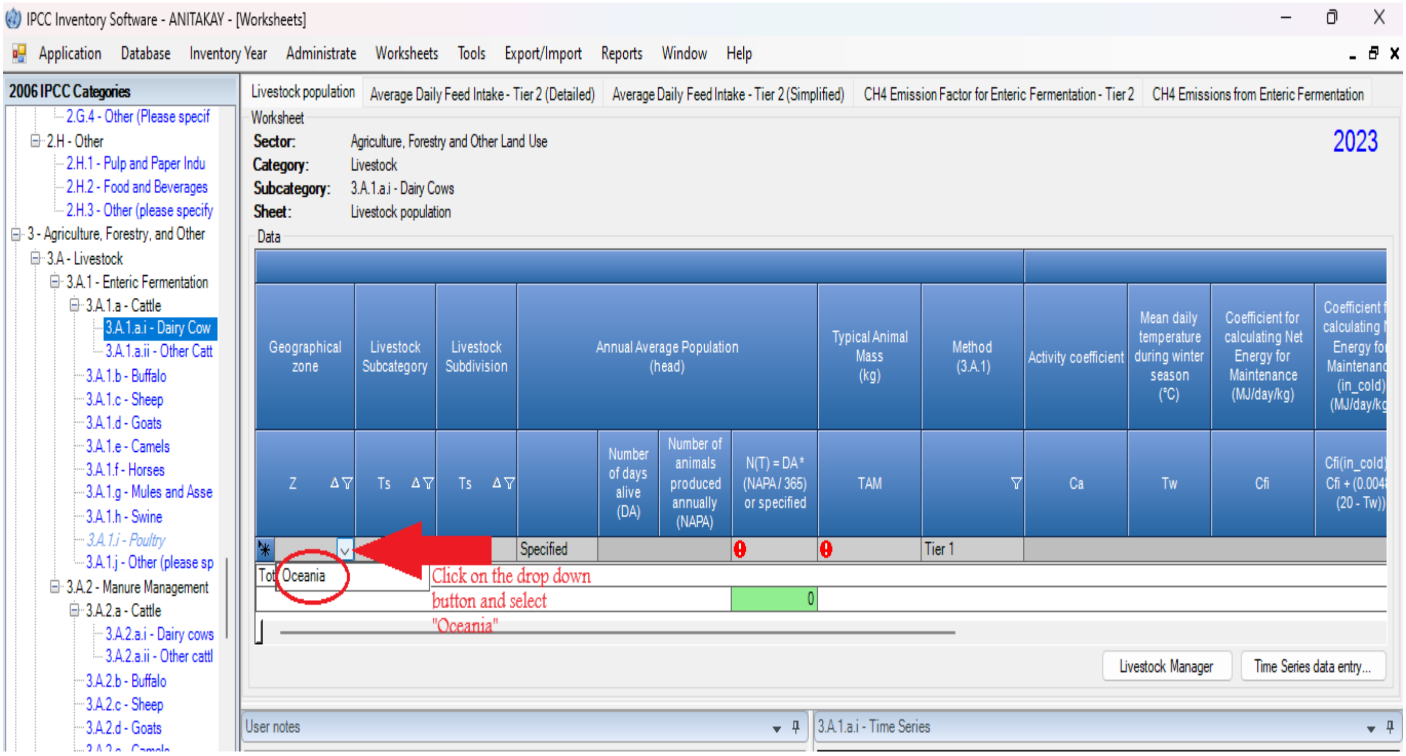
1.7 Click on the "Livestock Manager" tab (See illustration below).



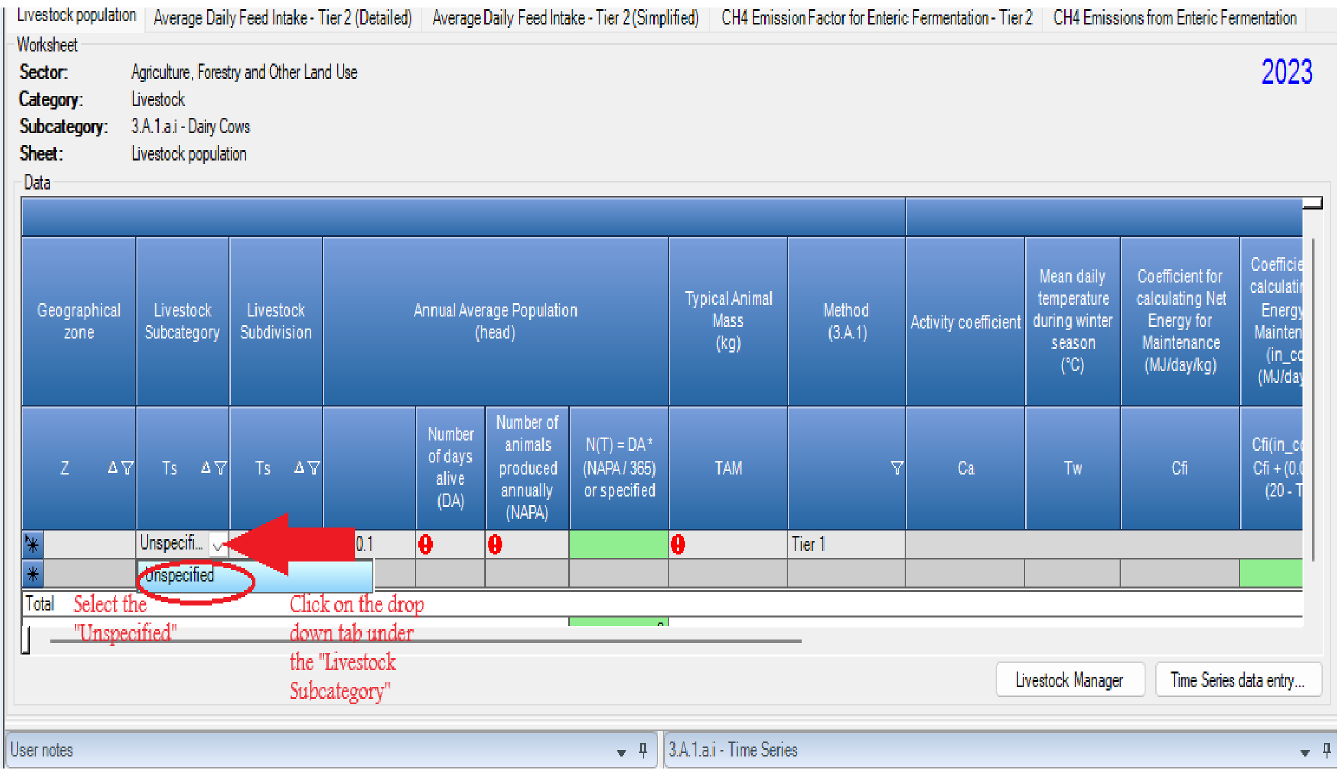
1.8 Enter "Oceania" into the first cell under the "Geographical zone" tab, then click on the drop-down bar under the "Annual Average Temperature" tab and select "24". Select save on the right-hand corner and click the X button (See illustration below)



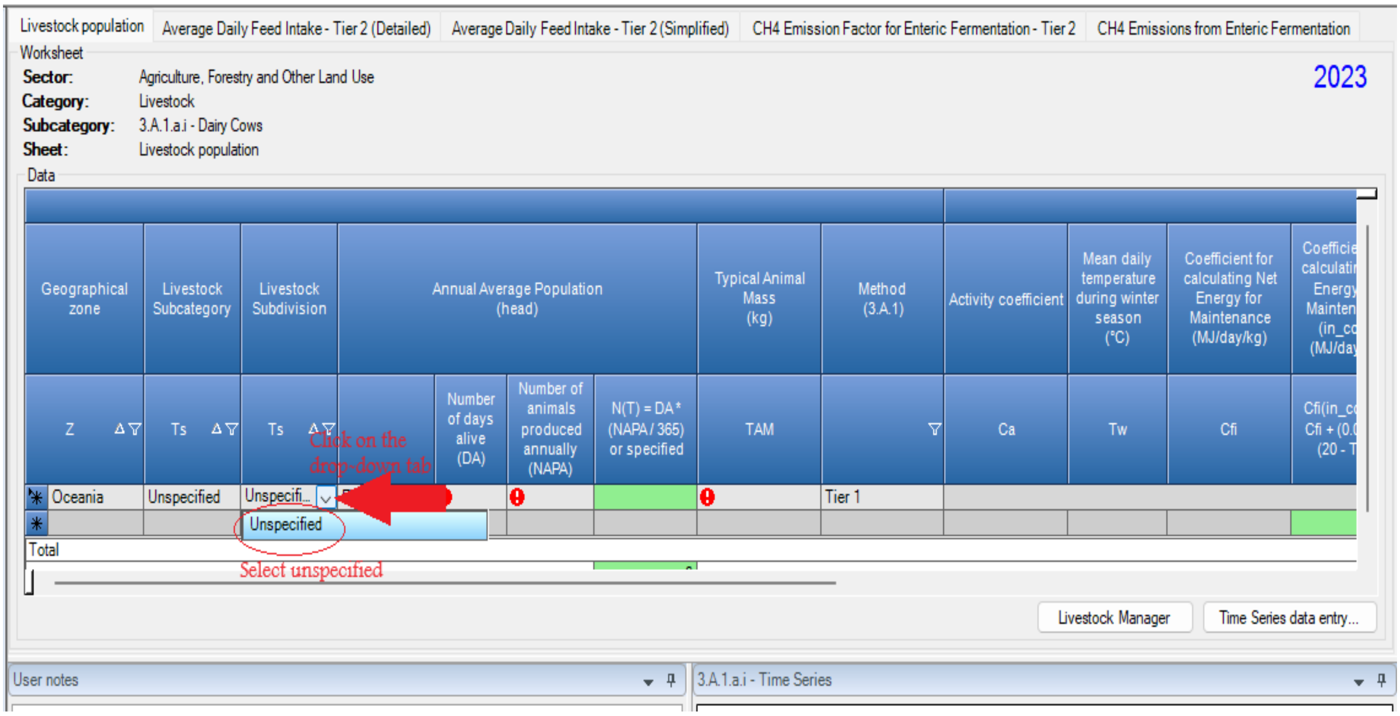
1.9 Click on the drop-down button under the tab “Geographical Zone” and select “Oceania” (see illustration below)



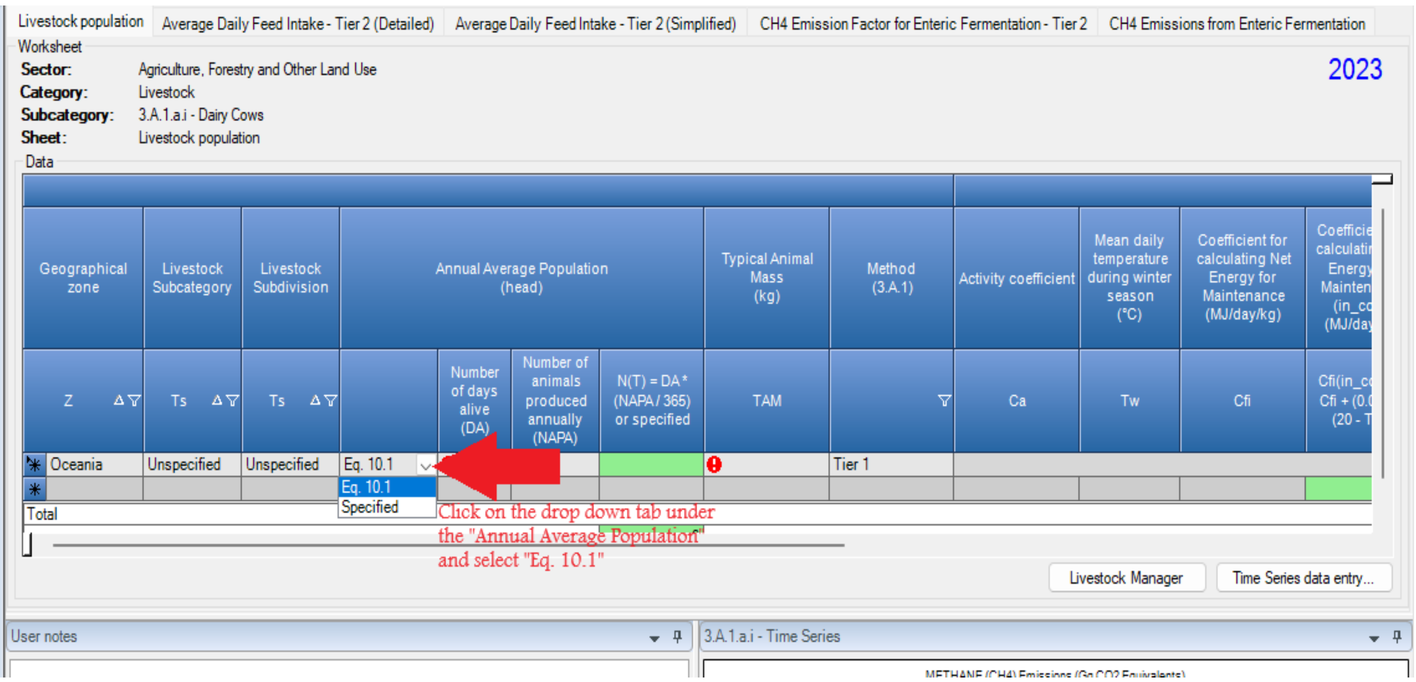
2.0 Click on the drop-down tab under the “Livestock Subcategory” tab in the table and select “unspecified” (see Illustration below).



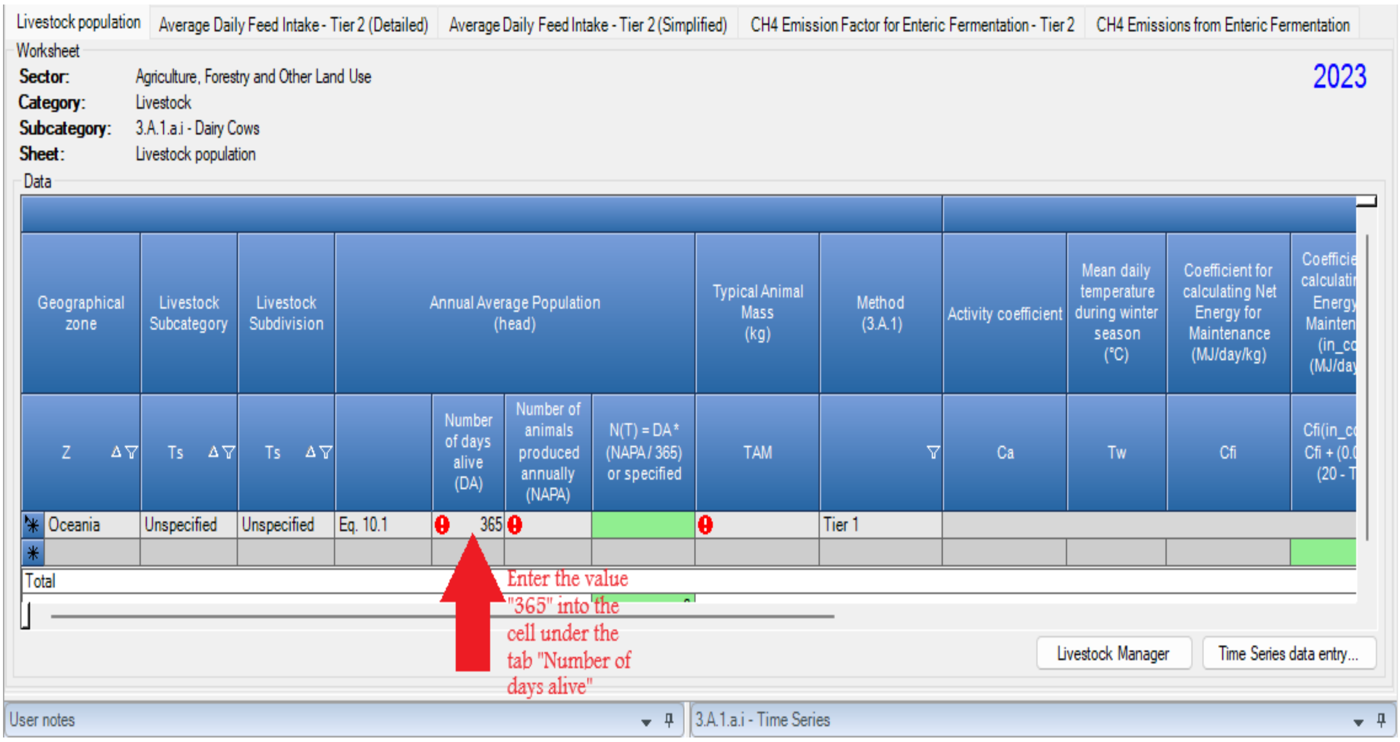
2.1 Under the “Livestock Subdivision” tab, click on the drop-down tab and select “Unspecified”



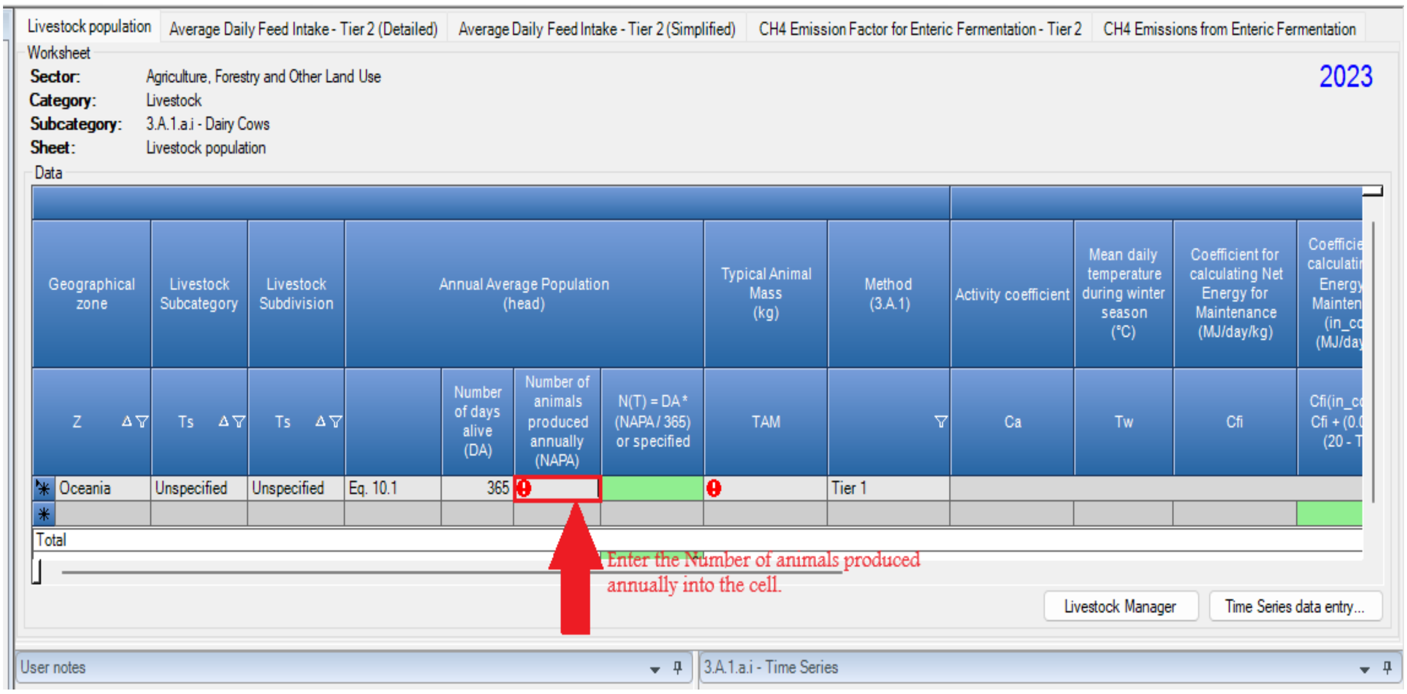
2.2 Under the “Annual Average Population (head)” tab in the table, click on the drop-down tab and select “Eq. 10.1” (see illustration below).



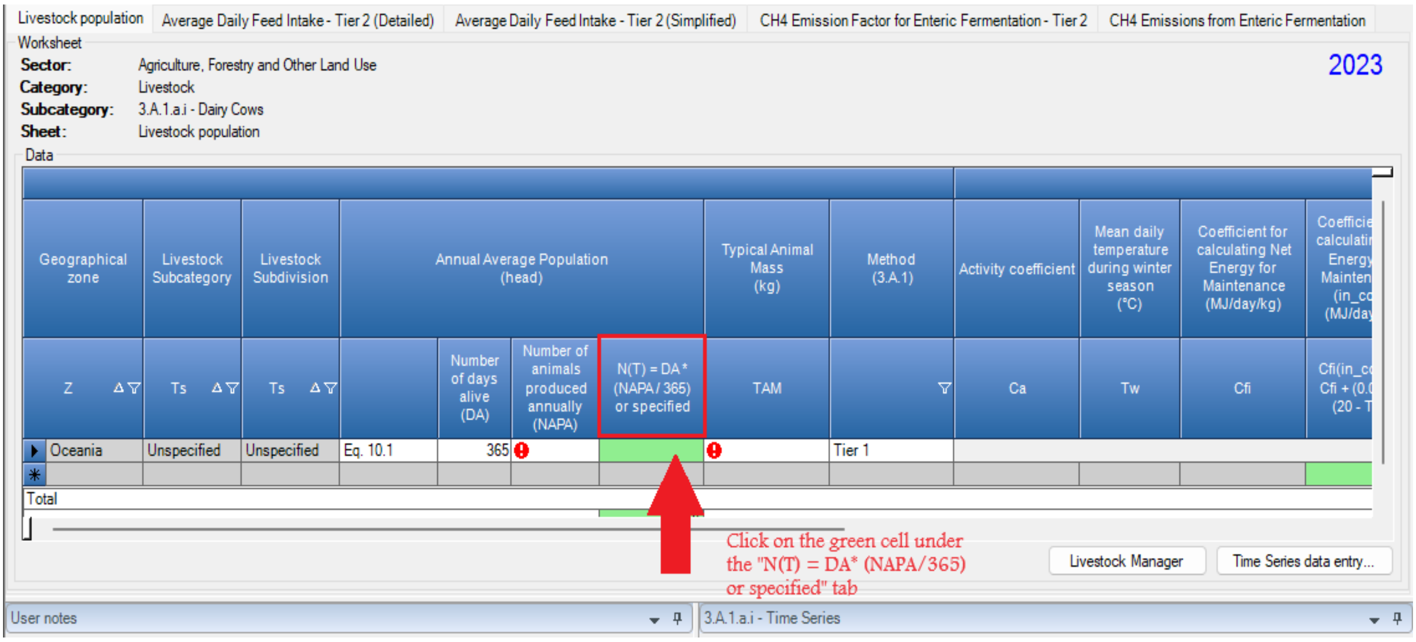
2.3 Under the tab 'Number of days alive (DA)" enter into the cell "365" (See illustration below). Note that the number of days alive can be seen from annex Table 5 in the report.



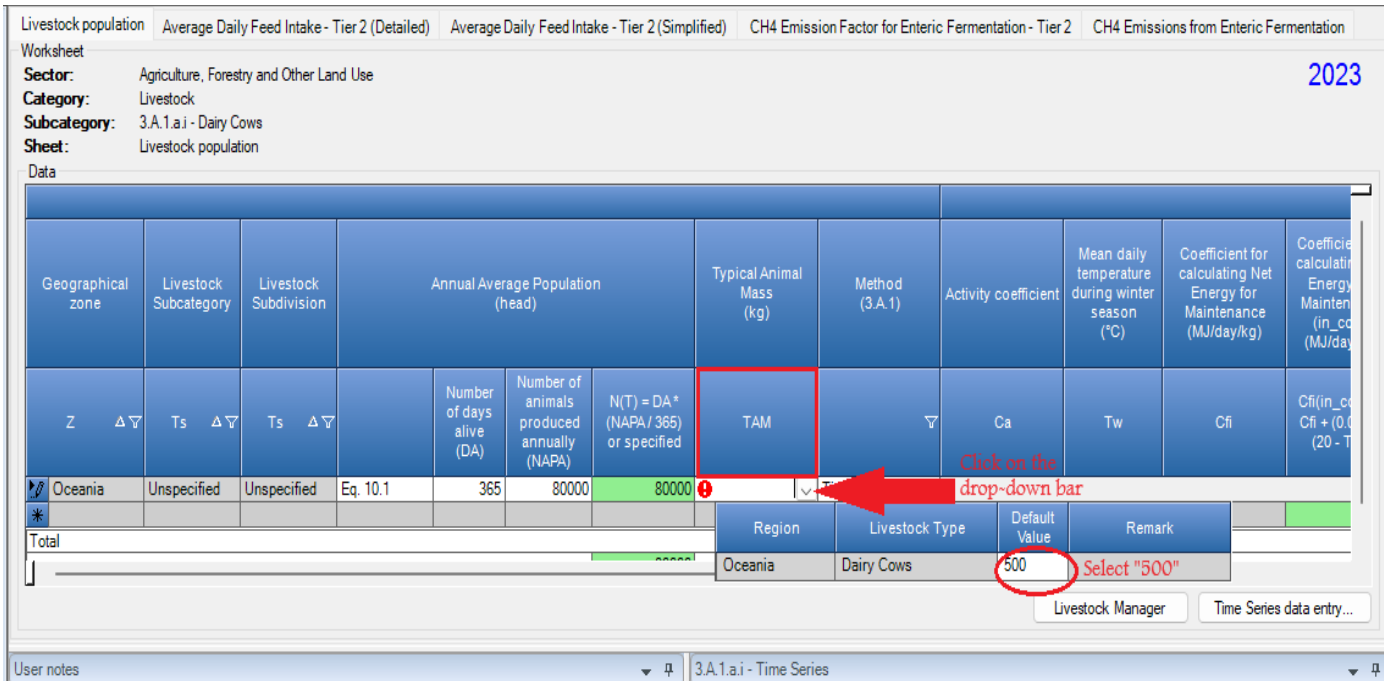
2.4 Enter the number of animals for the inventory year into the cell under the tab "Number of animals produced annually (NAPA).



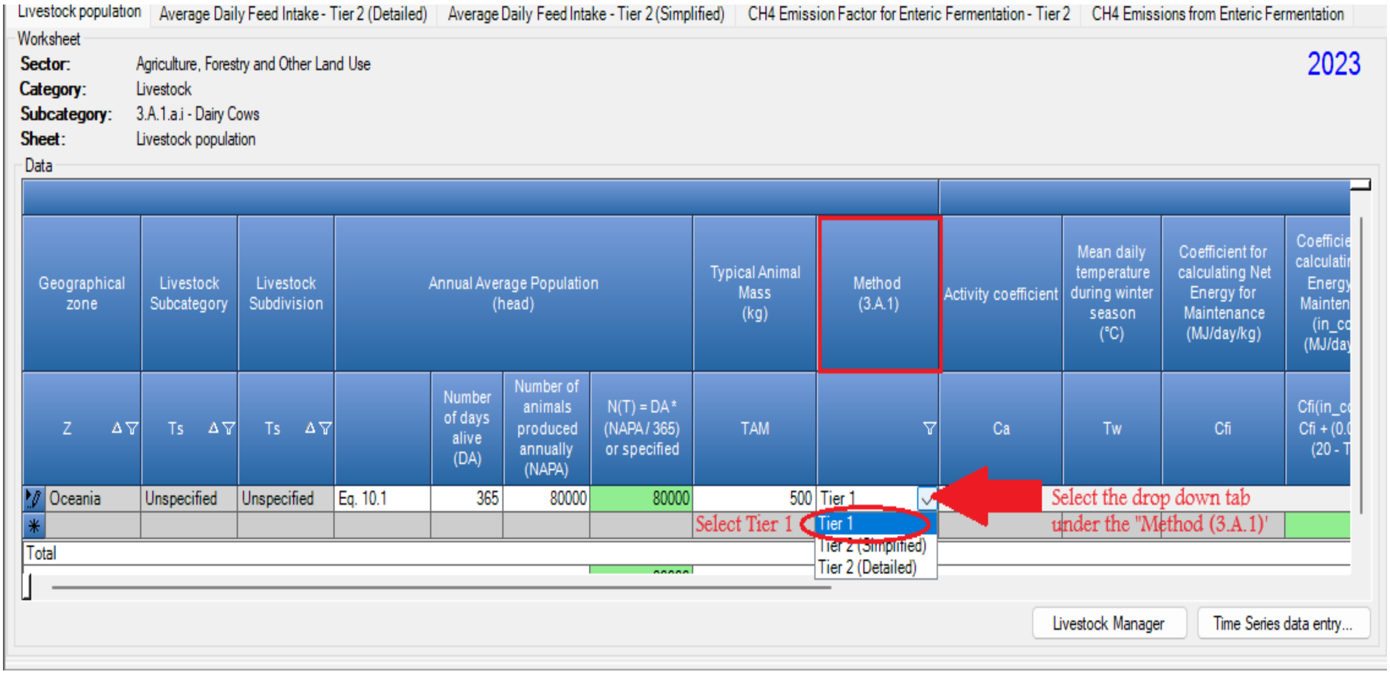
2.5 Click on the Green cell under the tab "N(T) = DA* (NAPA/365) or specified" tab to generate the value (See illustration below).



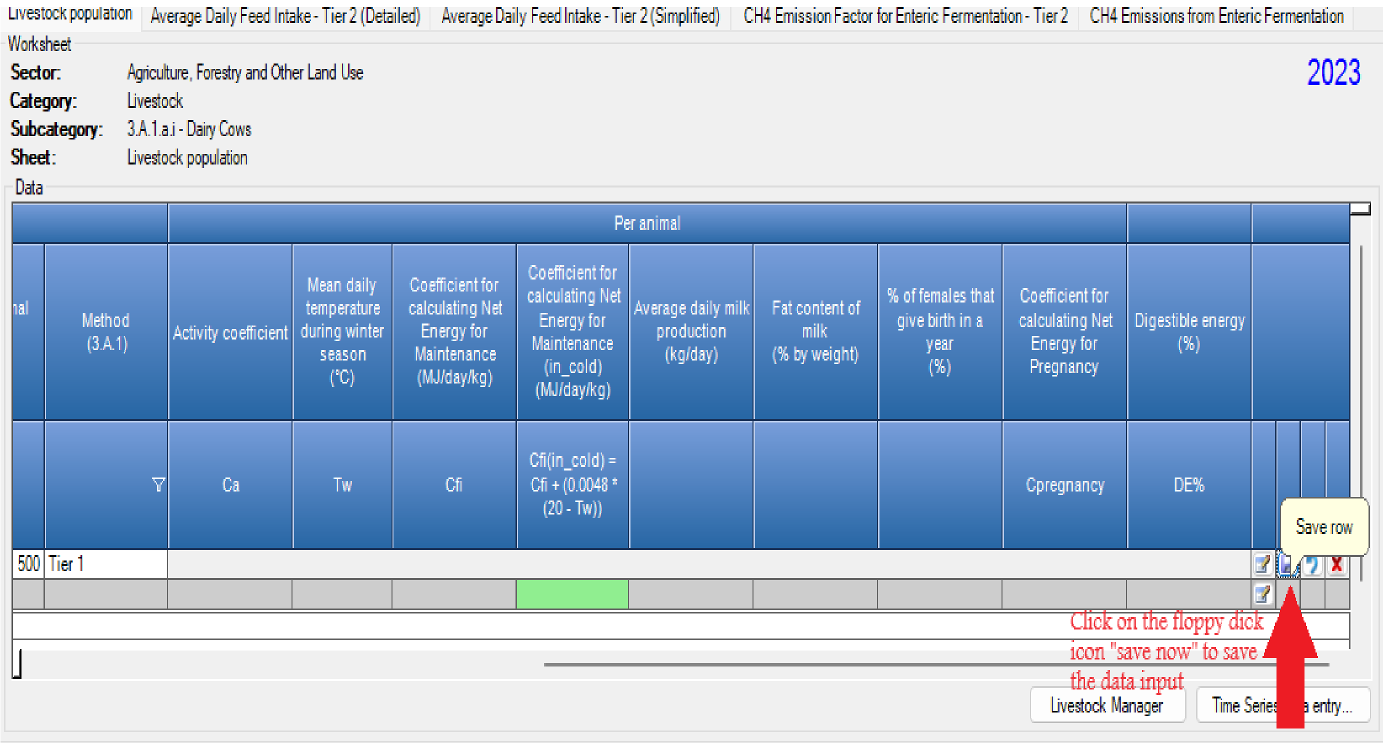
2.6 Click on the drop-down bar under the tab "TAM" and select the Default value of "500" (See illustration below). Note that typical animal mass can be cross-checked from Table 3 in this report.



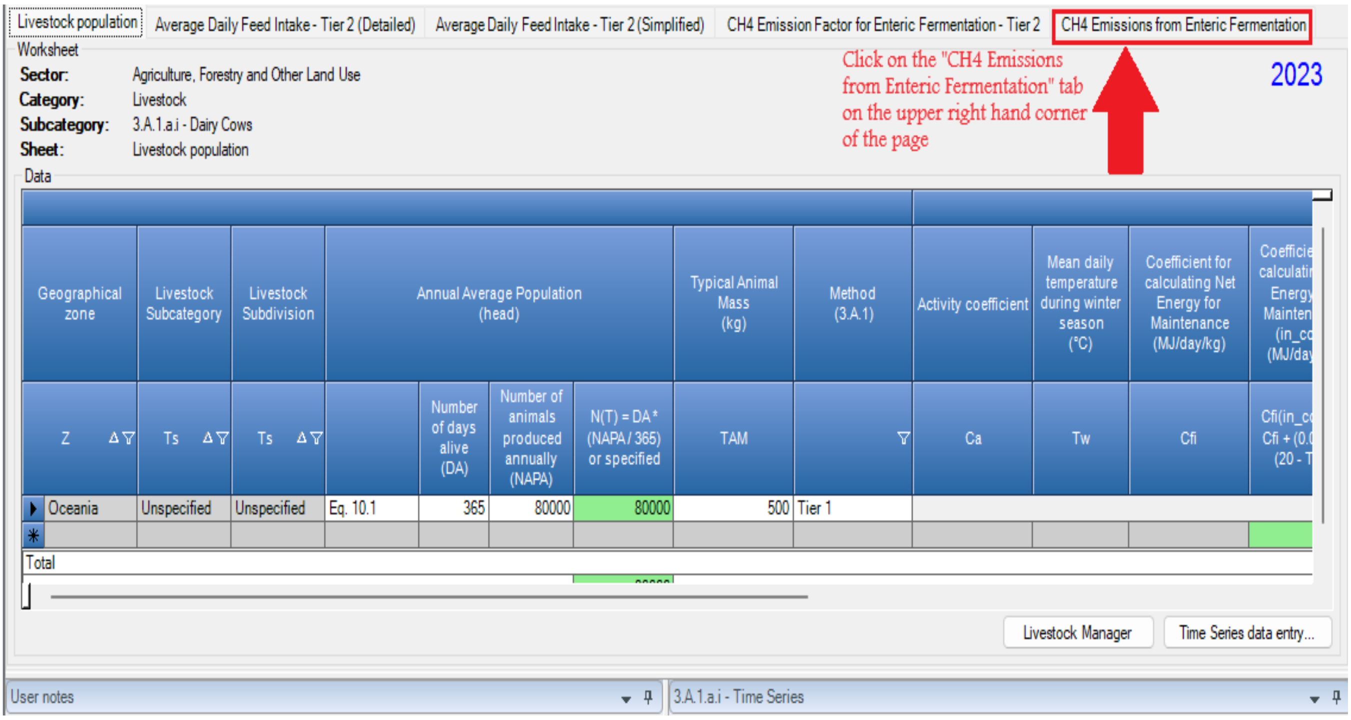
2.7 under the "Method (3.A.1)" tab, click on the drop-down bar and select "Tier 1" (See illustration below).



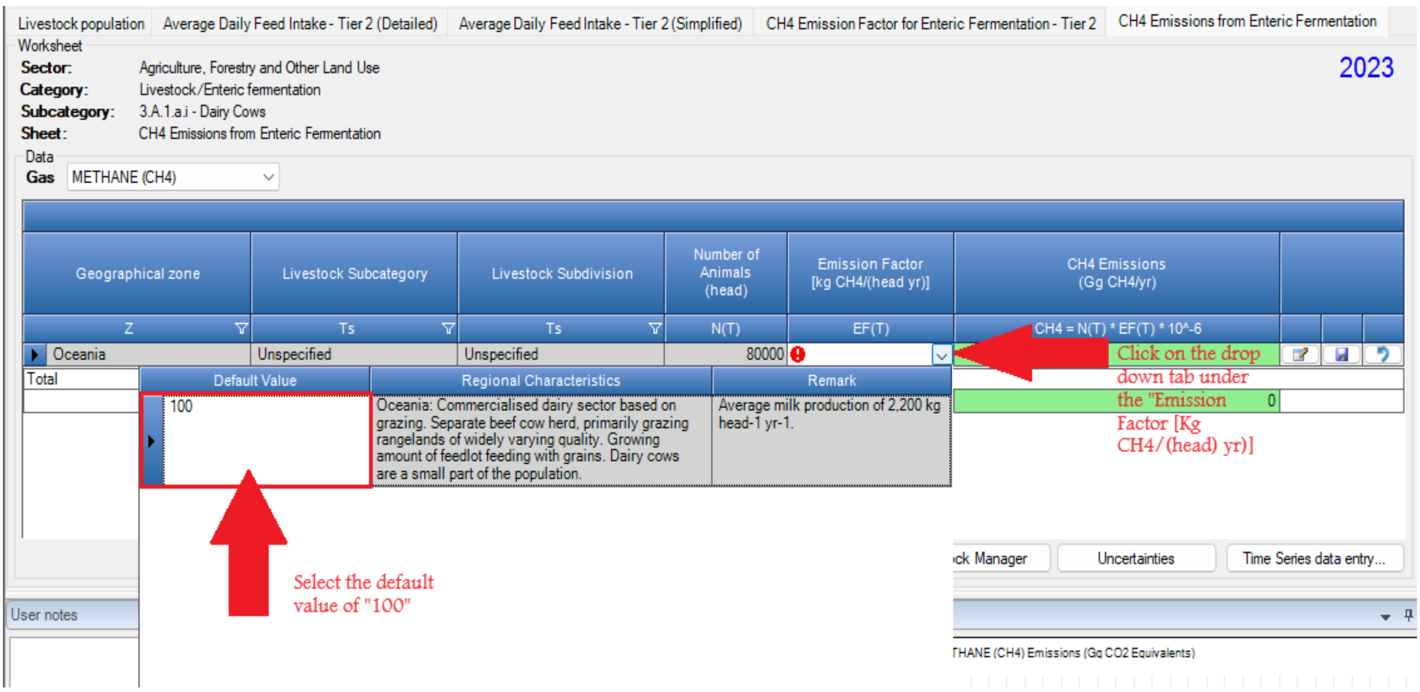
2.8 Scroll to the corner of the table and select the floppy disk icon to save the data input (See illustration below).



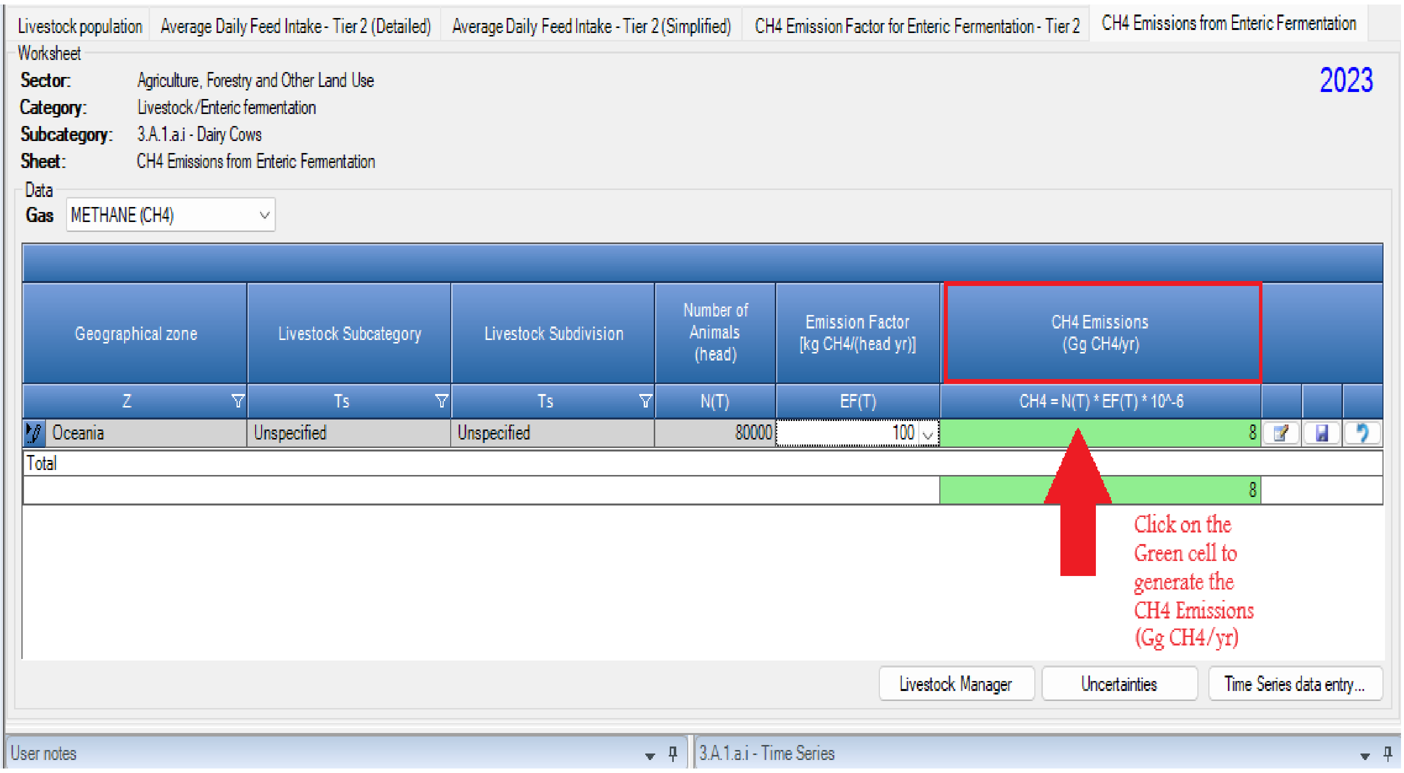
2.9 Click on the "CH_4 Emissions from the Enteric Fermentation" tab on the upper right-hand corner of the page (See illustration below).



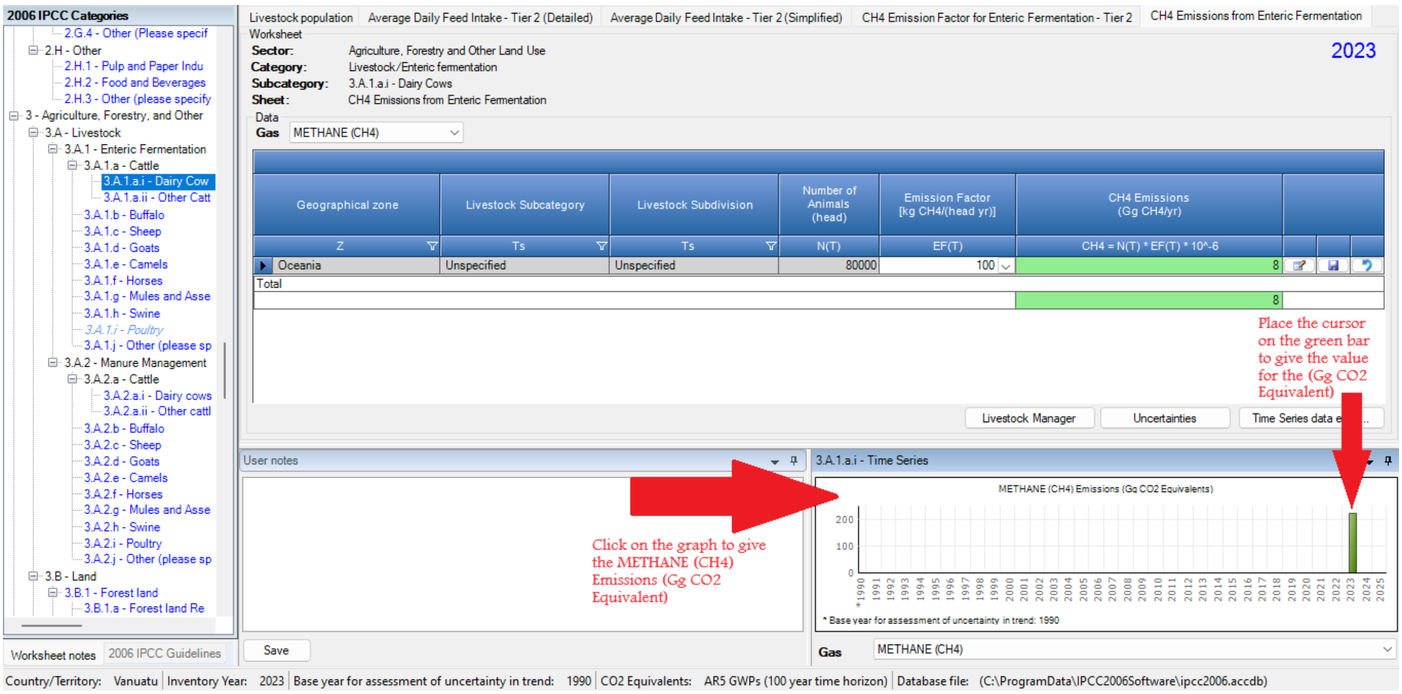
3.0 under the tab "Emission Factor [kg CH_4/(head yr)]", click on the drop-down button and select the default value of "100"



3.1 Under the “CH_4 Emissions (Gg CH_4/yr)” tab, click on the green cell to generate the value for the CH_4 Emissions (Gg CH_4/yr) (See illustration below).



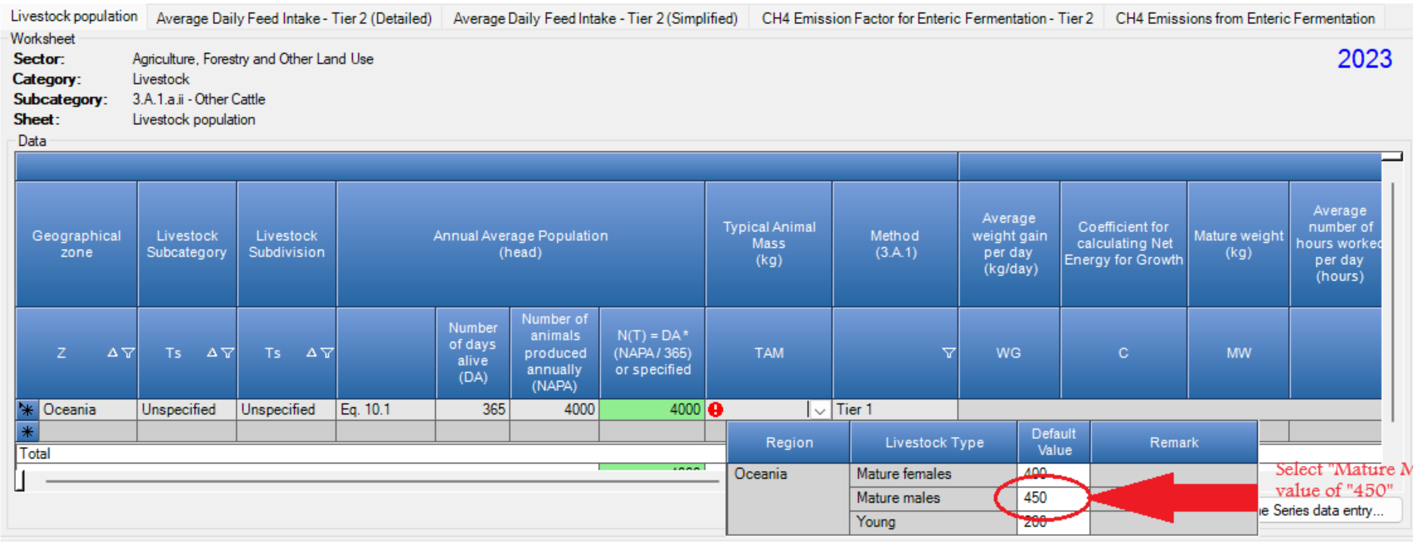
3.2 click on the graph below entitled “Methane (CH_4) Emissions (Gg CO_2 Equivalent) to generate the bar graph. Then place the cursor on the green bar to give the Gg CO_2 Equivalent produced in that year by the dairy cows.



SUBCATEGORY 3.A.1.a.ii – Other Cattle

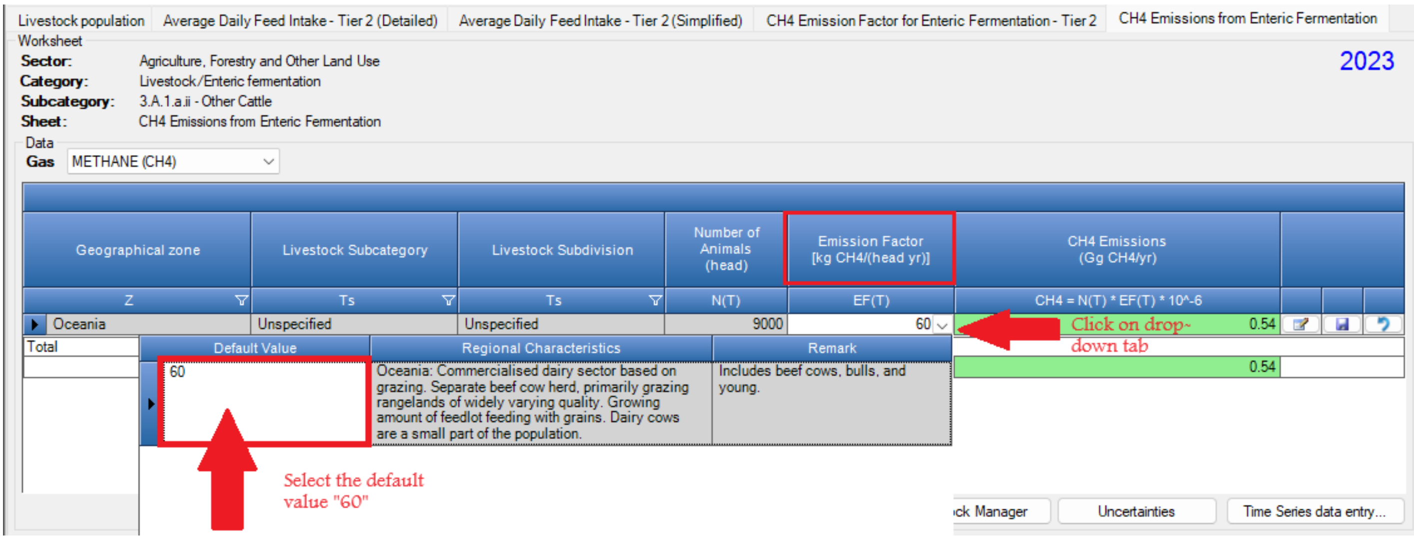
3.3 Click the subcategory 3.A.1.a.ii – Other Cattle

3.4 repeat steps 1.9 to 2.4 till you reach "Typical animal mass" then select "mature male" default value of "450" (See Illustration below).



3.5 Repeat steps 2.7 to 2.9

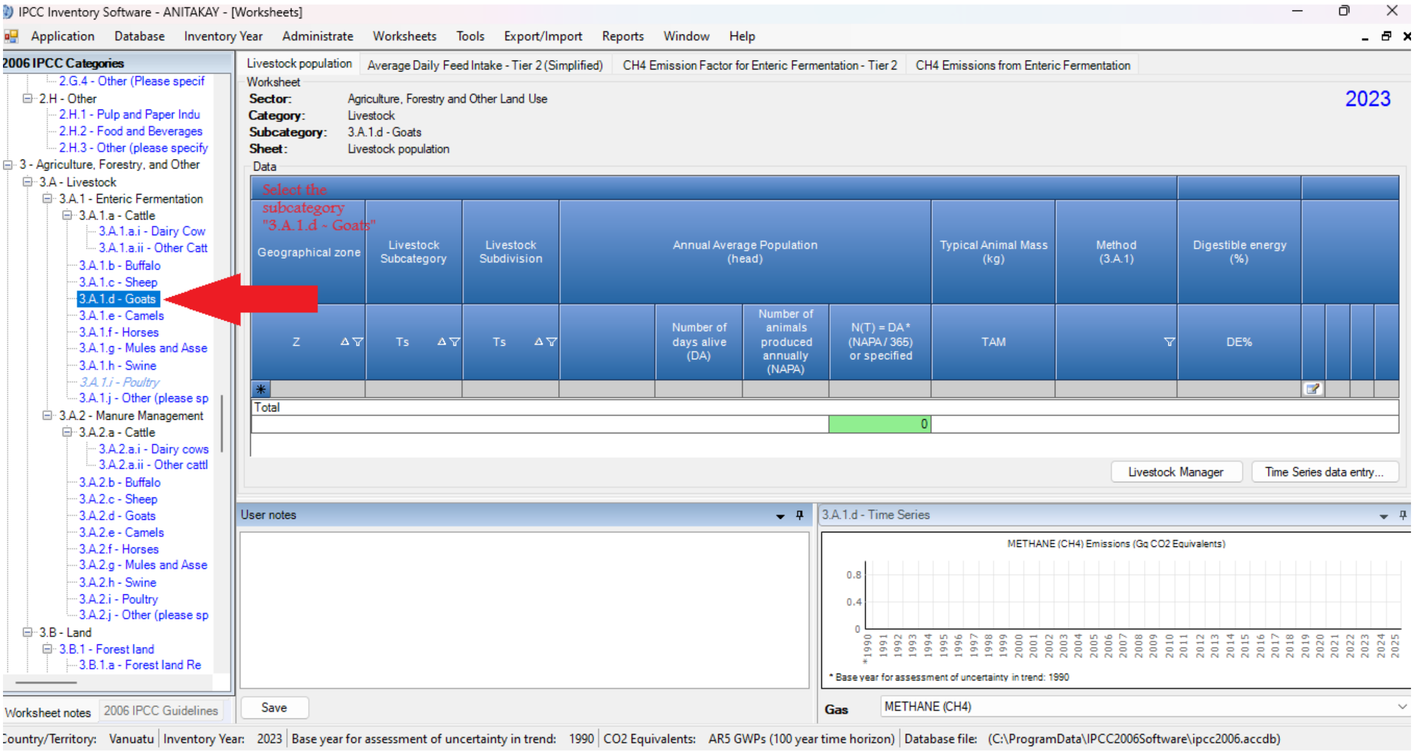
3.6 Select the default value "60" Under the "Emissions Factor [kg CH_4/(head yr)]" (See illustration below).



3.7 click on the graph below entitled "Methane (CH_4) Emissions (Gg CO_2 Equivalent) to generate the bar graph. Then place the cursor on the green bar to give the Gg CO_2 Equivalent produced in that year by the subcategory 3.A.1.a.ii – other (See illustration in step 3.2).

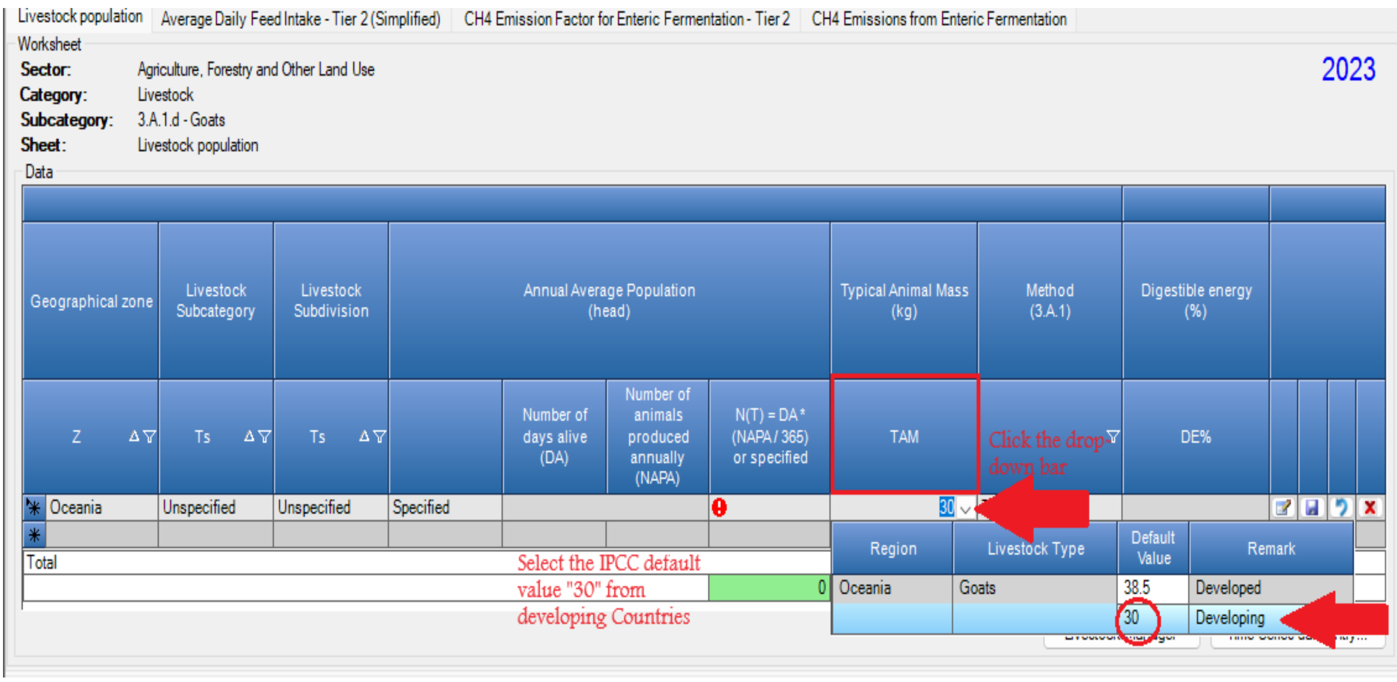
SUBCATEGORY 3.A.1.d – Goats

3.8 click on the subcategory "3.A.1.d – Goats" from the "2006 IPCC Categories" tab on the left-hand side of the page (See Illustration below)



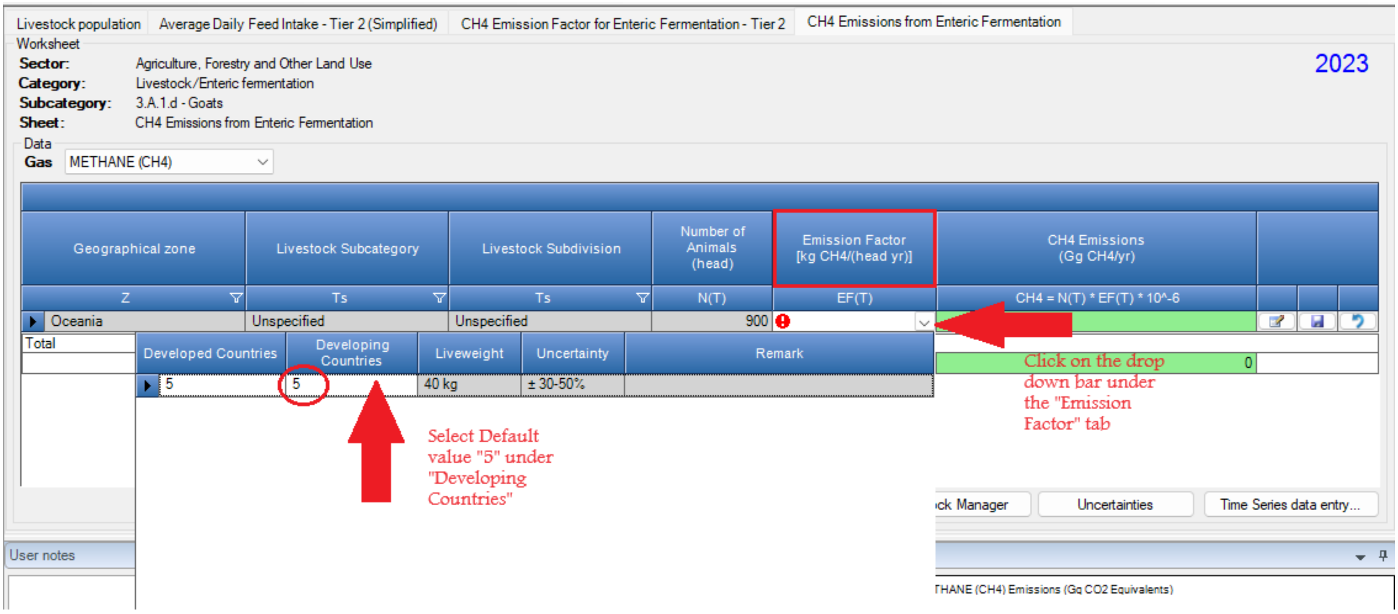
3.9 Repeat steps 1.9 to 2.4

4.0 Under the "Typica Animal Mass (TAM)" Select the default "30" as Vanuatu is a developing country.



4.1 repeat steps 2.7 to 2.9

4.2 under the Emission Factor [kg CH_4/(head yr)] select the default value of "5" under the "Developing Countries" tab (See illustration below)



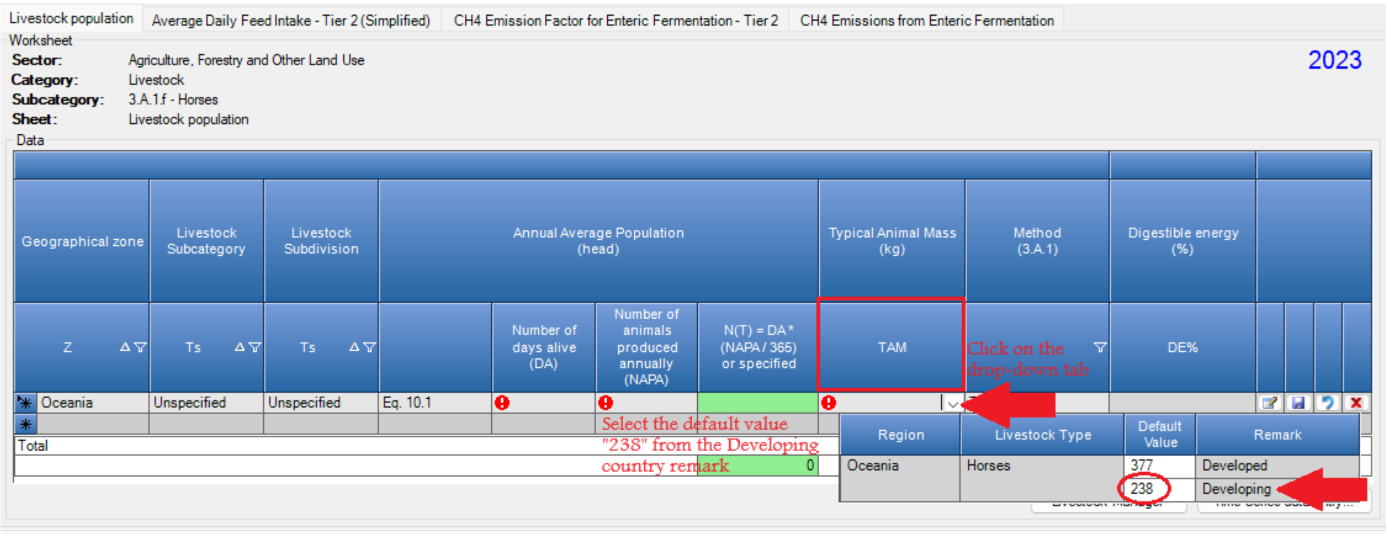
4.3 Click on the green cell under the "CH_4 Emissions (Gg CH_4/yr)" tab to generate the value of methane Emissions in (Gg). Then click on the graph below and place to cursor on the green bar to generate the value of the CO_2 equivalent.

SUBCATEGORY 3.A.1.f - Horses

4.4 Select the Subcategory 3.A.1.f – Horse from the "2006 IPCC categories" tab on the left-hand side of the page.

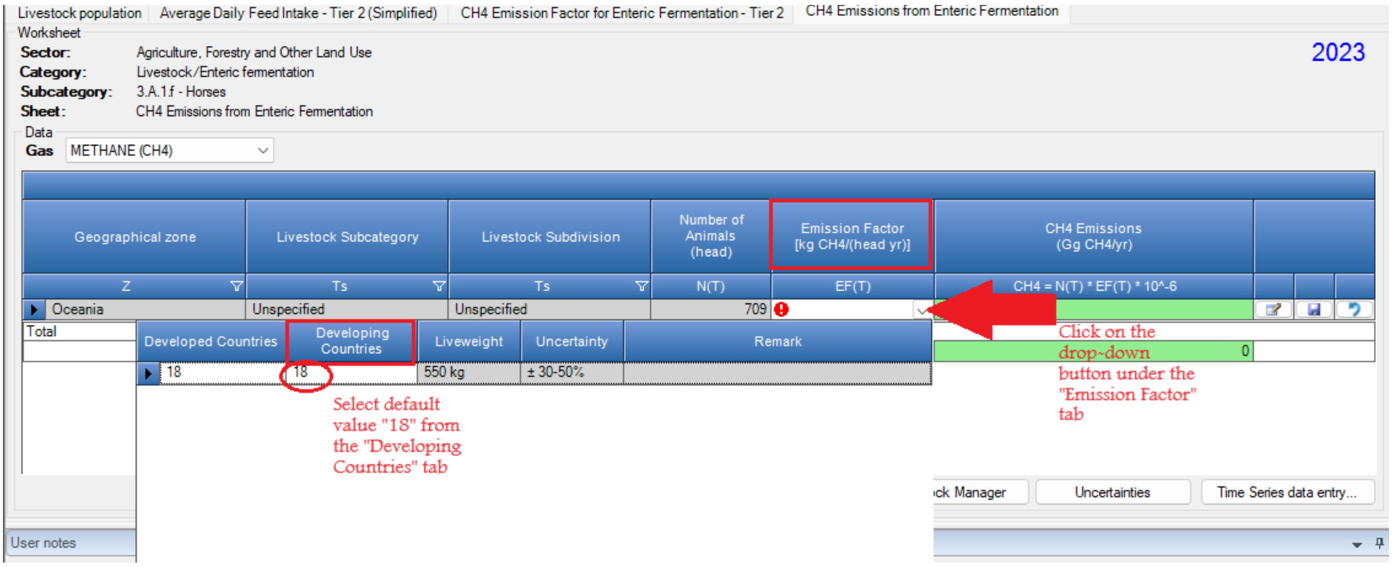
4.5 Repeat steps 1.9 to 2.4

4.6 Under the "Typical Animal Mass (TAM)" click the drop-down tab and select the default value of "238" from the Developing Countries Remark.



4.7 Repeat steps 2.7 to 2.9

4.8 under the “Emission Factor “click the drop-down bar and select the default value of “18” from the “Developing Countries “tab (See illustration below)

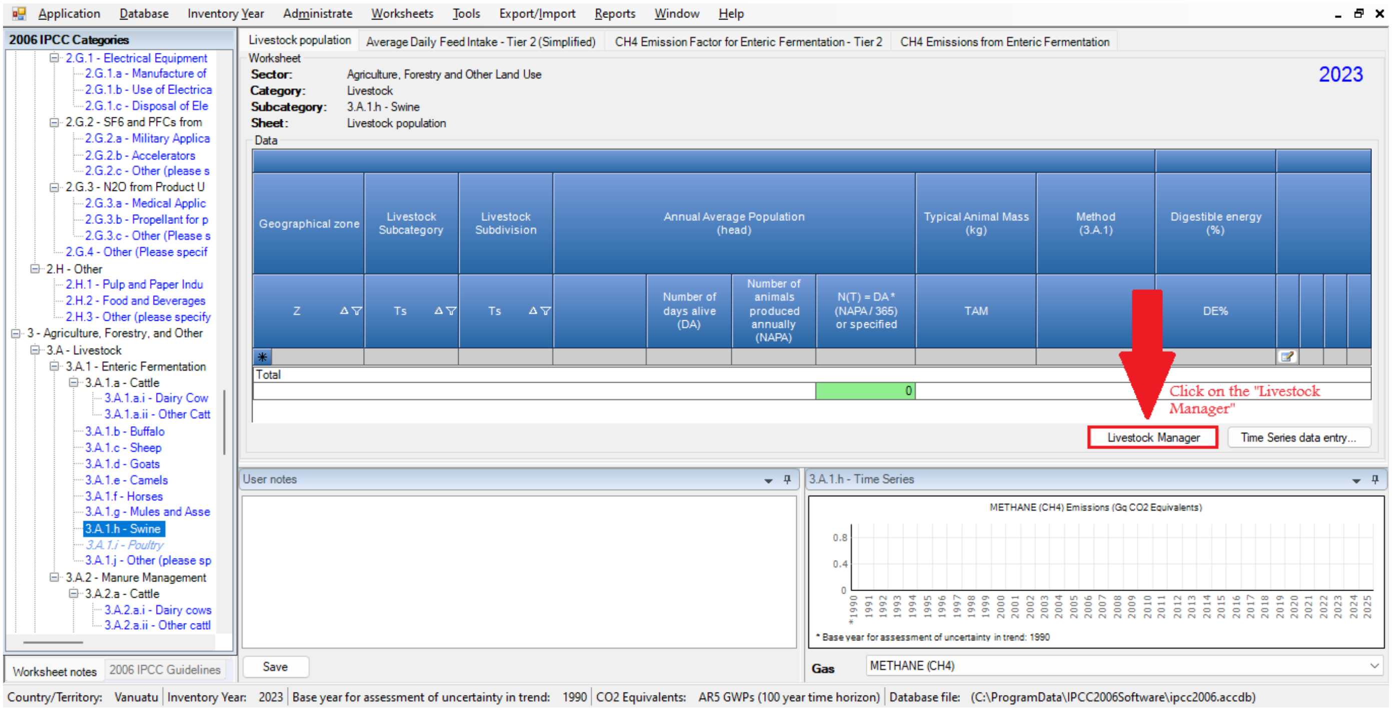


4.9 Click on the green cell under the CH_4 Emissions (Gg CH_4/yr) tab to generate the total methane Emissions from the year. Then place the cursor on the green bar in the graph below to give the total CO_2 Equivalent produced from the subcategory 3.A.1.f - Horses in that year (See Illustration in step 3.2).

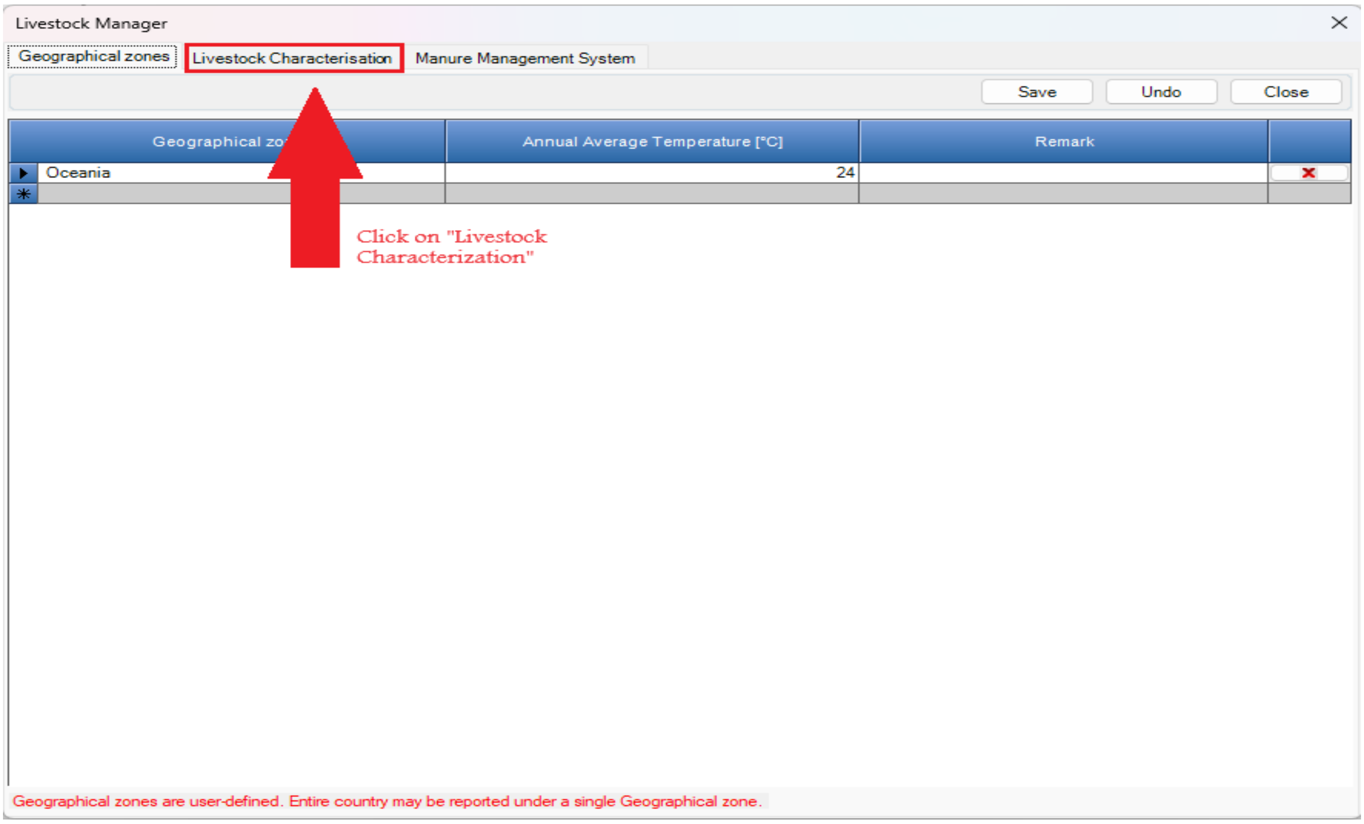
SUBCATEGORY 3.A.1.d- Swine

5.0 Select the subcategory “3.A.1.d -Swine” on the left-hand side of the page under the “2006 IPCC Categories” tab.

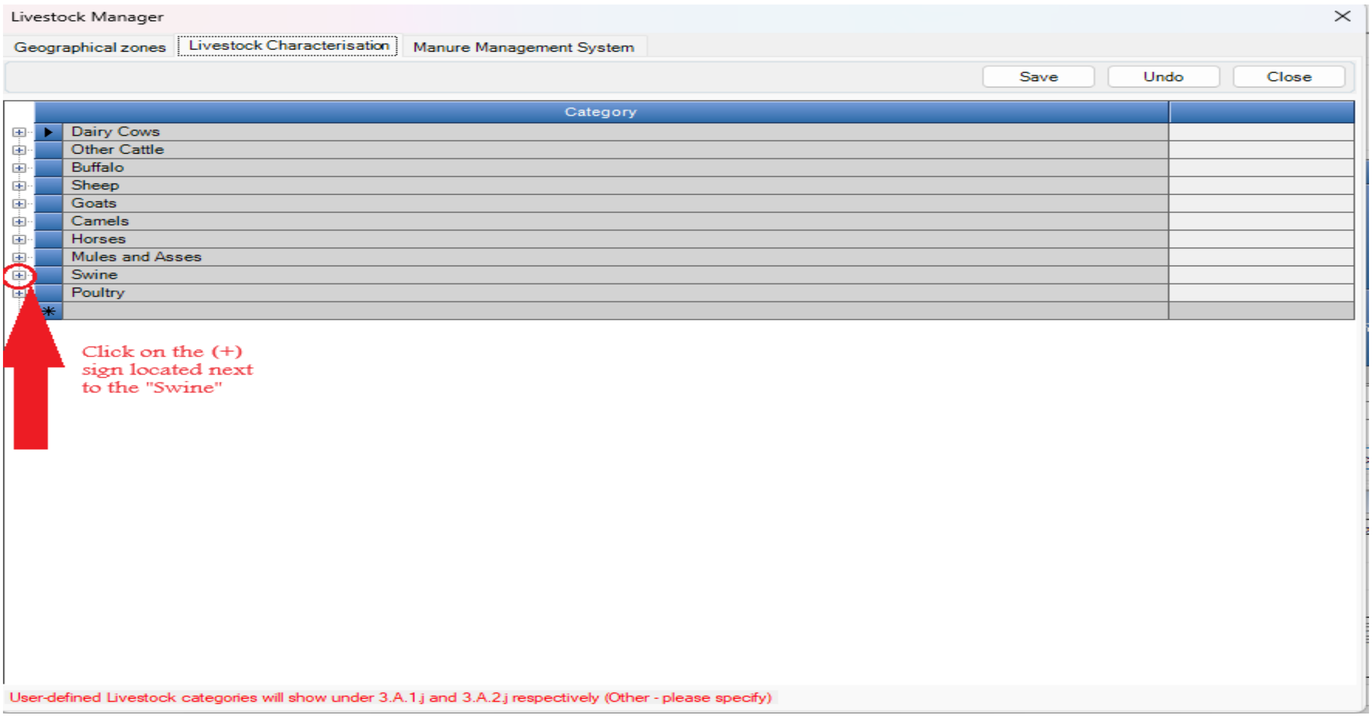
5.2 Click on the “Livestock manager” tab (See illustration below).



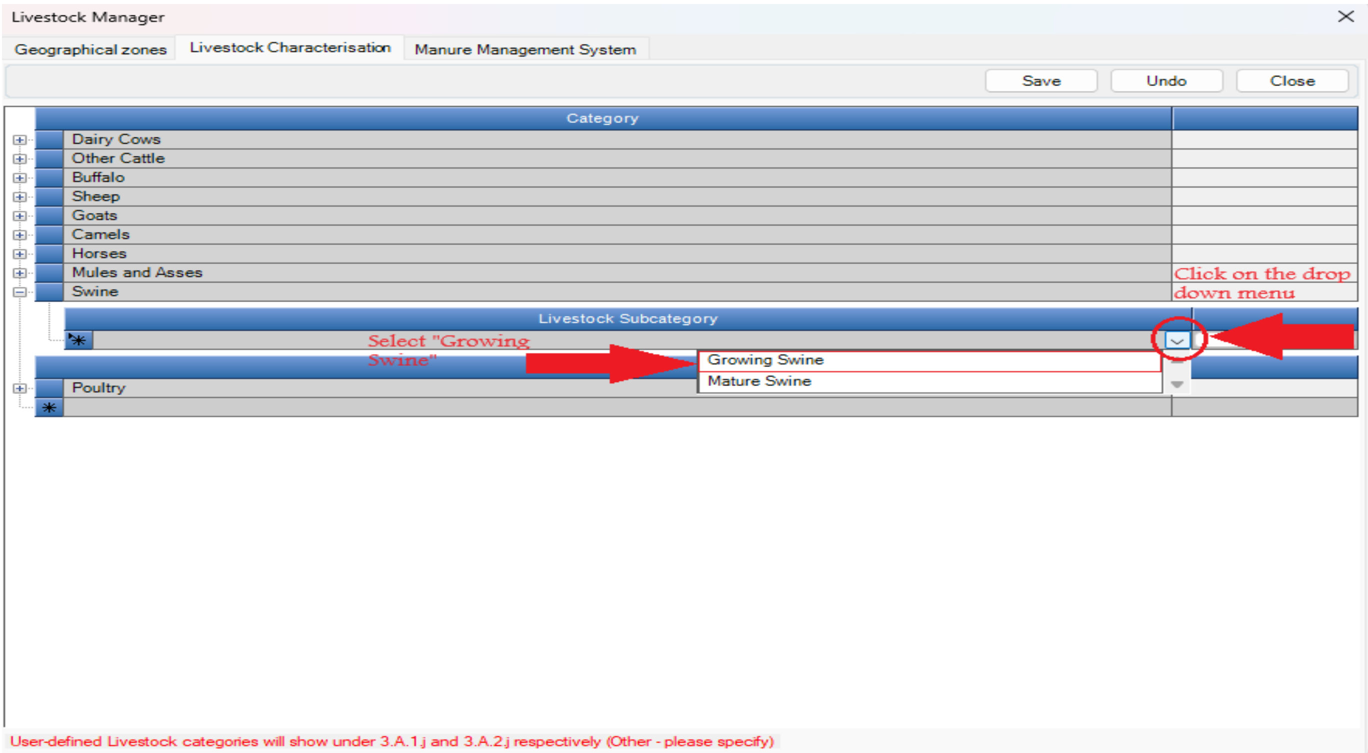
5.3 Click on "Livestock Characterization" tab at the top of the page (See illustration below)



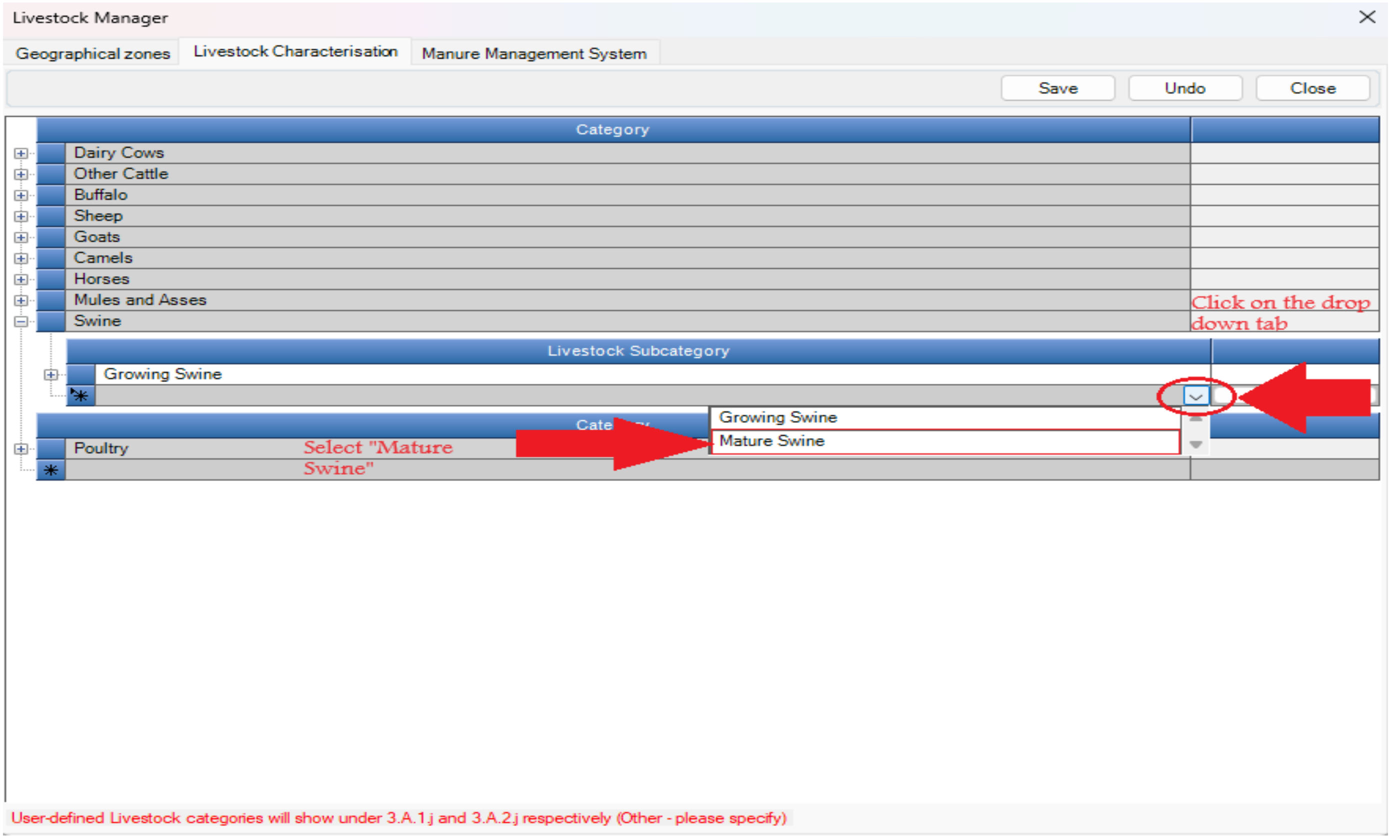
5.4 Click on the (+) sign located next to the "Swine" in the table (See illustration below).



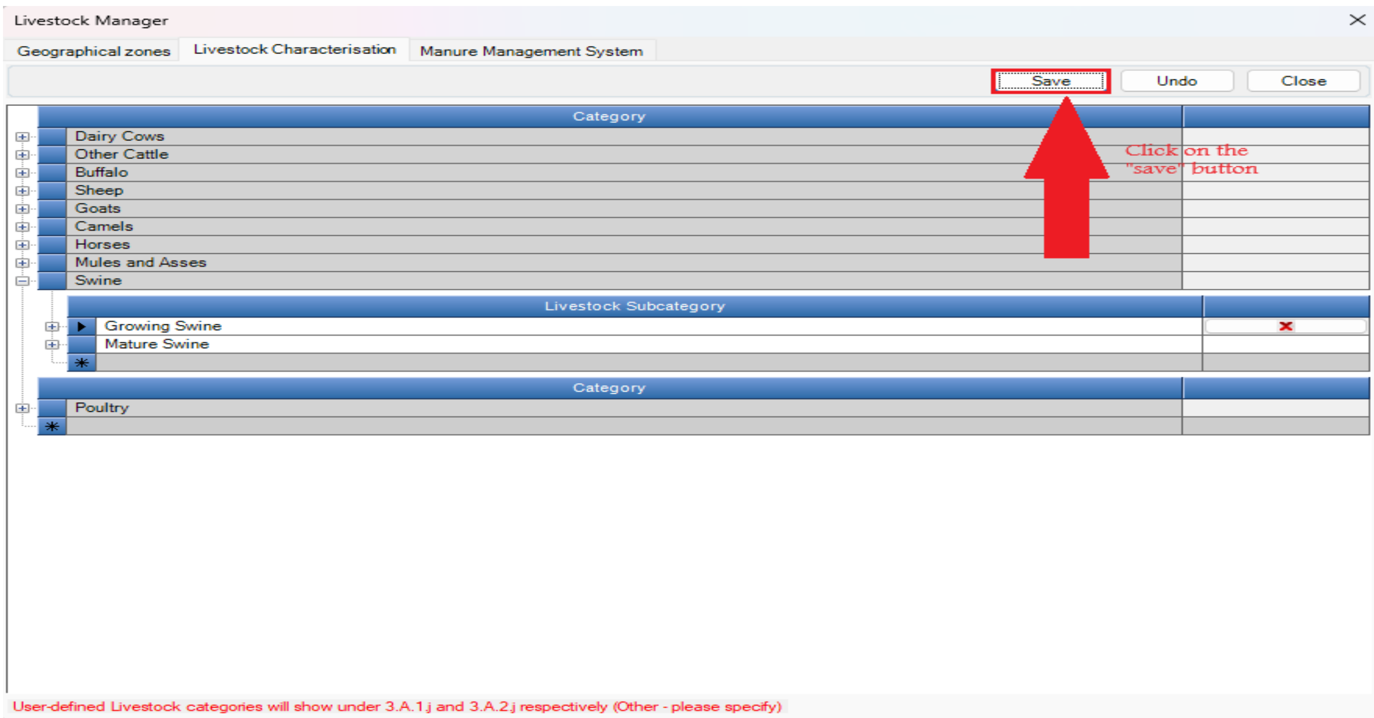
5.5 Click on the drop-down menu under the "livestock subcategory" and select "Growing Swine" (See illustration below).



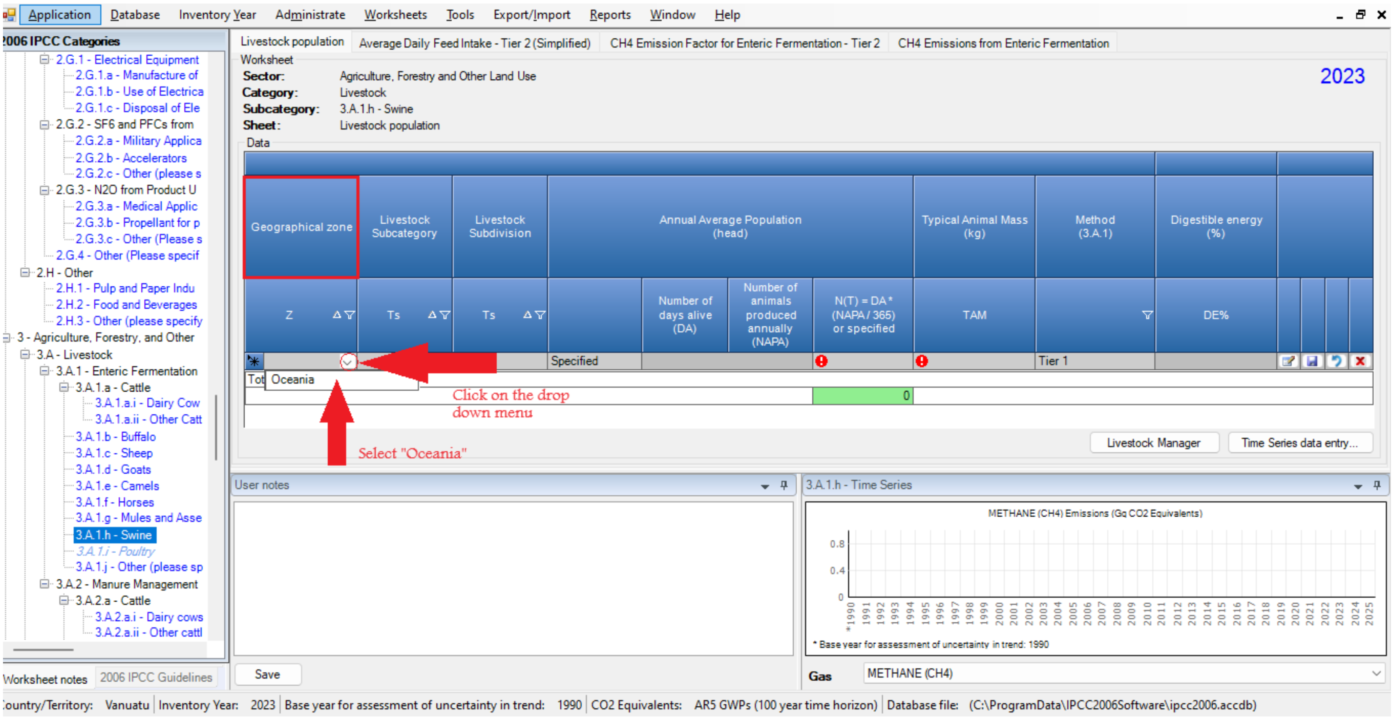
5.6 In the second cell under “Growing Swine” click on the drop-down menu select “Mature swine” (See illustration below).



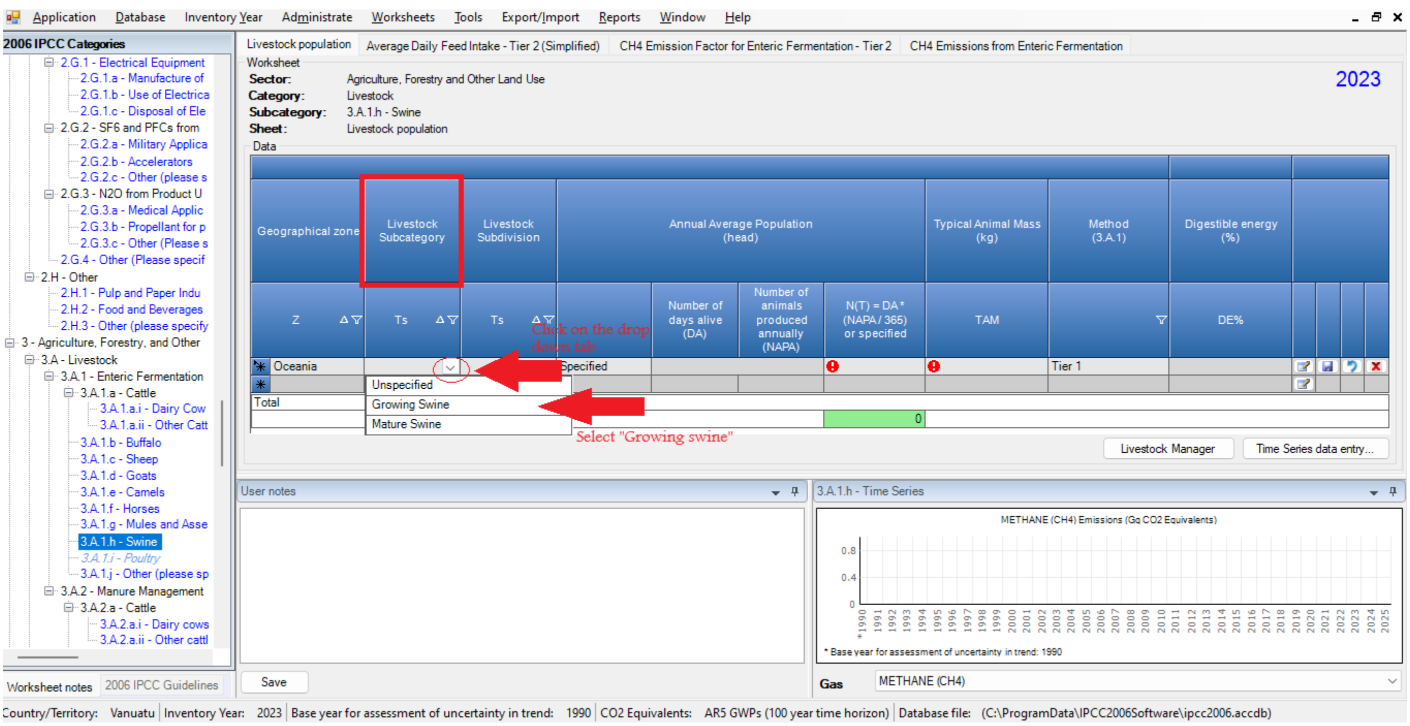
5.7 Click on the “Save” button (See illustration below).



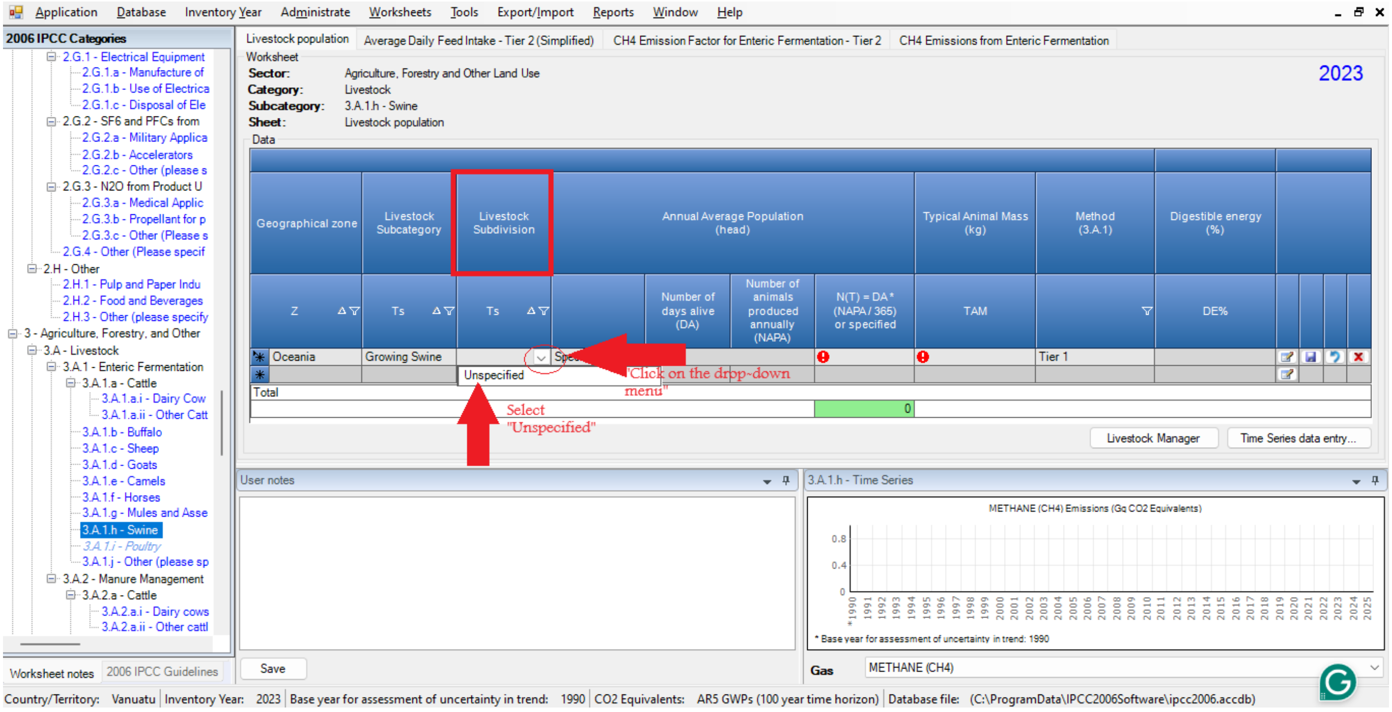
5.8 Click on the drop-down tab under the “Geographical Zone” and select “Oceania” (See illustration below).



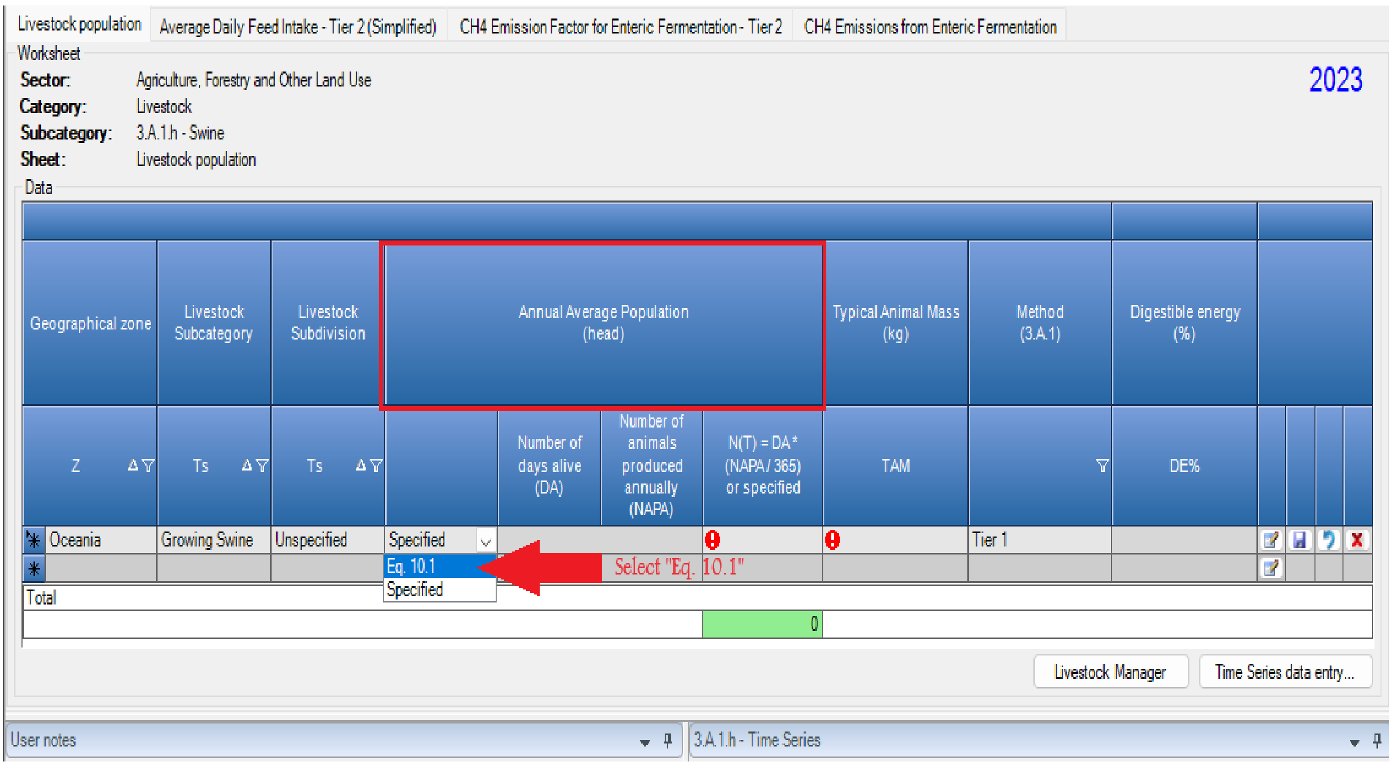
5.9 Click on the drop-down tab under the “Livestock Subcategory” and select “Growing Swine” (See illustration below).



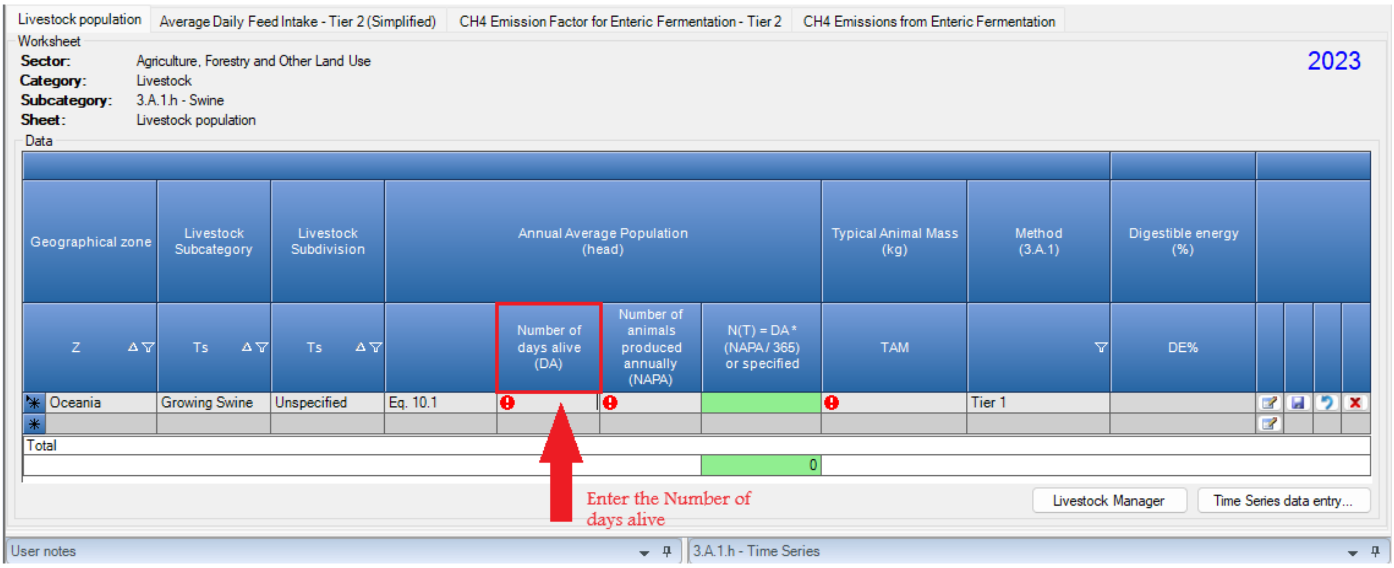
6.0 Click on the drop-down menu under the “Livestock subdivision” and select Unspecified (See illustration below).



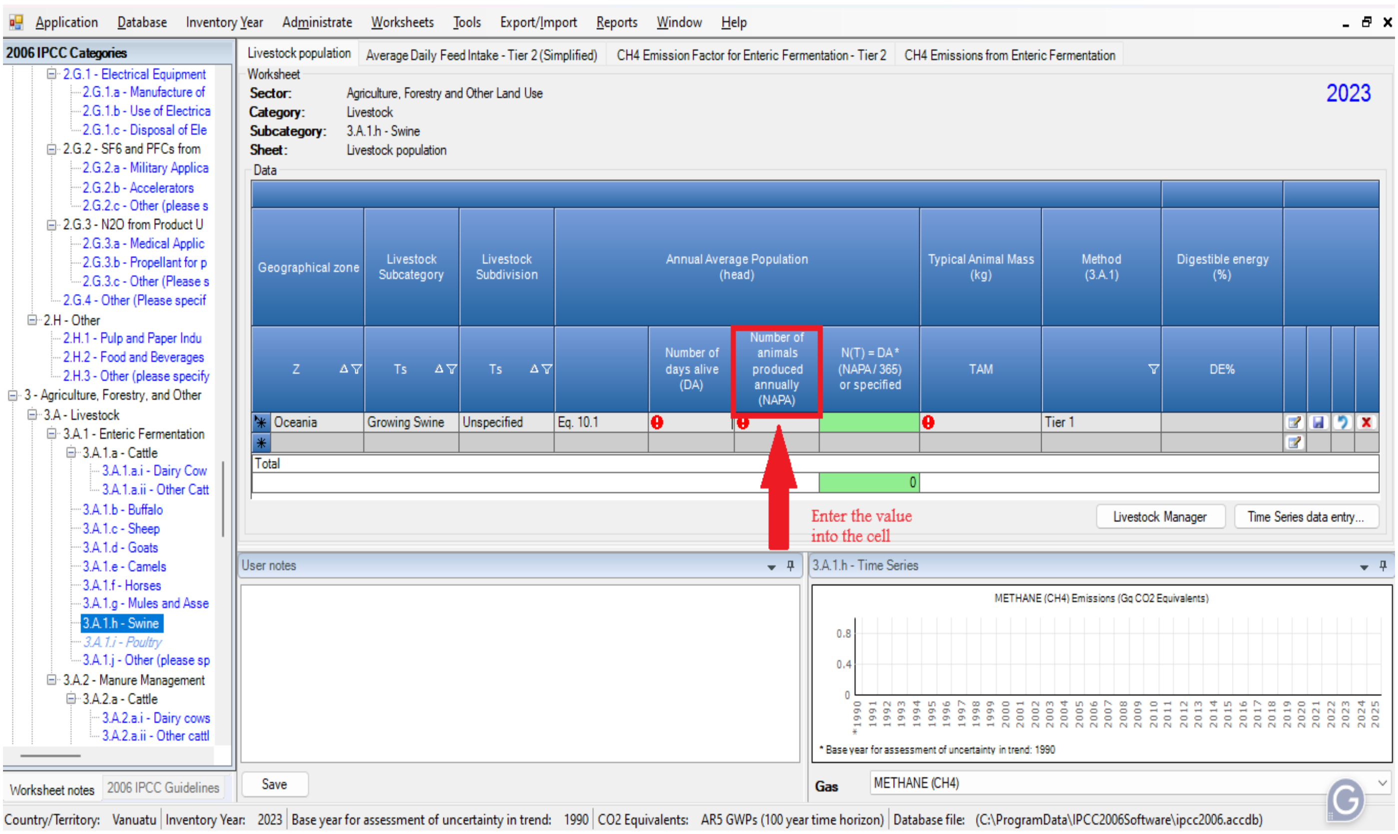
6.1 Under the “Annual Average Population” tab, click on the drop-down bar in the first cell and select “Eq. 10.1” (See illustration below).



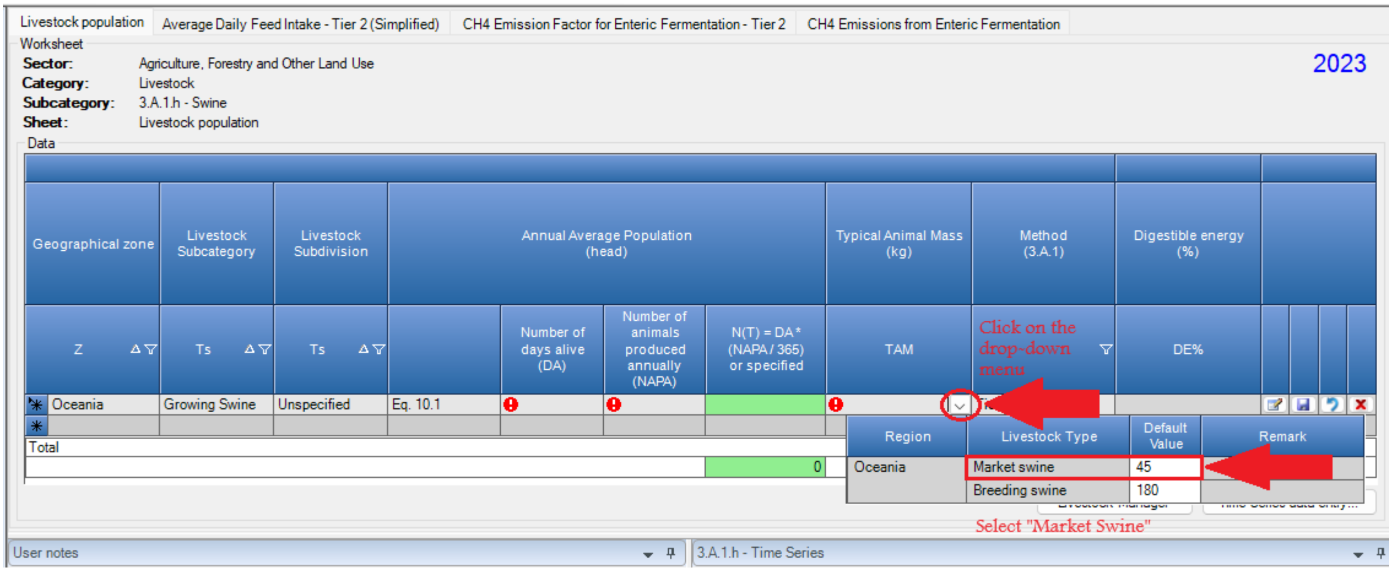
6.2 Under the "Number of day alive" tab in the table , enter the number of days alive into the cell. (See illustration below)



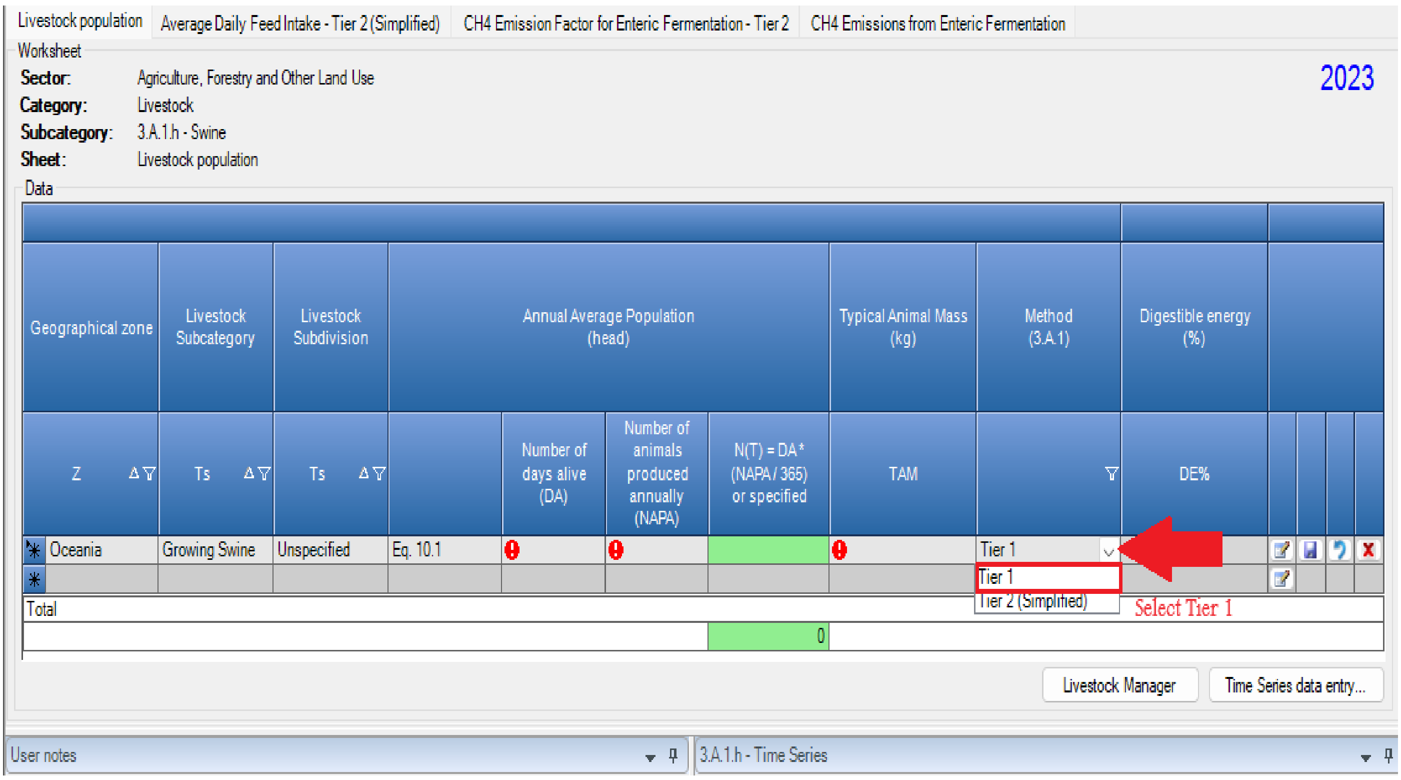
6.3 under the "Number of animals produced annually" tab enter the value into the cell (See illustration below).



6.4 Under the "TAM" tab, click on the drop down menu and select "Market swine"



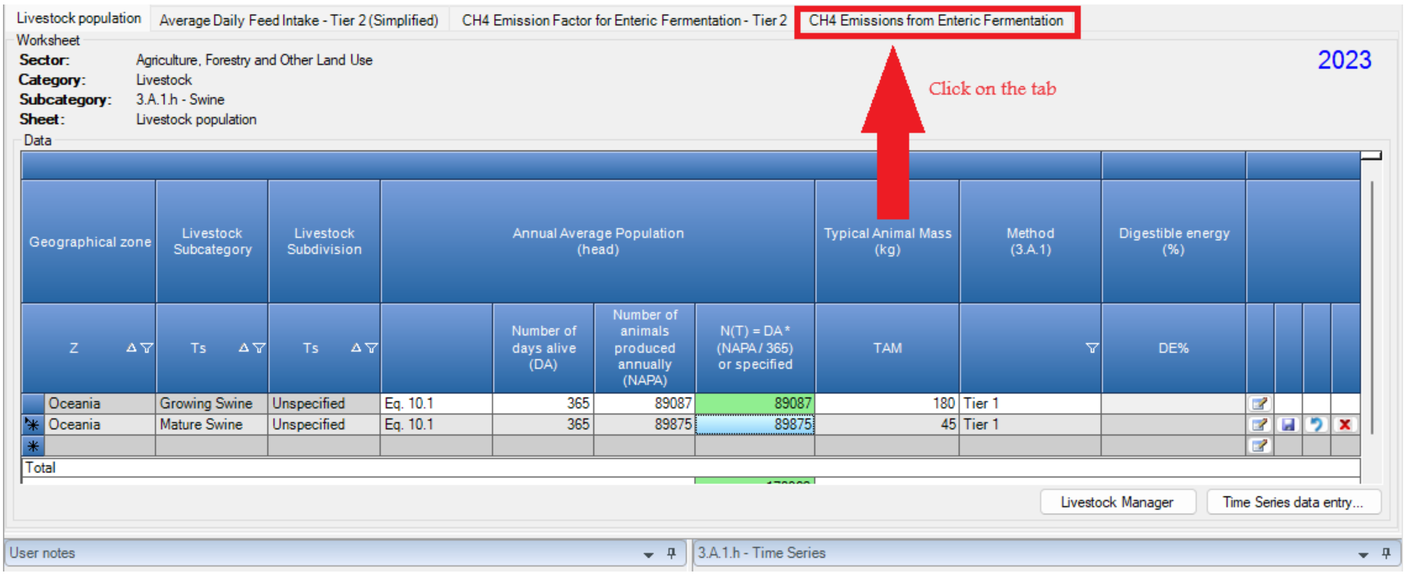
6.5 "Under the "Method (3.A.1) "tab, click on the drop-down menu and select "Tier 1".



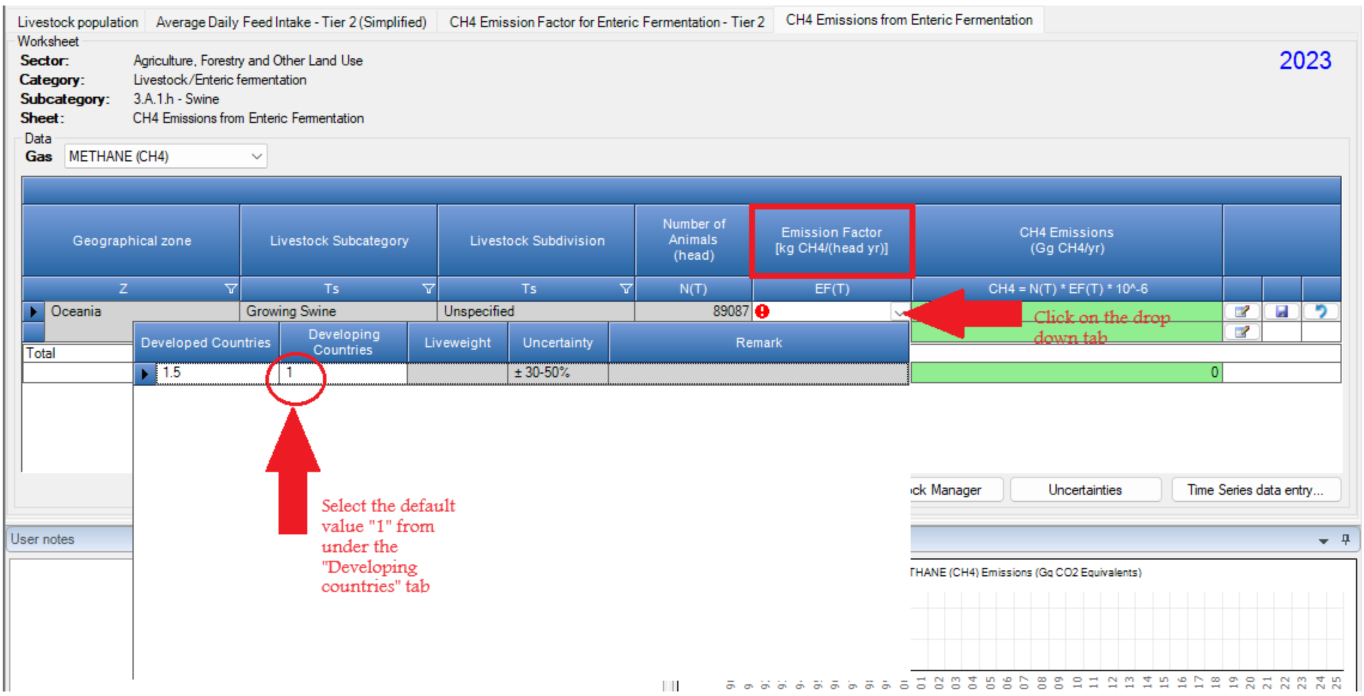
6.6 Repeat step 5.8 to 6.4 making alterations to step 5.9 and 6.4.

Under "livestock Subcategory" select "Mature Swine" and under the "TAM" tab select "Breeding Swine"

6.7 Click on the "CH_4 Emissions from Enteric Fermentation" tab (See illustration below).



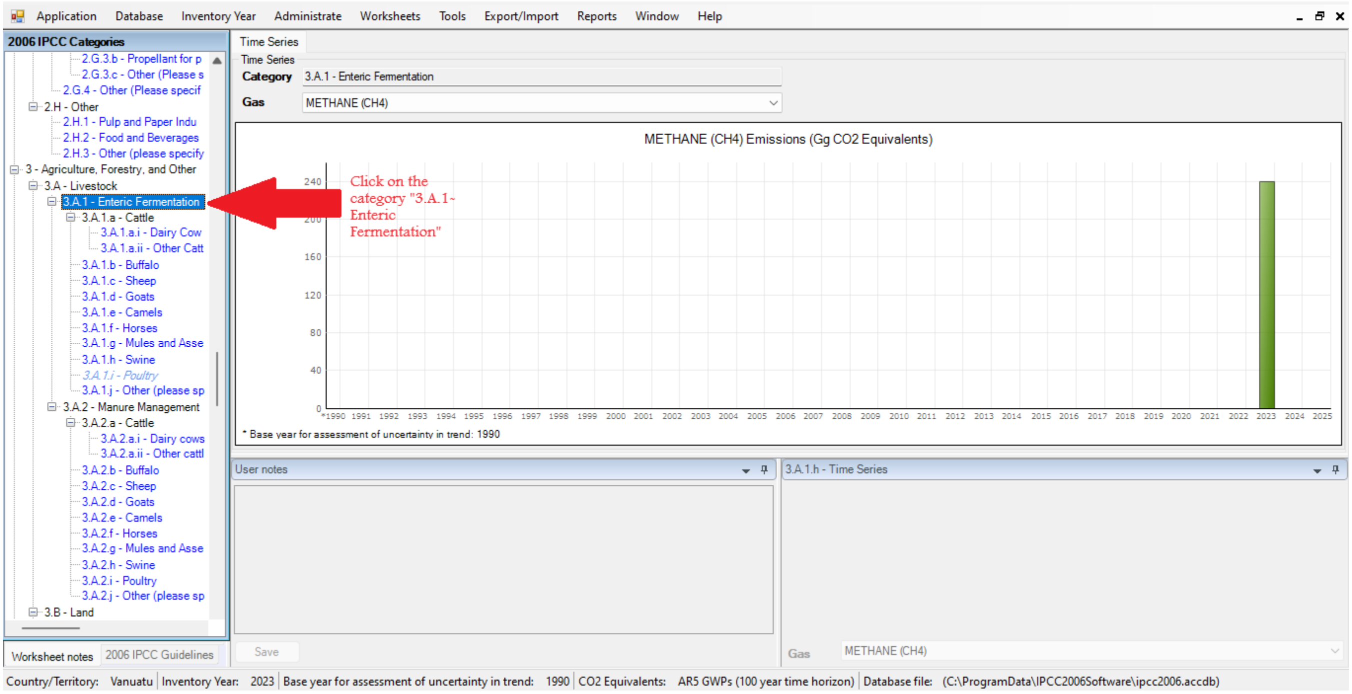
6.8 Under the "Emissio Factor [Kg CH_4(head yr)] click on the drop-down menu and select the value "1" from Developing countries (See illustration below).



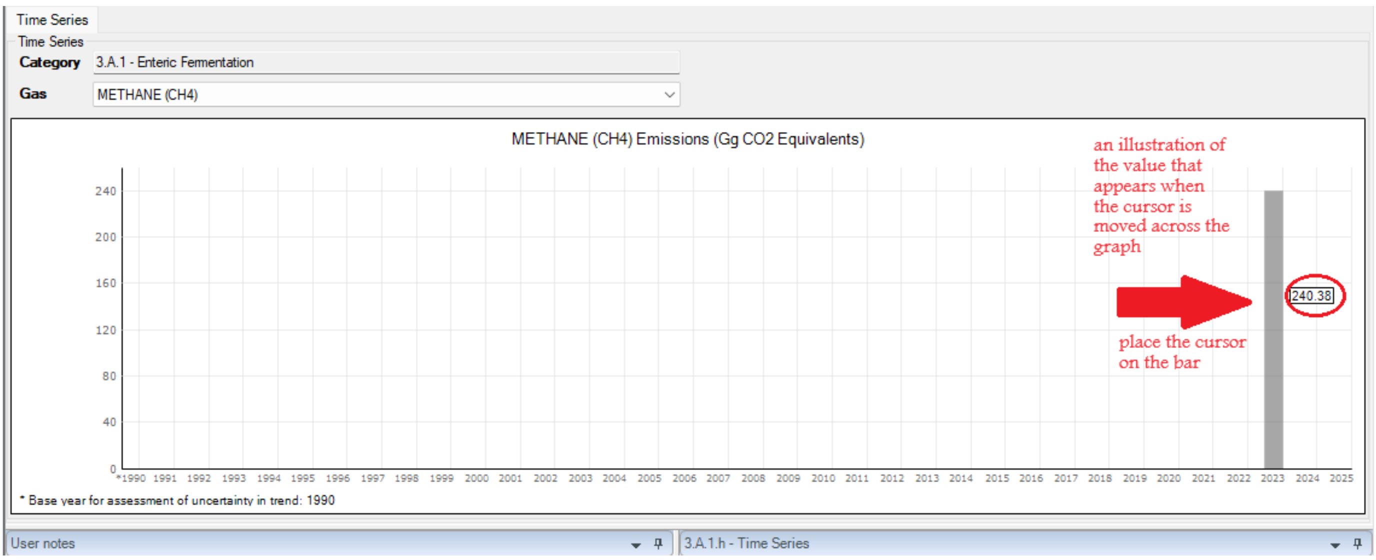
6.9 repeat step 6.8 for the next cell down

Total Ch_4 Emissions (Gg CO_2 Equivalents) Produced By The Category 3.A.1- Enteric Fermentation

7.0 Click on category 3.A.1 – Enteric Fermentation from the "2006 IPCC Categories" (See illustration below)



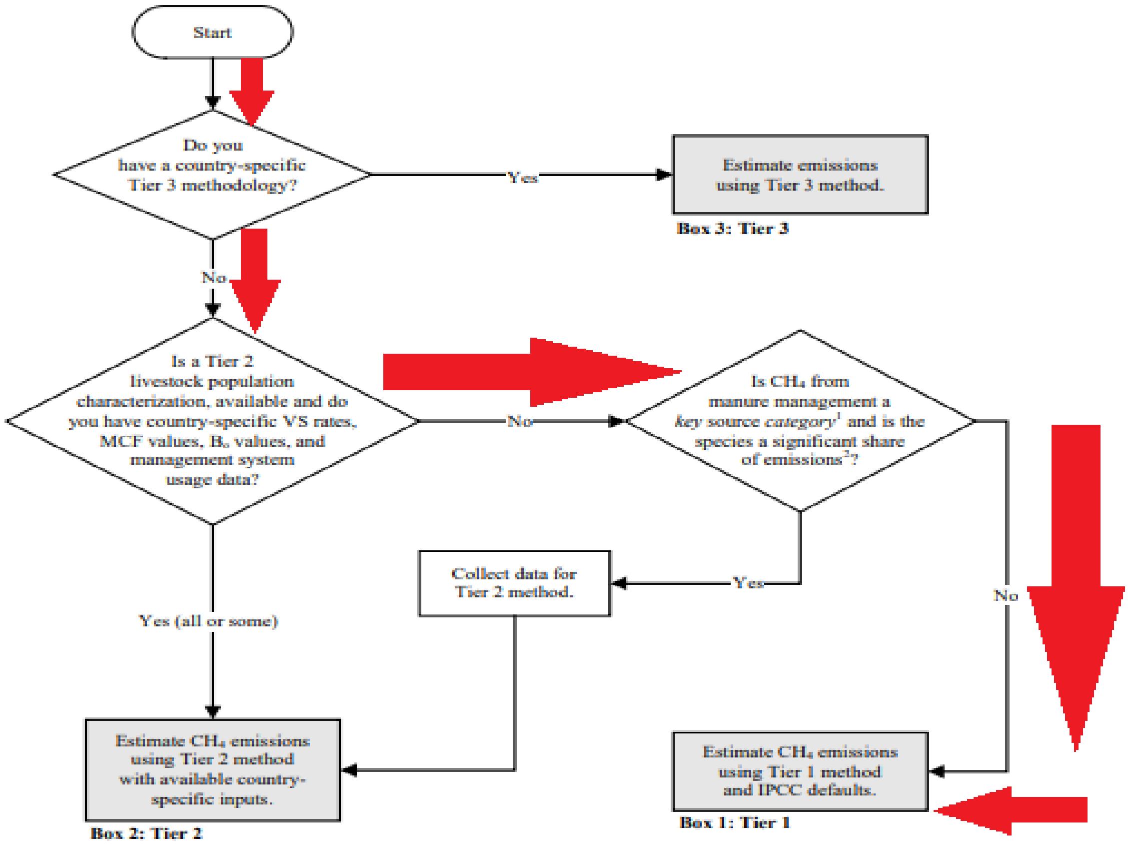
7.1 place the cursor on the green bar in the graph to get the total METHANE (CH_4) Emissions (Gg CO_2 Equivalents) produced by the Enteric Fermentation process in Vanuatu. (See illustration below).



3.3.1 METHODOLGY FOR MANURE MANAGEMENT and N2O EMISSIONS

Figure 4 displays the decision tree employed for selecting the method approach for actual CH4 emissions from category 3.A.2 – Manure Management. The decisions implemented during this operation are indicated by the red arrows.

Figure 10.3 Decision tree for CH_4 emissions from Manure Management

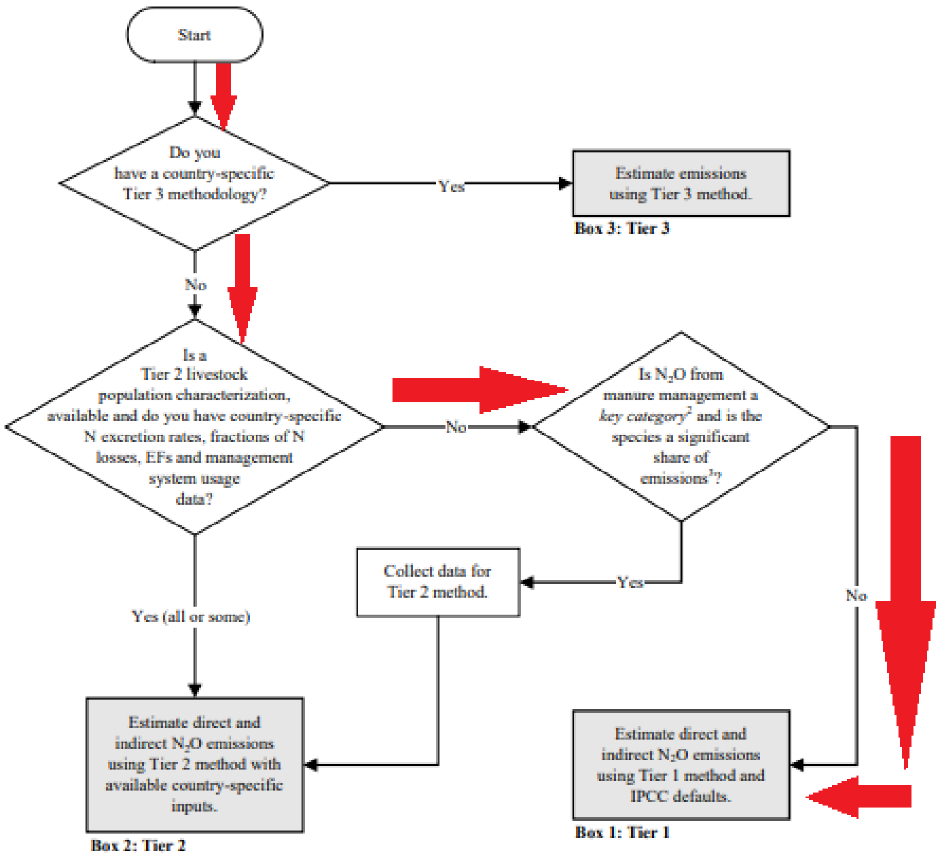


(2006 IPCC guidelines, Vol. 4, Ch. 10, Figure 10.3)

Note: Due to the national circumstances (lack of resources) Vanuatu does not yet have reliable country-specific emission factors and parameters and therefore, is applying the default parameters and Tier 1 methods to estimate CH4 emissions from the 3.A.2 – Manure Management category.

Figure 5 displays the decision tree employed for selecting the method approach for actual N2O emissions from category 3.A.2 – Manure Management. The decisions implemented during this operation are indicated by the red arrows.

Figure 10.4 **Decision tree for N_2O emissions from Manure Management (Note 1)**



(2006 IPCC guidelines, Vol. 4, Ch. 10, Figure 10.4)

Note: Due to the national circumstances (lack of resources) Vanuatu does not yet have reliable country-specific emission factors and parameters and therefore, is applying the default parameters and Tier 1 methods to estimate N_2O emissions from the 3.A.2 – Manure Management category.

3.3.2 STEP- BY- STEP CALCULATION, DOCUMENTING RESOURCES USED

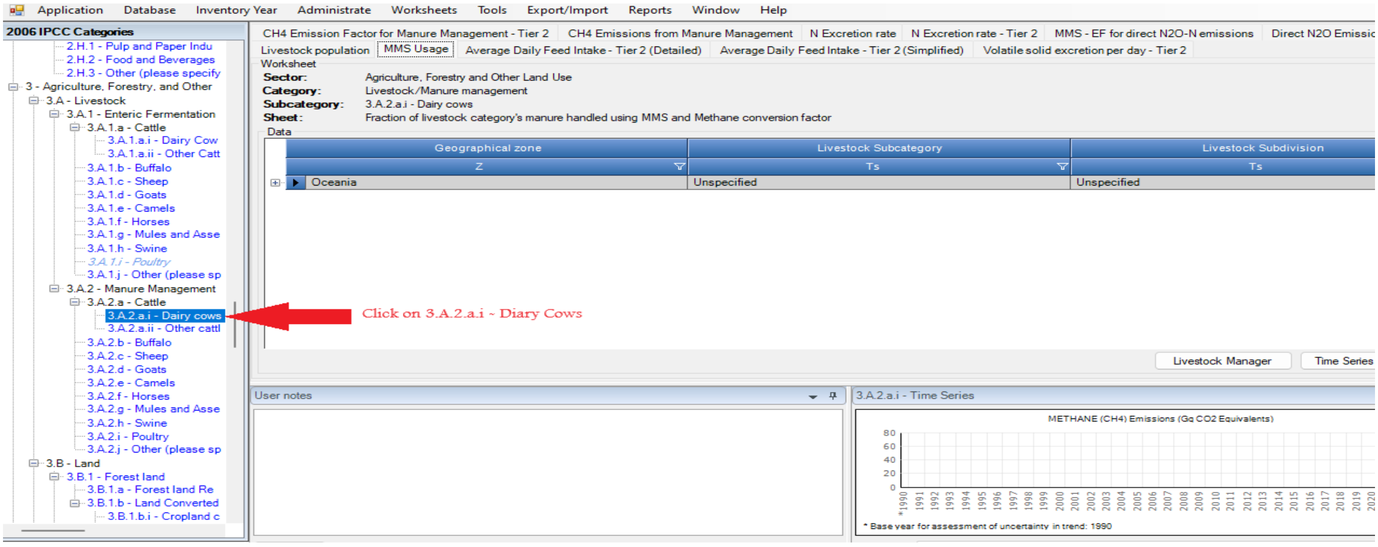
1.0 Open the VER. 2.901 IPCC INVENTORY SOFTWARE - 32BIT

1.8 Launch the IPCC software ver. 2.901 IPCC Inventory software - 32bit for national GHG inventories.

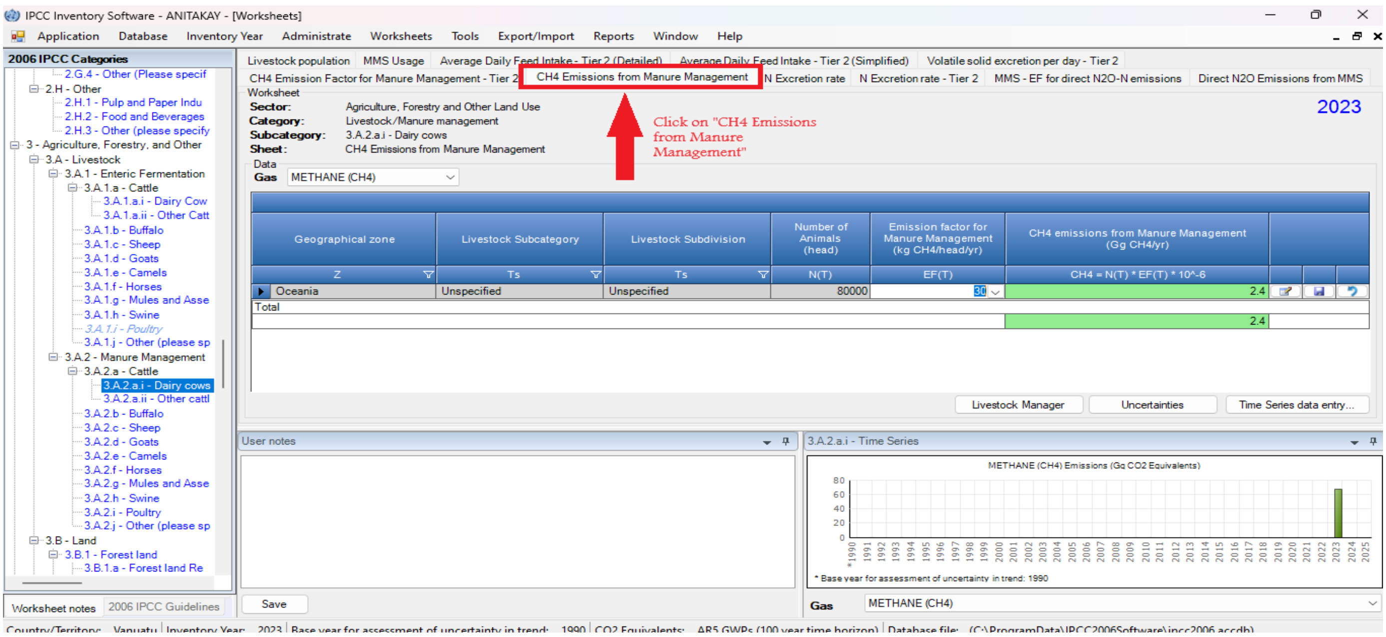
1.9 Type in your password and username.

1.10 Type in the year of your choosing or the current inventory year.

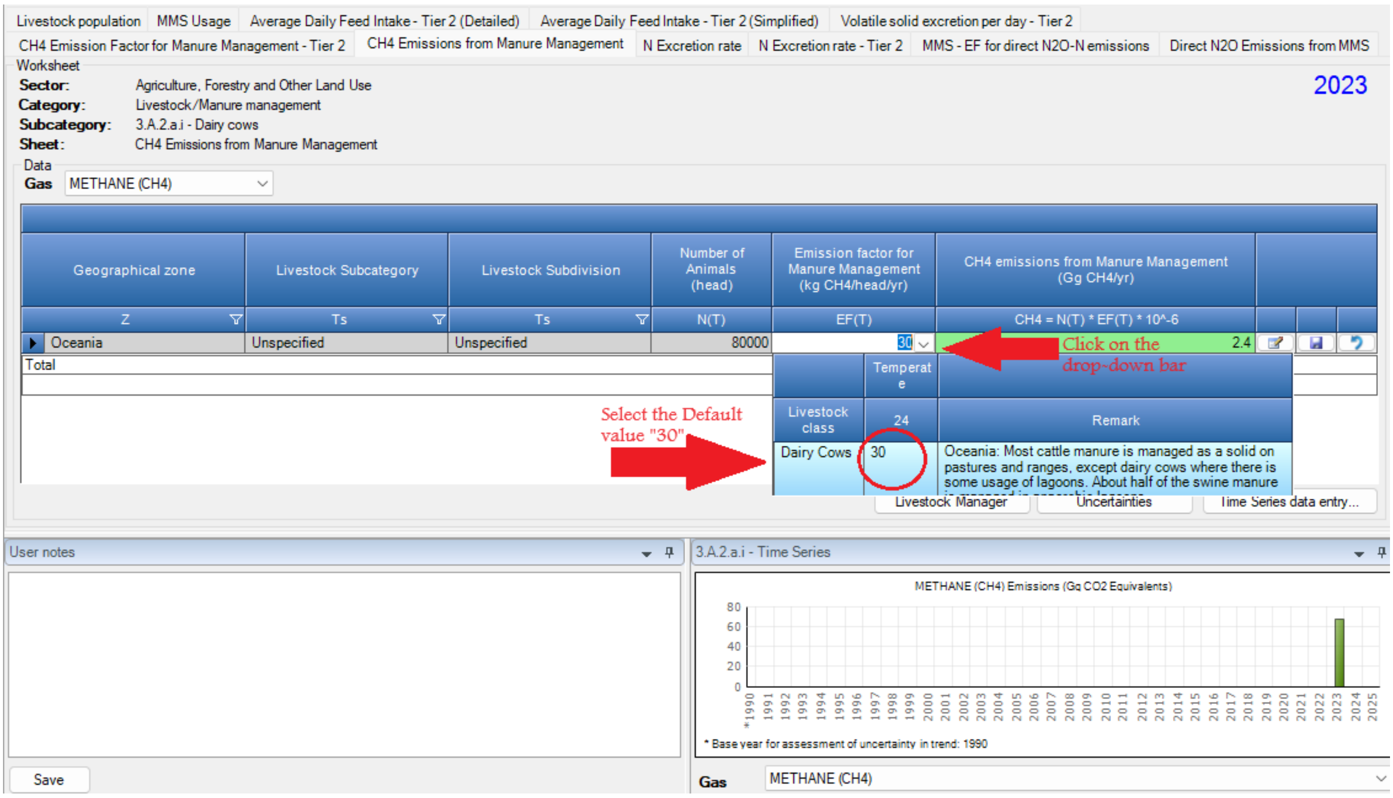
1.11 Locate the bar on the left-hand corner of the page labeled "2006 IPCC categories" and scroll down till you reach 3.A.2 – Manure Management and click on the subcategory 3.A.2.a.i – Dairy Cows (See illustration below).



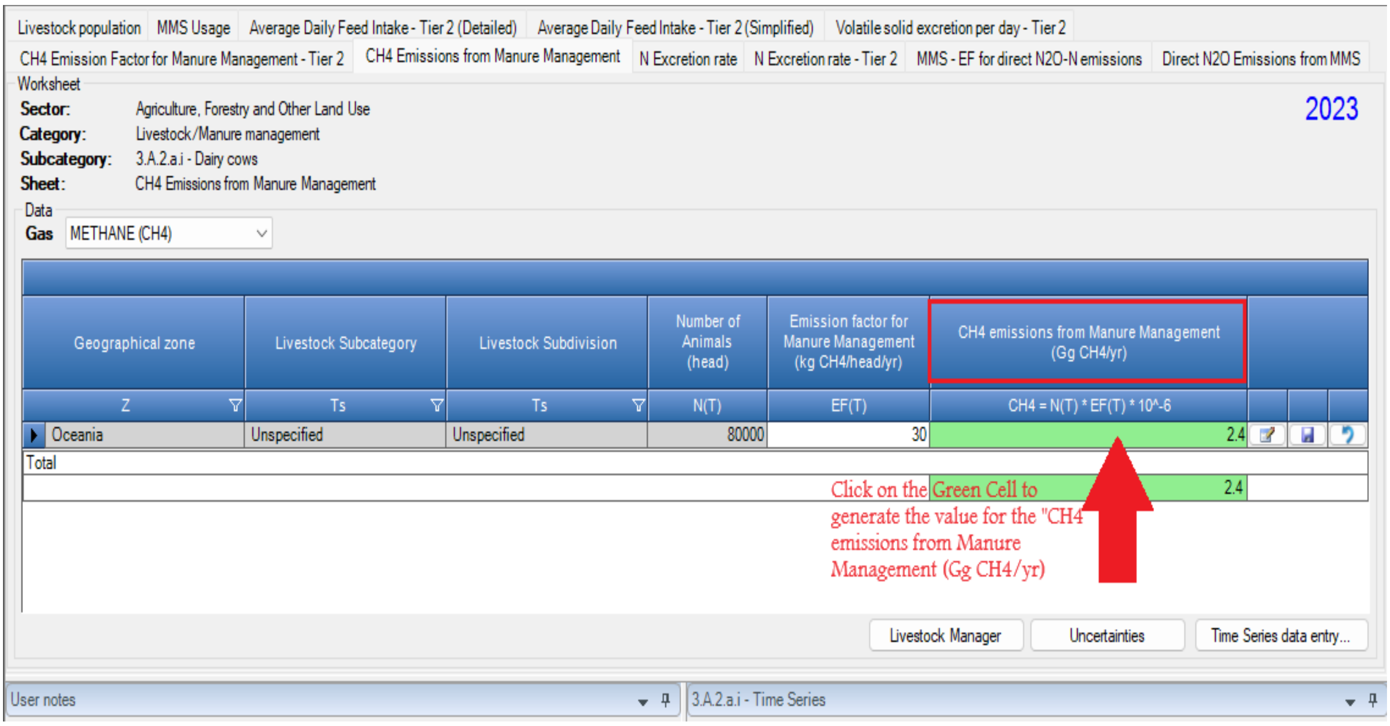
1.5 Click on the “CH_4 Emissions from Manure Management” tab, located near the top of the page (See Illustration below).



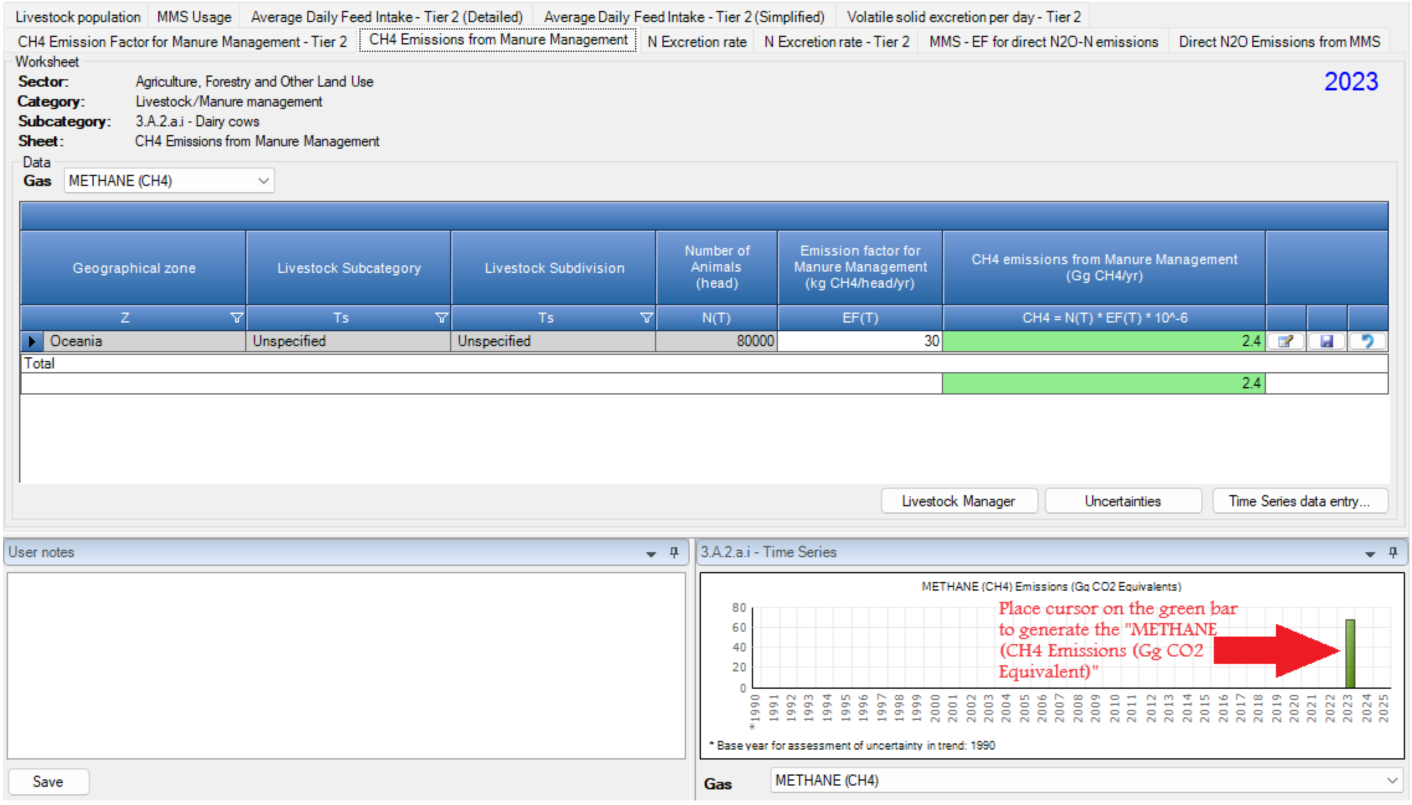
1.6 Click on the drop-down bar located under the "Emission factor for Manure Management (kg CH_4/head/yr)" tab and select the default value "30" (See illustration below). (See Annex Table 10.14)



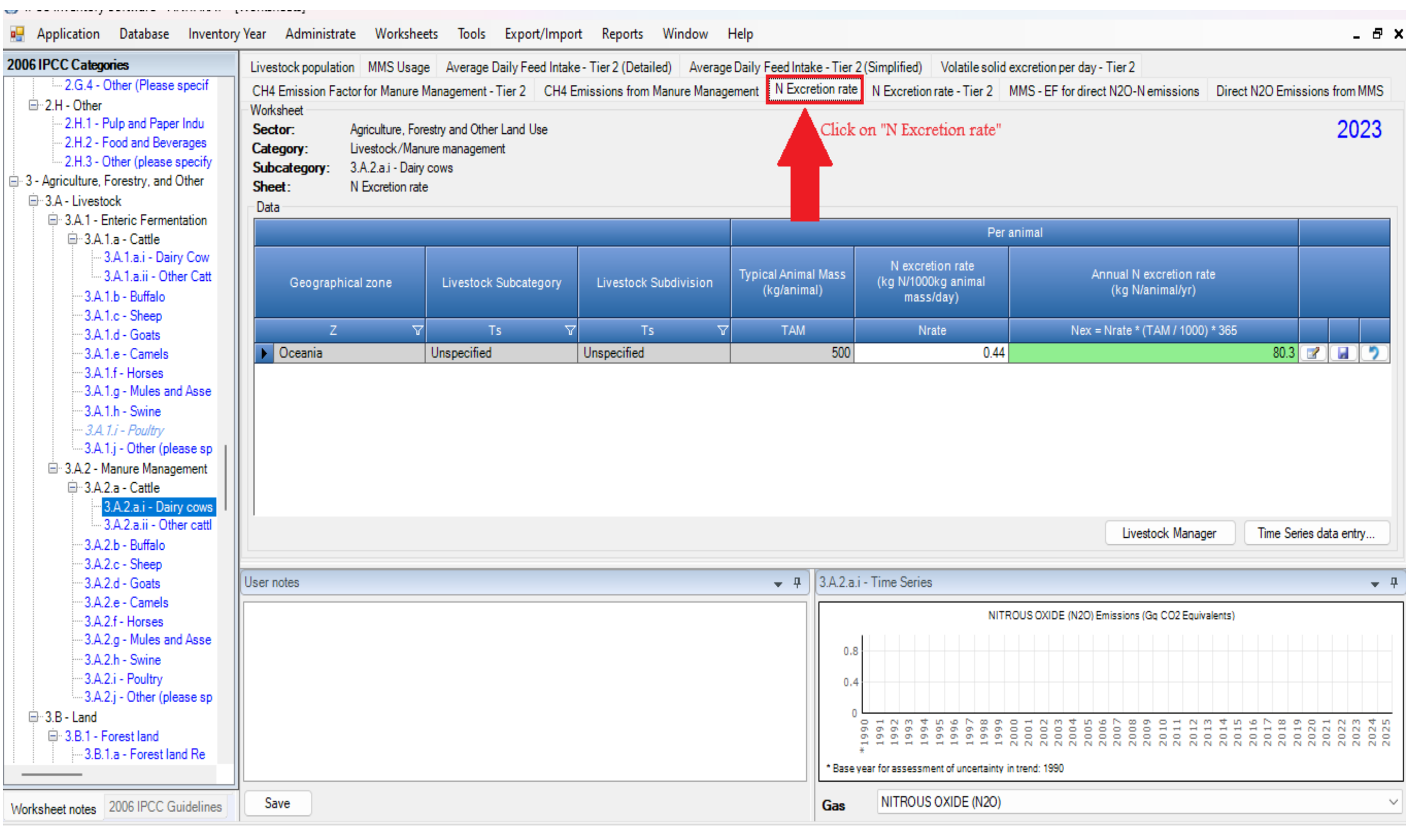
1.7 Click on the Green Cell under the tab "CH_4 emissions from Manure Management (Gg CH_4/yr) to generate the value for CH_4 emissions.



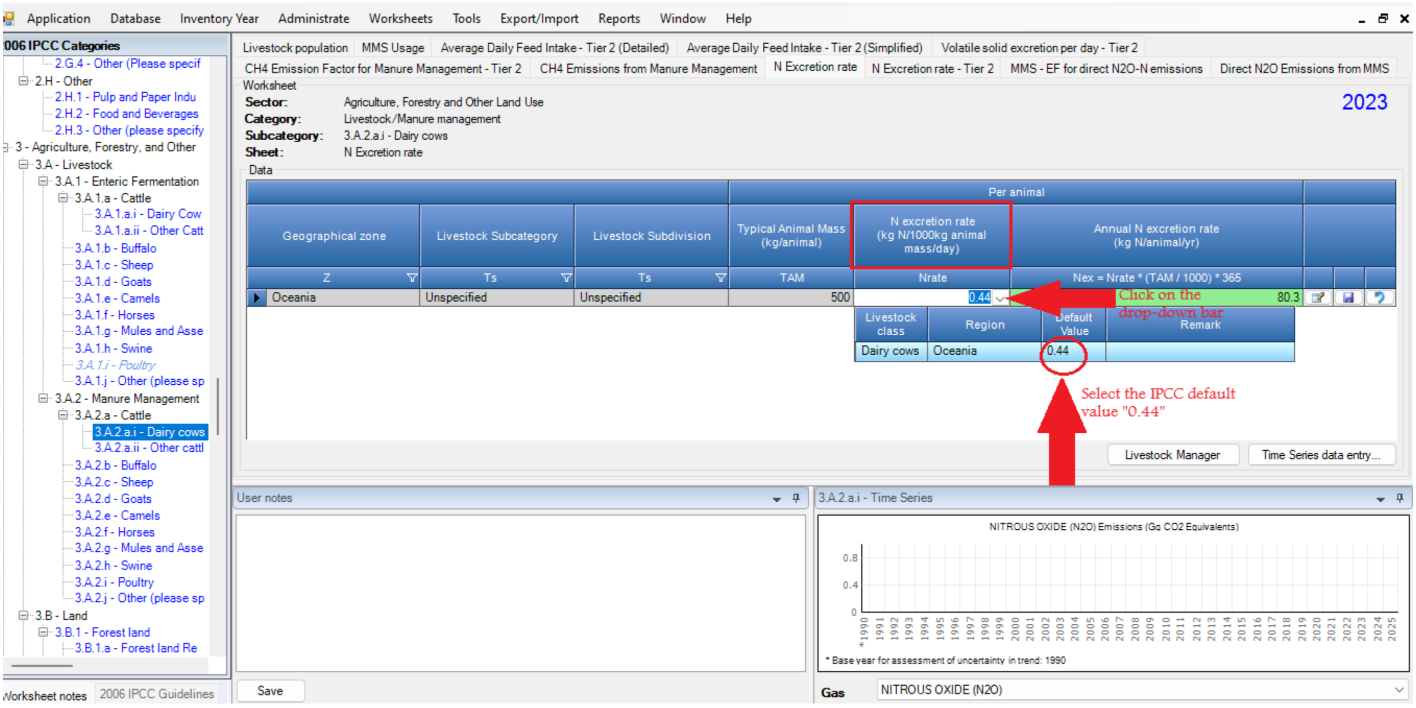
1.8 Place the cursor on the green bar in the "Time series graph) to generate the value (Gg CO_2 Equivalent) for the Dairy cows in the chosen inventory year (See illustration below).



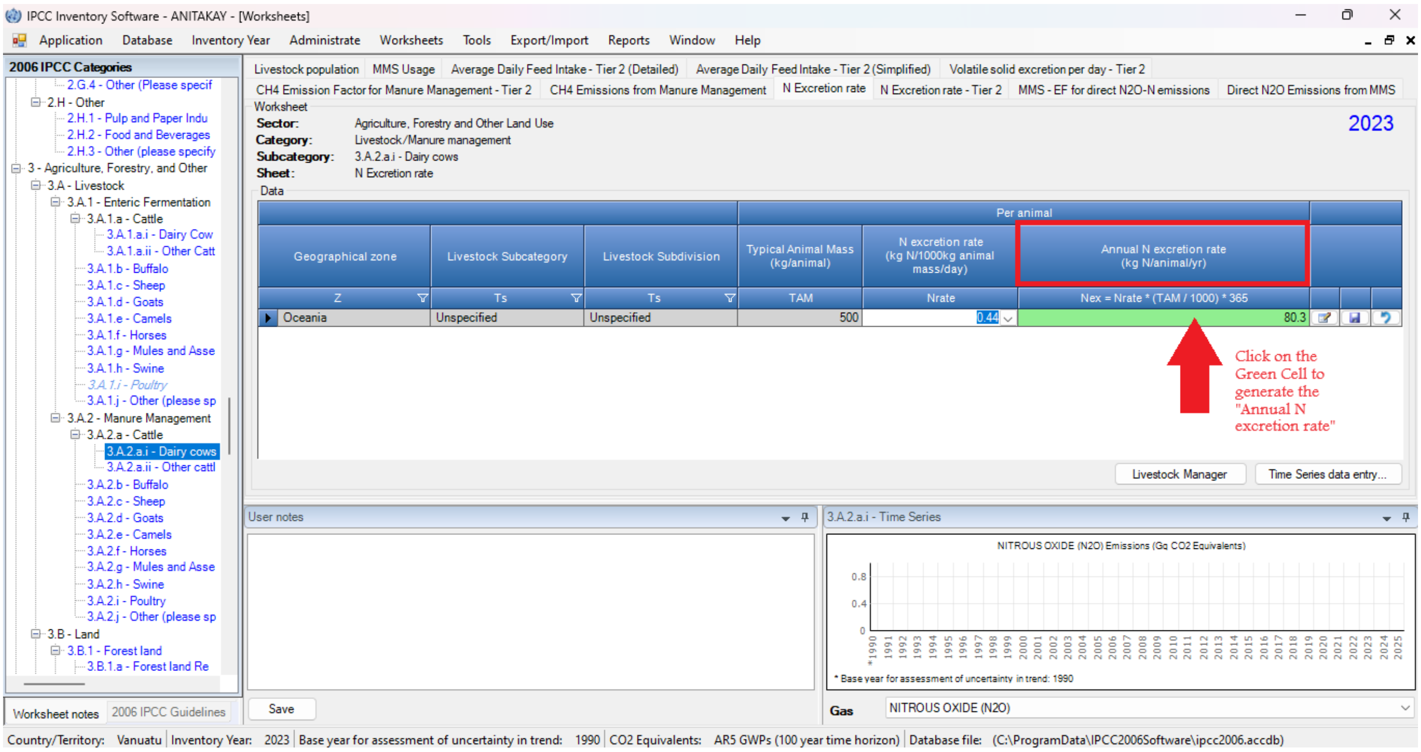
1.9 Click on the "N Excretion rate" tab located near the upper page (See illustration below).



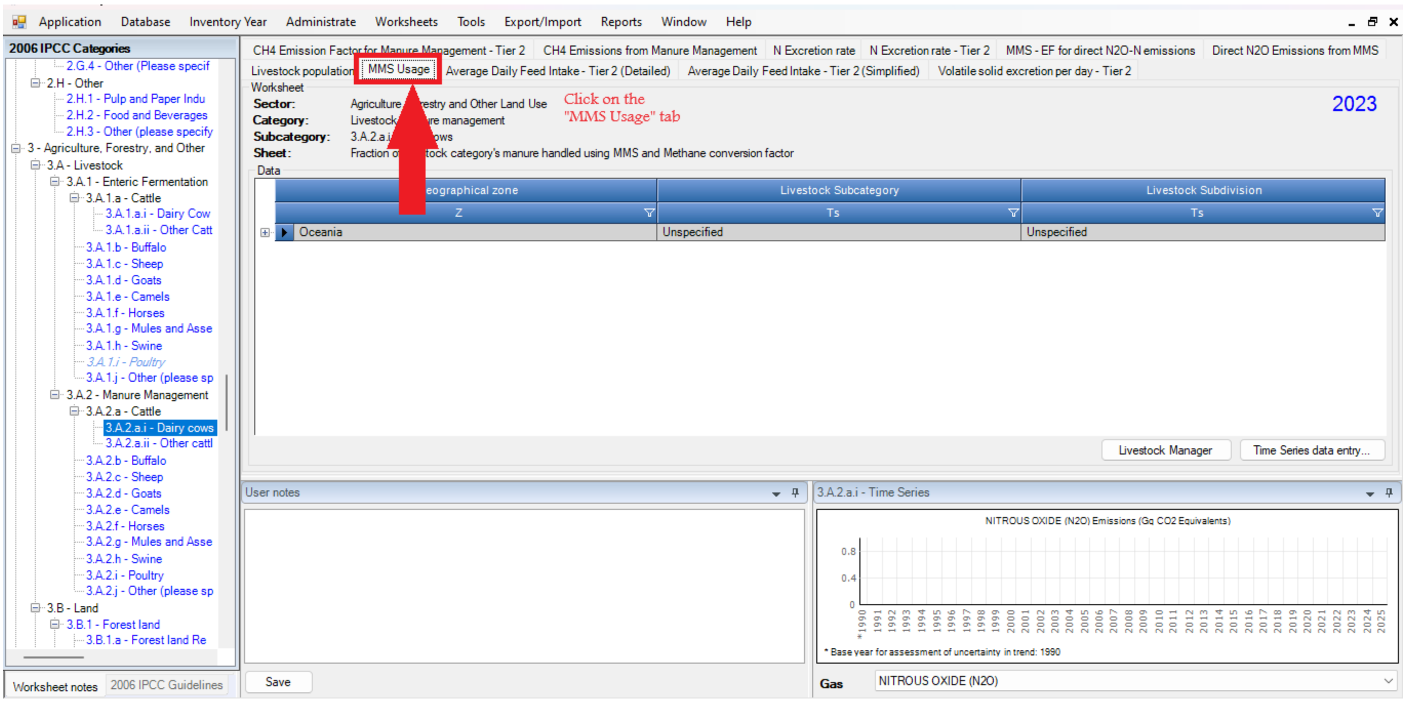
2.0 Under the tab “N excretion rate (kg N/1000kg animal mass/day), click on the drop-down bar and select the IPCC default value of “0.44” (See illustration below). (See Annex Table 10.19)



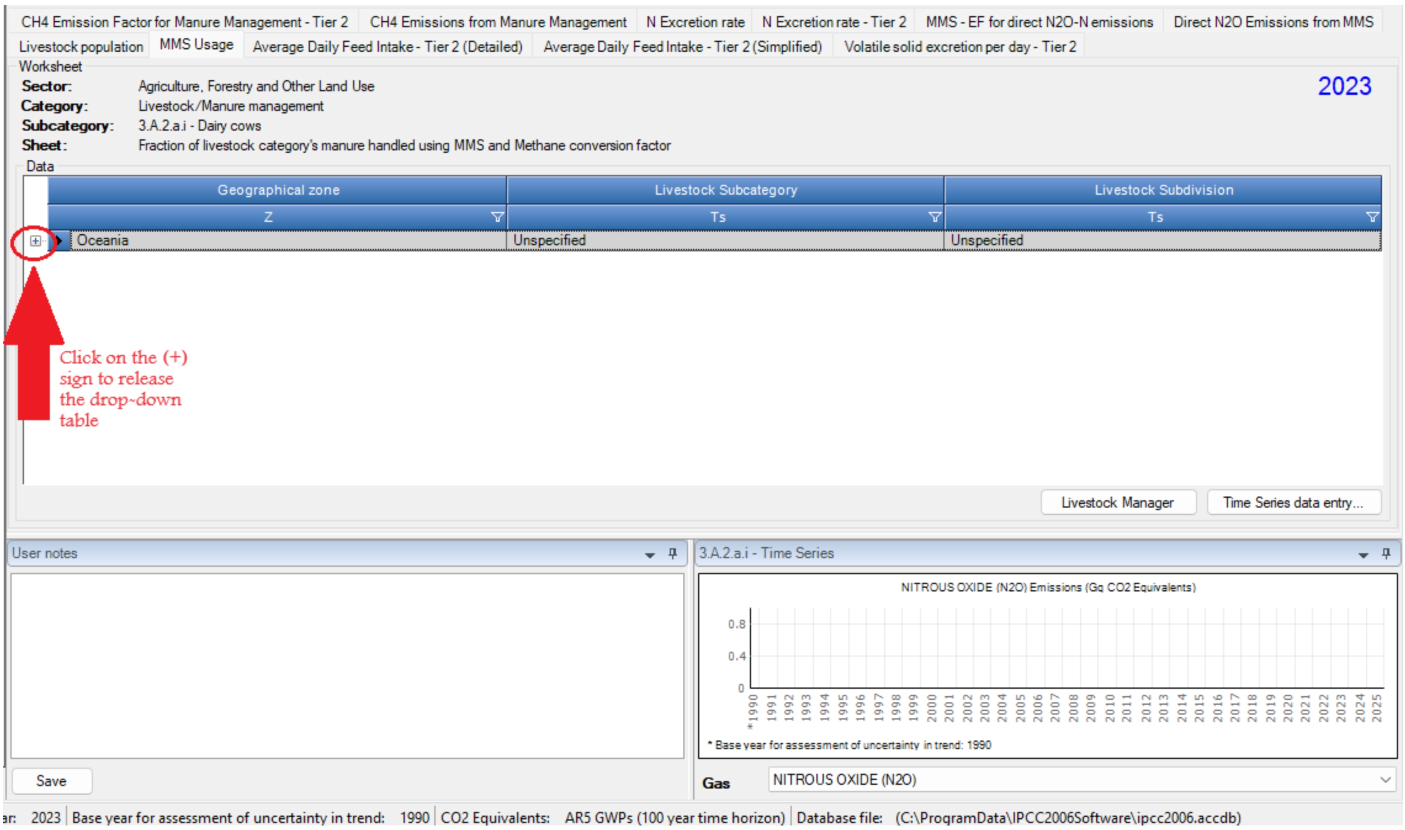
2.1 Click on the Green Cell located under “the Annual N excretion rate (kg N/animal/yr)” to generate the Annual N excretion rate (kg N/animal/yr) (See illustration below).



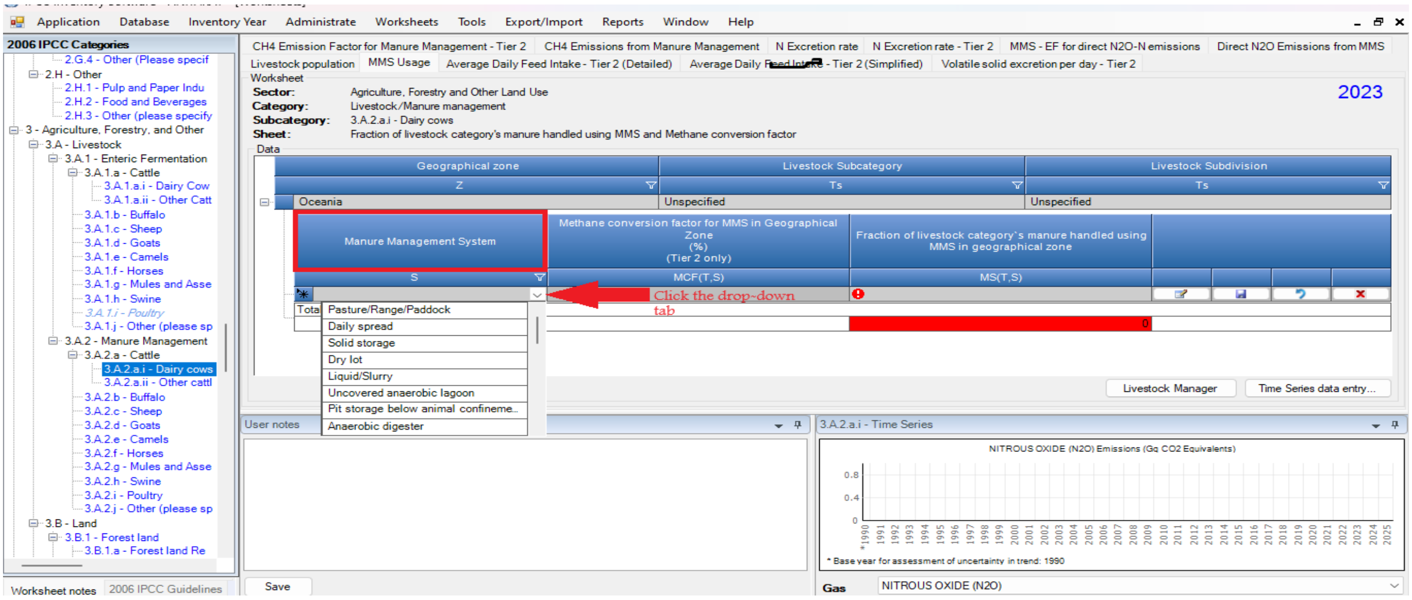
2.2 Click on the “MMS Usage” tab located at the top part of the page (See illustration below)



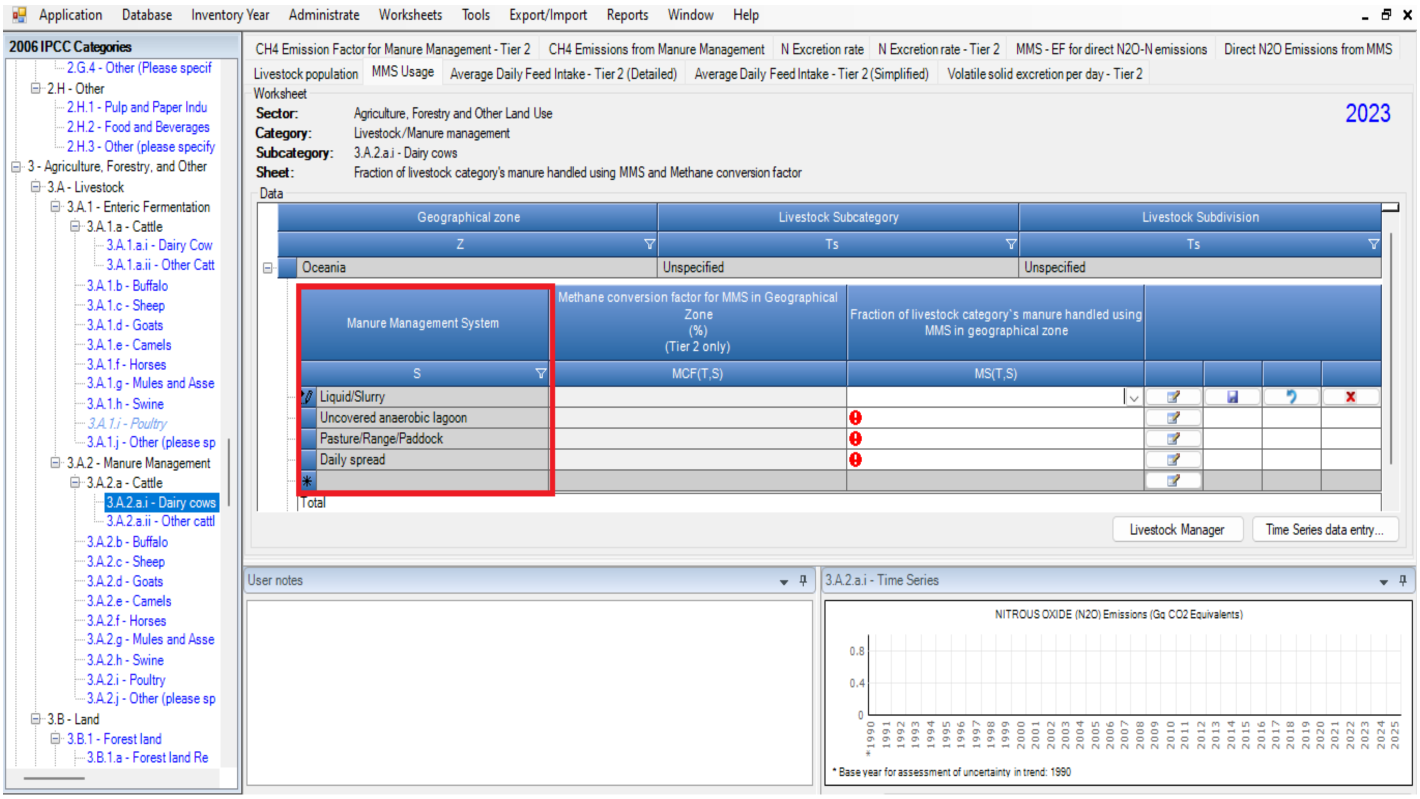
2.3 Click on the (+) sign near the “Oceania” tab to release the drop-down table (See illustration below)



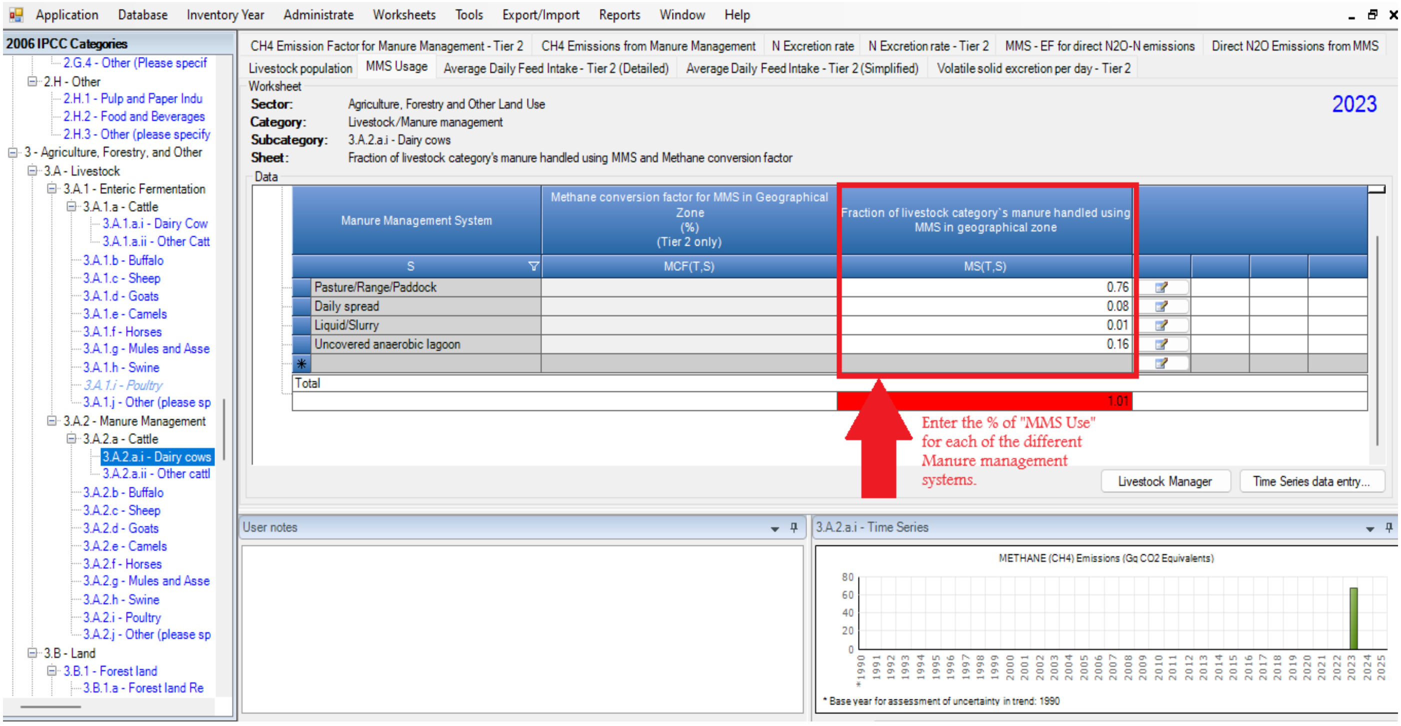
2.4 Under the "Manure Management System" click on the drop-down tab to release the types of manure management systems (See illustration below)



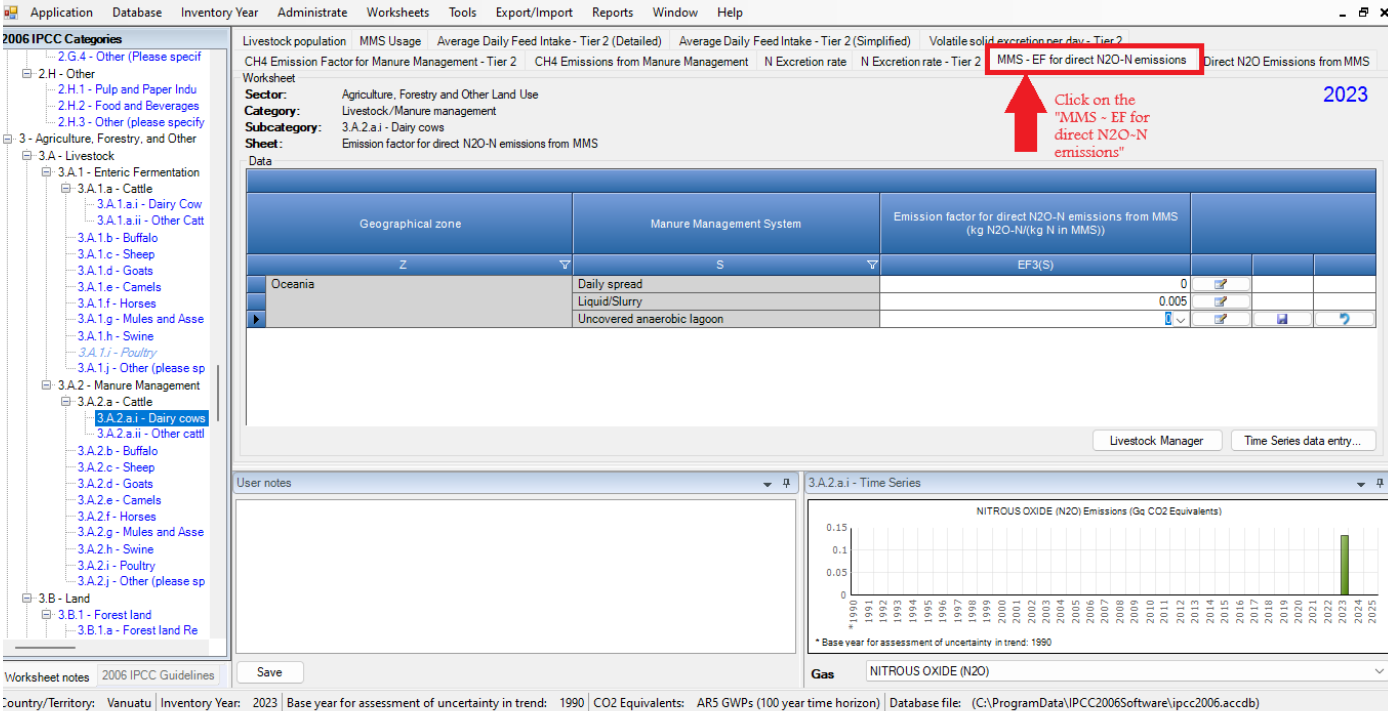
2.5 Using TABLE 3 below select the different types of manure management systems used for the dairy cow (See illustration below)



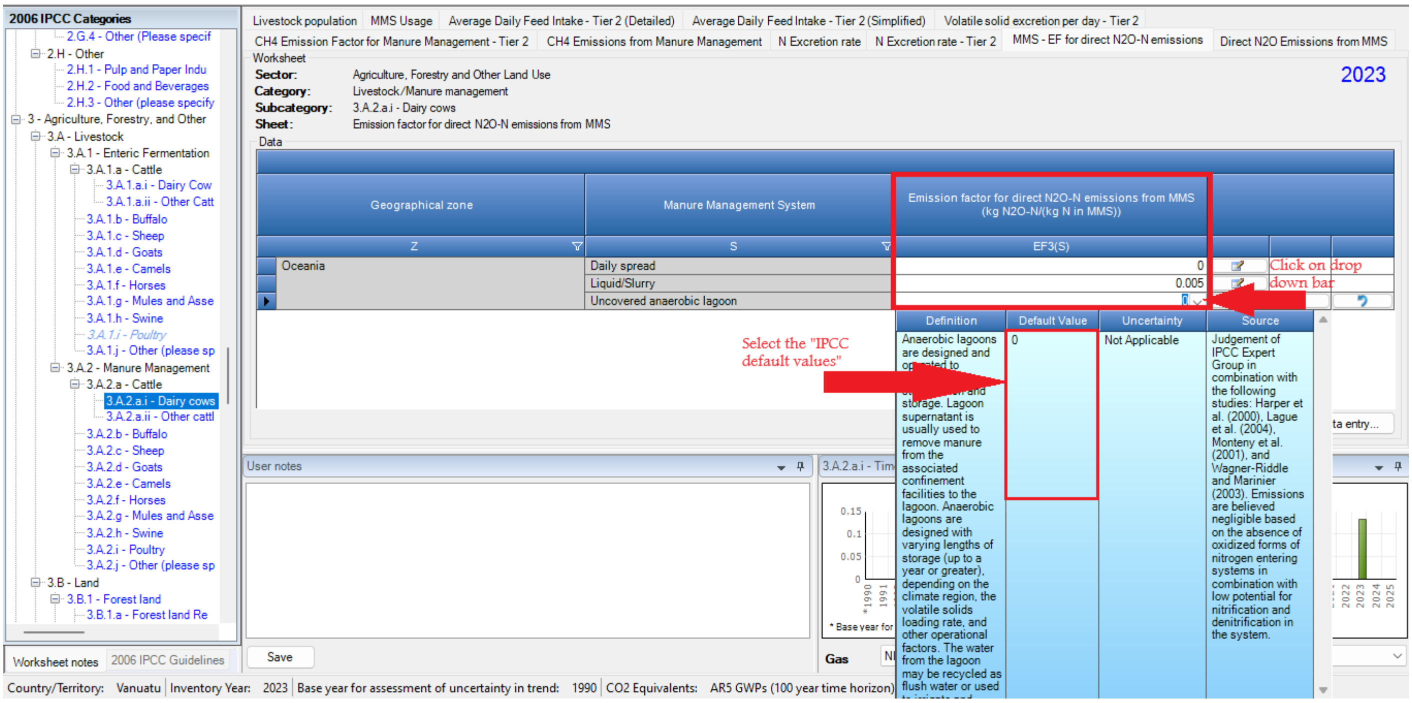
2.6 Under the "Fraction of livestock category's manure handled using MMS in the geographical zone", click on the drop-down bar and enter the Default values from (Table 3 in Annex) (see Illustration below). Note that the total "Fraction of livestock category's manure handled using MMS in the geographical zone", has to equal "1".



2.7 Click on the "MMS – EF for direct N2O-N emissions" tab located at the top of the page (See illustration below).



2.8 Under the tab "Emission factor for direct N_2O-N emissions from MMs (kg N_2O-N(kg N in MMS)" select the default values(cross check Annex , Table 4) (See illustration below).



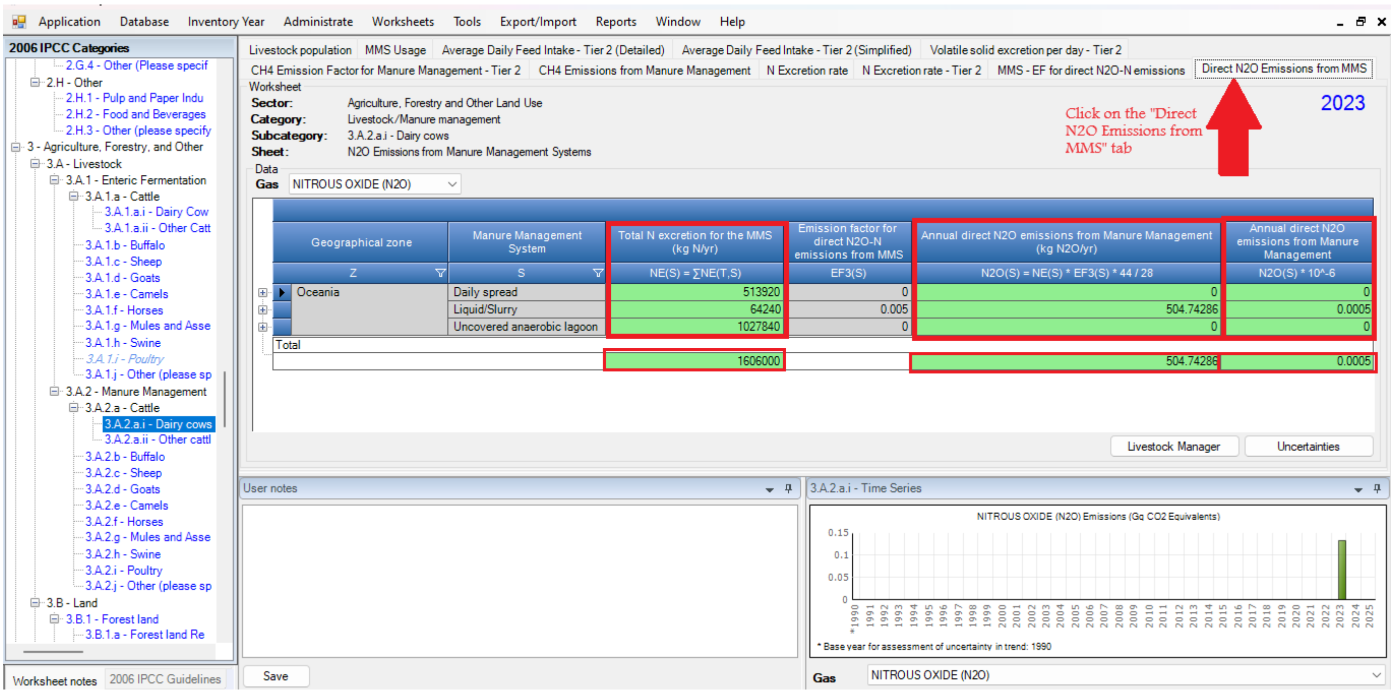
2.9 Click on the "Direct N_2O Emissions from MMS" tab at the top of the page. Under the "Direct N_2O Emissions from MMS" page the following values can be accounted for from the following tabs:

1. Total N Excretion for the MMS (Kg N/yr)

2. Annual direct N_2O emissions from the manure management (Kg N_2O/yr)

3. Annual direct N_2O emissions from manure management

(See illustration below)

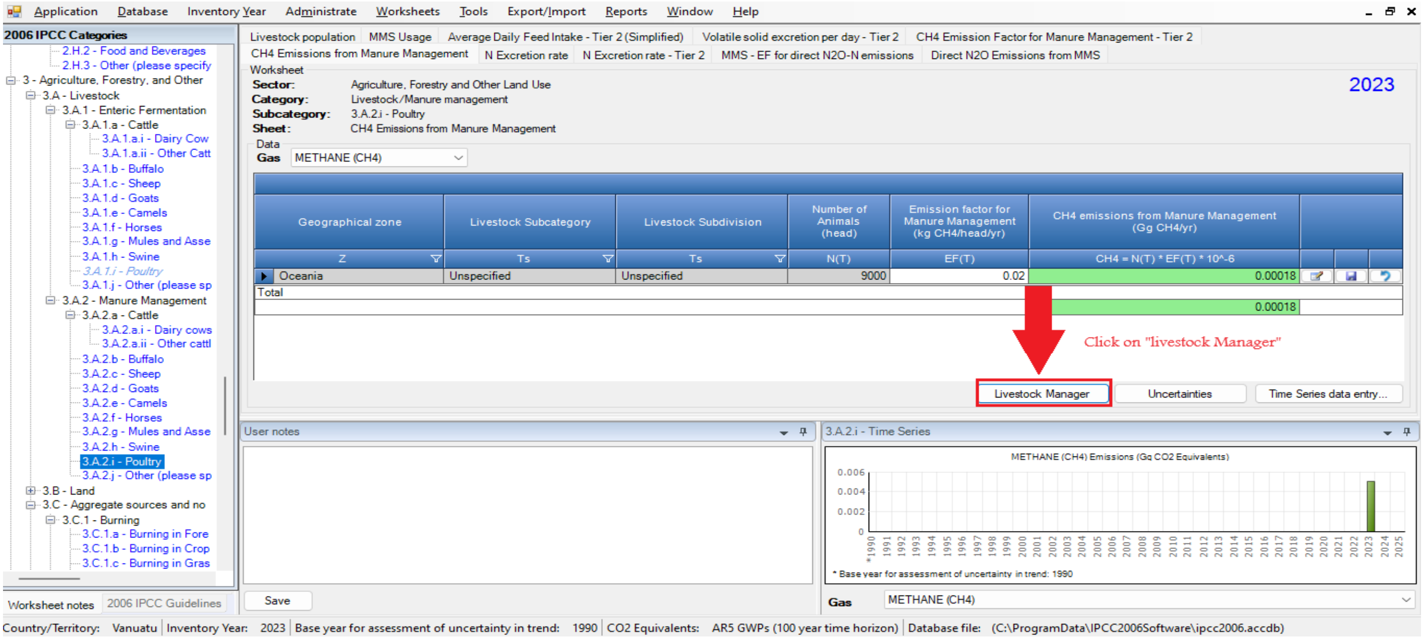


3.0 Repeat steps 1.5 to 2.9 for the following live stocks

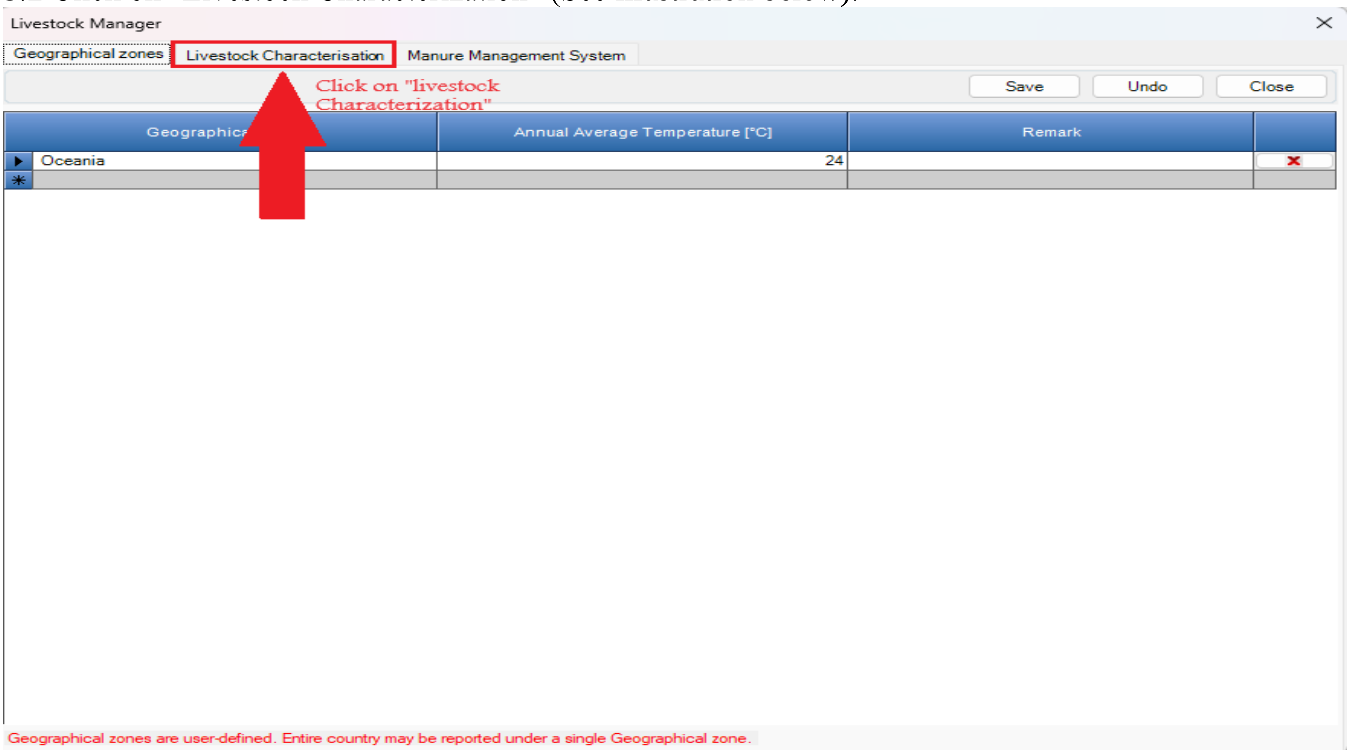
- 3.A.2.ii – Other Cattle
- 3.A.2.d – Goats
- 3.A.2.f – Horses
- 3.A.2.h – Swine

<u>3.A.2.i – Poultry</u>

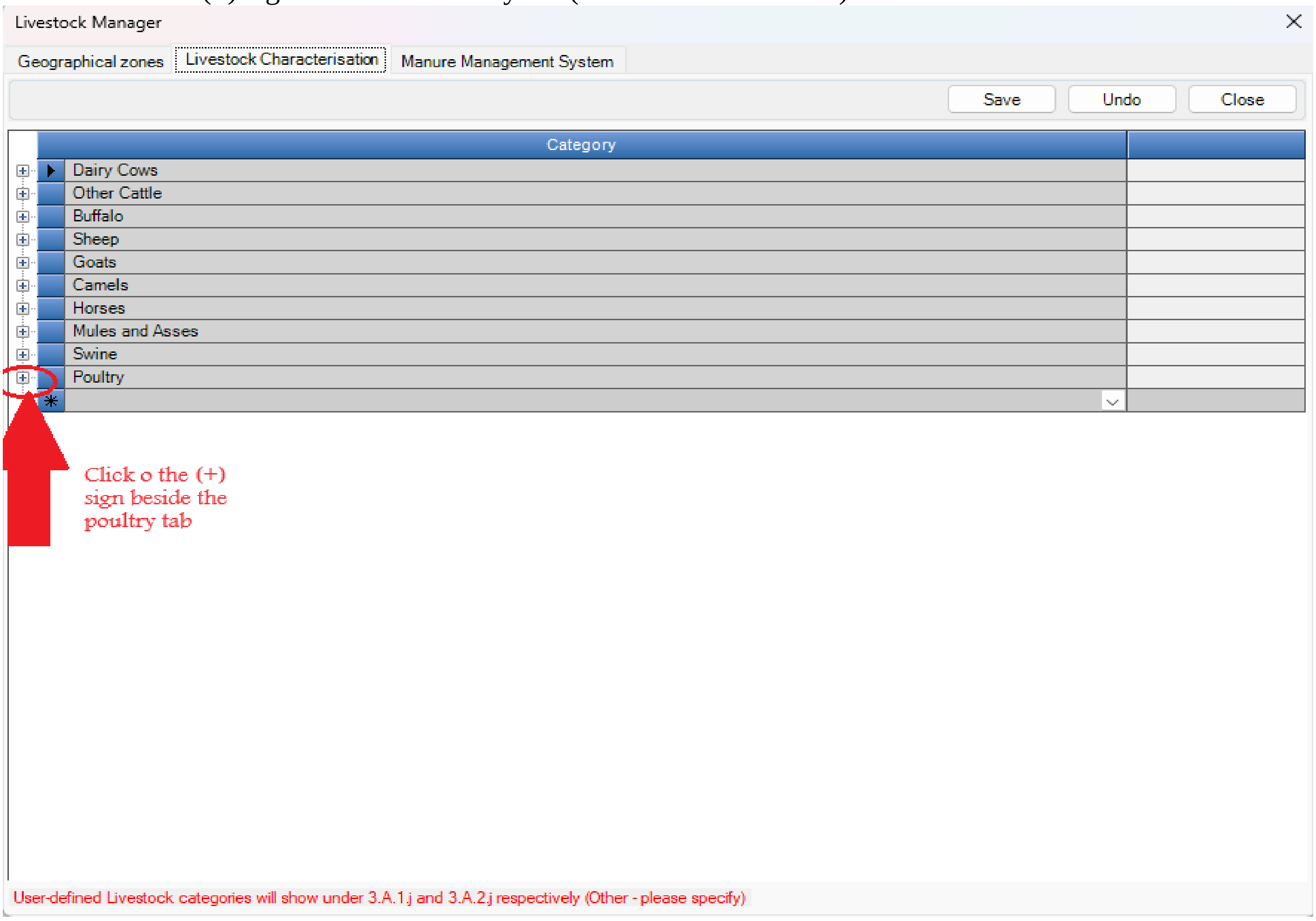
3.1 click on the "Livestock Manager"



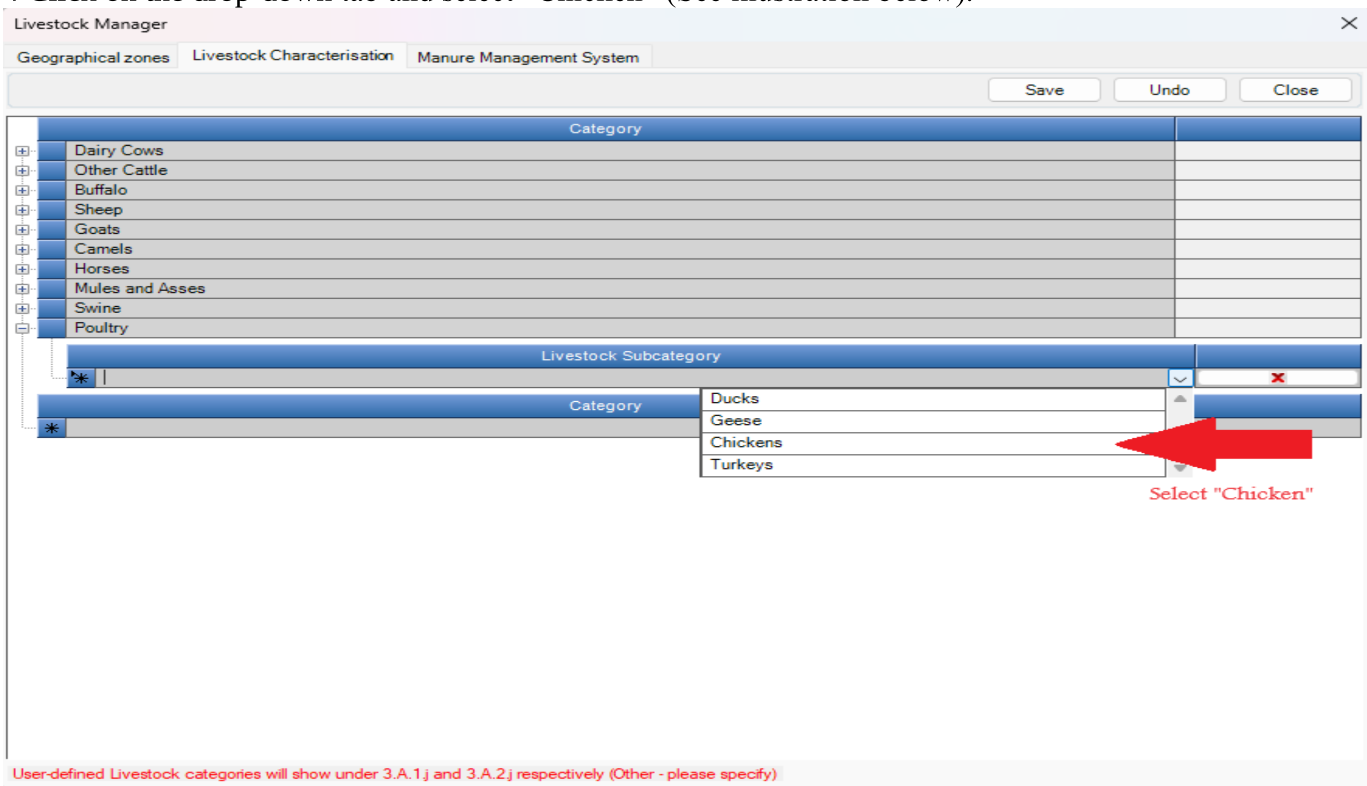
3.2 Click on "Livestock Characterization" (See illustration below).



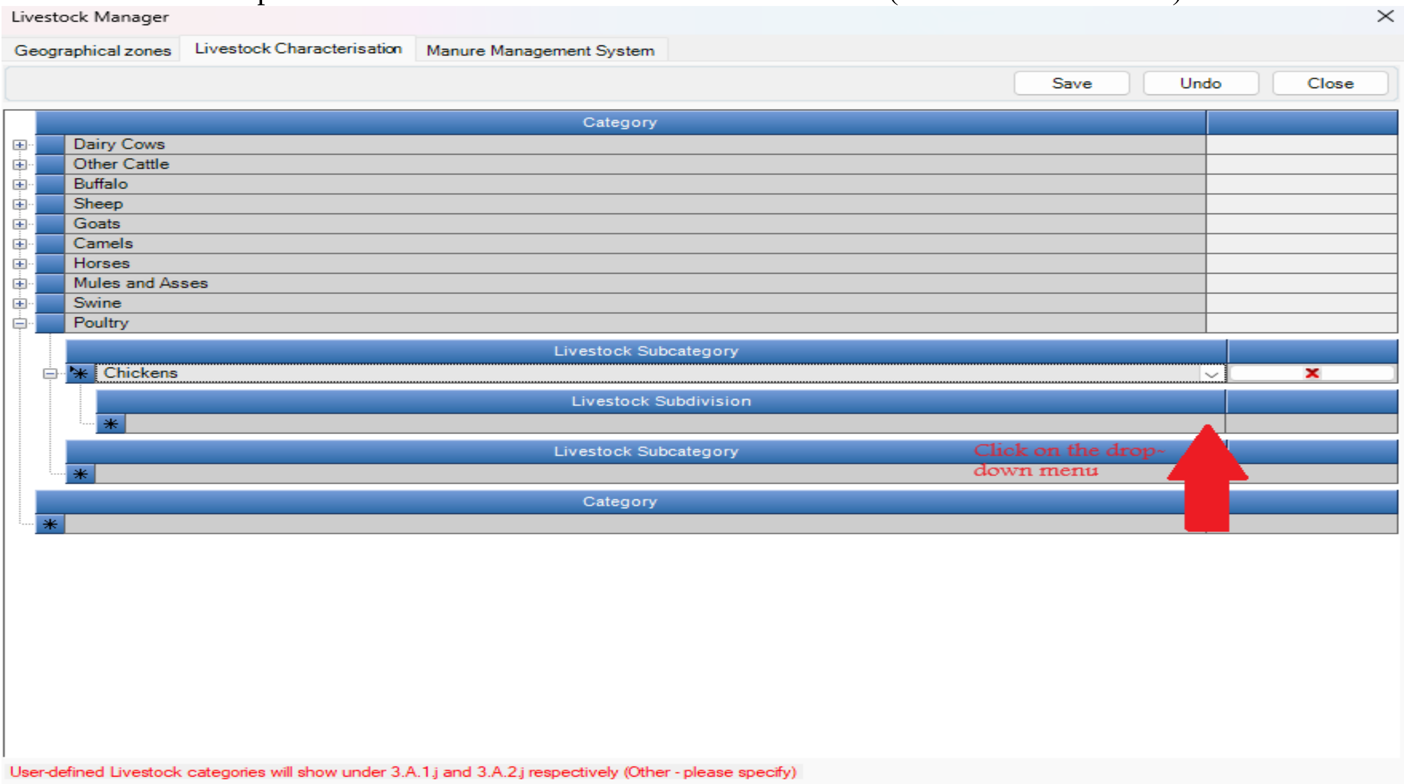
3.3 Click on the (+) sign beside the Poultry tab (See illustration below).



4 Click on the drop-down tab and select "Chicken" (See illustration below).



3.5 Click on the drop-down menu under the "Livestock subdivision" (see illustration below)

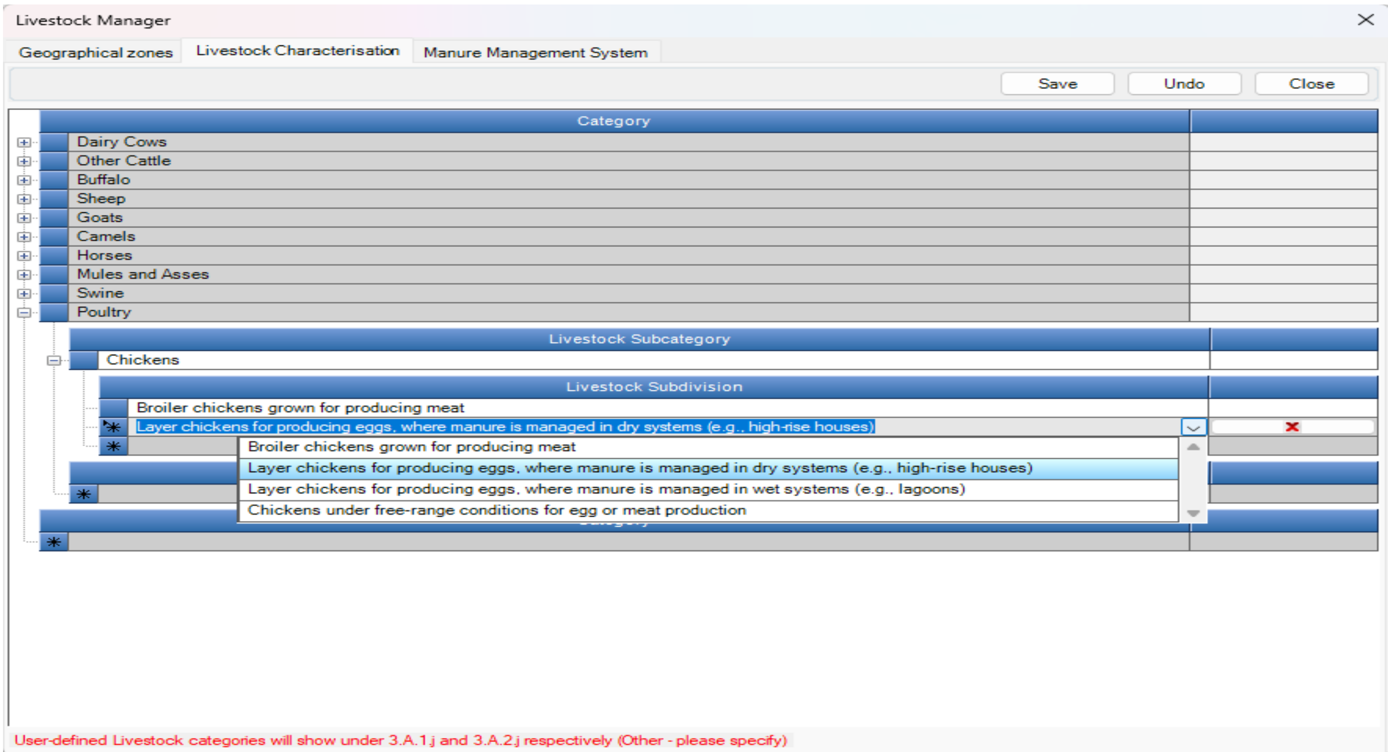


3.6 under livestock subdivision select:

1. Broiler Chicken grown for producing meat

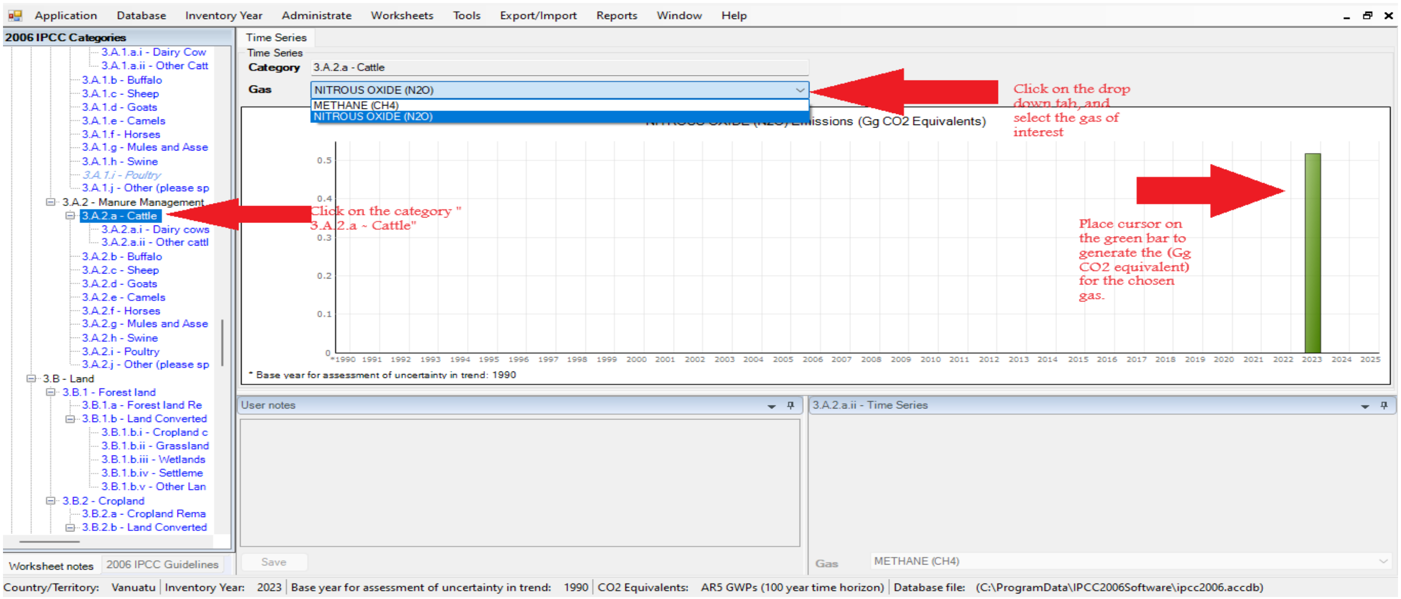
2. Layer chicken for producing eggs, where manure is managed in dry systems (High-rise houses)

And click save button

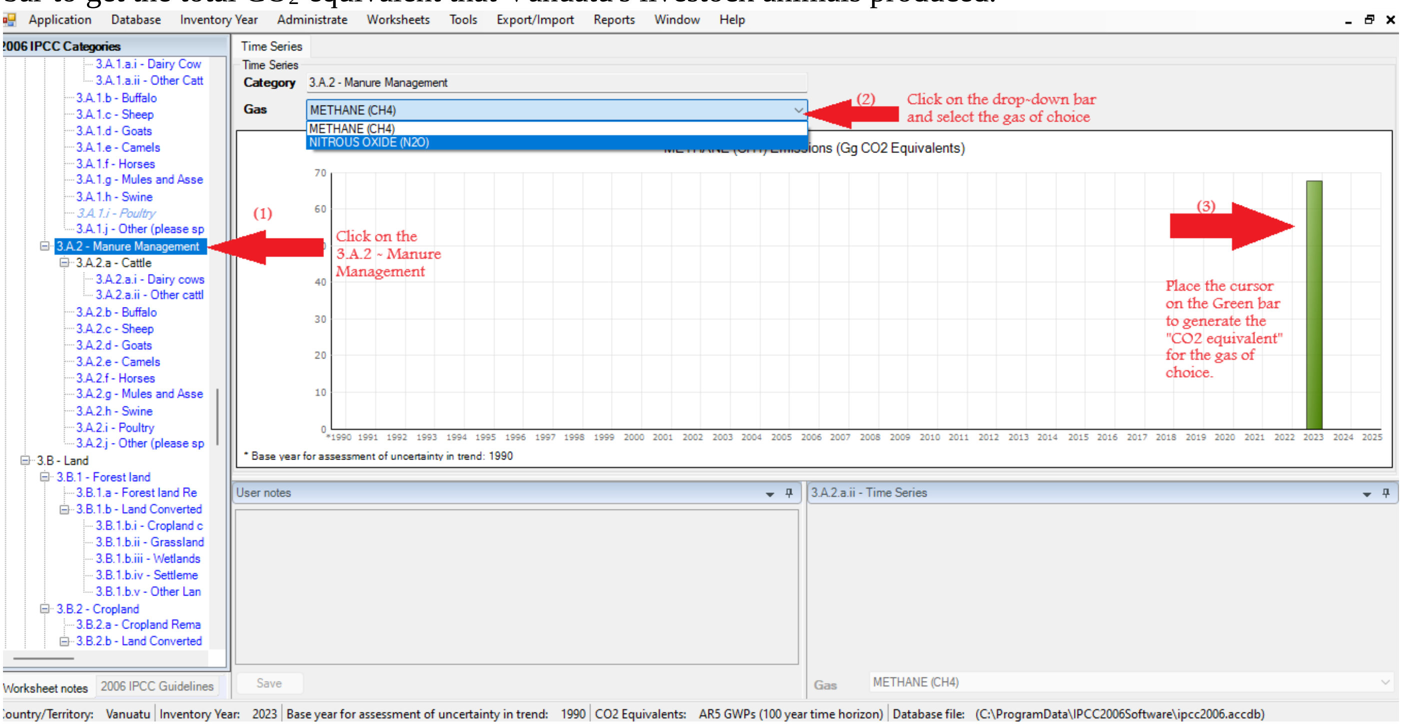


3.7 Repeat steps 1.5 to 2.9

Note: To determine the total CO_2 equivalent for each gas (CH_4 and N_2O) produced as the sum of the two subcategories 3. A.2. a. i - Diary Cattle and 3. A.2.a.ii - Other Cattle, click on the category 3. A.2.a - Cattle (See Illustration below). Click the "gas" drop-down menu and choose your preferred gas. To get the total CO2 equivalent for the particular gas produced by the dairy cows and other cattle, move the cursor over the green bar on the graph (See Illustration below).



3.8 Note: Click on the 3.A.2 - Manure Management category under the "2006 IPCC category" to obtain the total CO_2 equivalent produced from CH_4 and N_2O for all livestock. Next, choose your preferred gas by clicking on the drop-down option beneath the "Gas" bar. In the graph below, move the cursor over the green bar to get the total CO_2 equivalent that Vanuatu's livestock animals produced.



3.3.1 METHODOLOGY CHOICE

A fraction of volatilized nitrogen is managed in each manure management system by multiplying the amount of nitrogen excreted (from all livestock categories) in the Tier 1 calculation of N volatilization in the forms of NH3 and NOx (see Equation 10.26). The overall losses for all manure management systems are then equal to N. Utilizing default nitrogen excretion data, default manure management system data (see Annex 10A.2, Tables 10A-4 to 10A-8), and default fractions of N losses from manure management systems due to volatilization (see Table 10.22 in Annex) are how the Tier 1 approach is implemented (2006 IPCC Guidelines)

EQUATION 1: The Indirect N_2O emissions from volatilization of N in forms of NH_3 and NO_x ($N_2O_{G\ (mm)}$ are estimated using this equation

EQUATION 10.27

INDIRECT N_2O EMISSIONS DUE TO VOLATILISATION OF N FROM MANURE MANAGEMENT

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

Where:

$N_2O_{G\ (mm)}$ = indirect N2O emissions due to volatilization of N from Manure Management in the country, kg N2O yr^{-1} (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.56, EQUATION 10.27)

EF_4 = emission factor for N2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N_2O-N (kg NH3-N + NOx-N volatilized)$^{-1}$; default value is 0.01 kg N2O-N (kg NH_3-N + NO_x-N volatilized)$^{-1}$, given in Chapter 11, Table 11.3(see Annex). (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.56, EQUATION 10.27)

EQUATION 2:

EQUATION 10.26

N LOSSES DUE TO VOLATILIZATION FROM MANURE MANAGEMENT

$$N_{Volatilisation\text{-}MMS} = \sum_S [\sum_T [N_T * NEX_{(T)} * MS_{(T,S)}) * (\frac{Frac_{GASMS}}{100})_{(T,S)}]]$$

Where:

Volatilization-MMS = amount of manure nitrogen that is lost due to volatilization of NH3 and NOx, kg N yr^{-1} (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26).

N(T) = number of heads of livestock species/category T in the country (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26).

$Nex_{(T)}$ = annual average N excretion per head of species/category T in the country, kg N animal-1 yr^{-1} (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26).

$MS_{(T, S)}$ = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless(See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26)

$Frac_{GasMS}$ = percent of managed manure nitrogen for livestock category T that volatilises as NH3 and NOx in the manure management system S, % (See 2006 IPCC Guidelines, Vol.4, Ch.10, Pg.54, EQUATION 10.26)

3.3.2 STEP- BY- STEP CALCULATION, DOCUMENTING RESOURCES USED

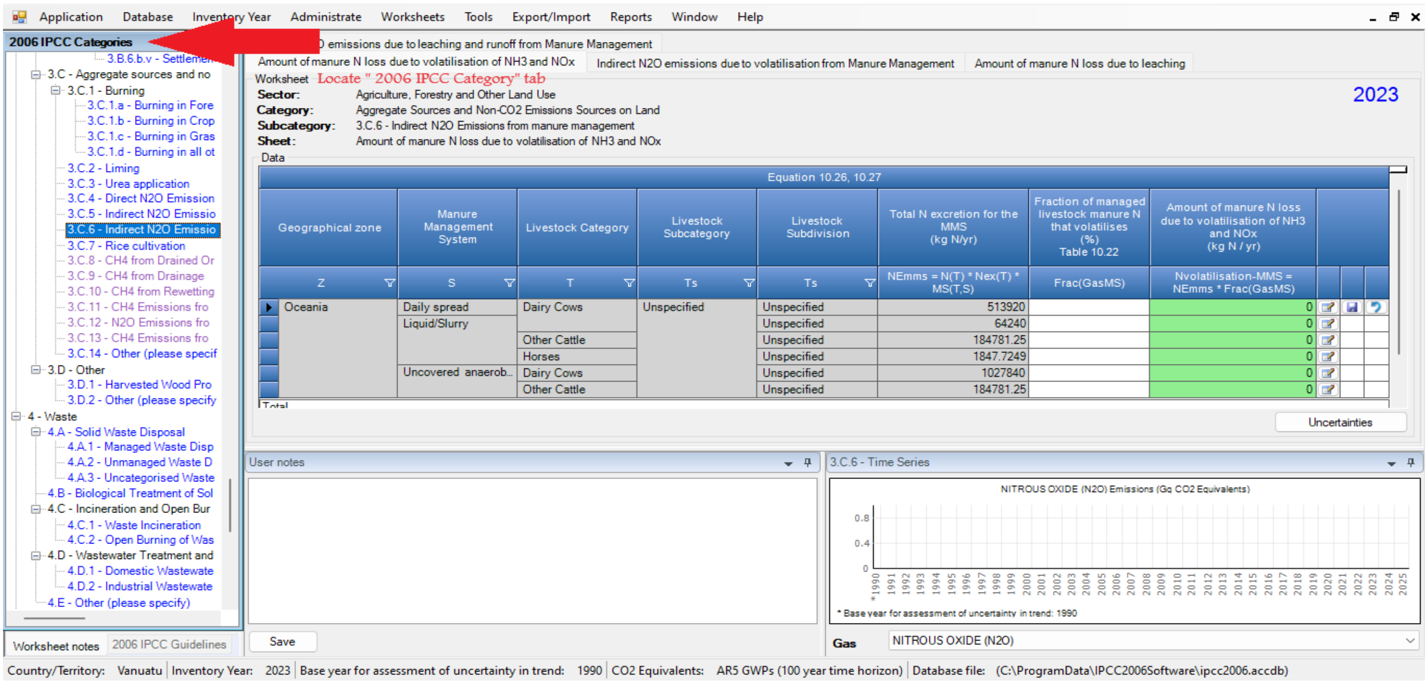
1.0 Open the [VER. 2.901 IPCC INVENTORY SOFTWARE - 32BIT]

1.12 Launch the IPCC software ver. 2.901 IPCC Inventory software - 32bit for national GHG inventories.

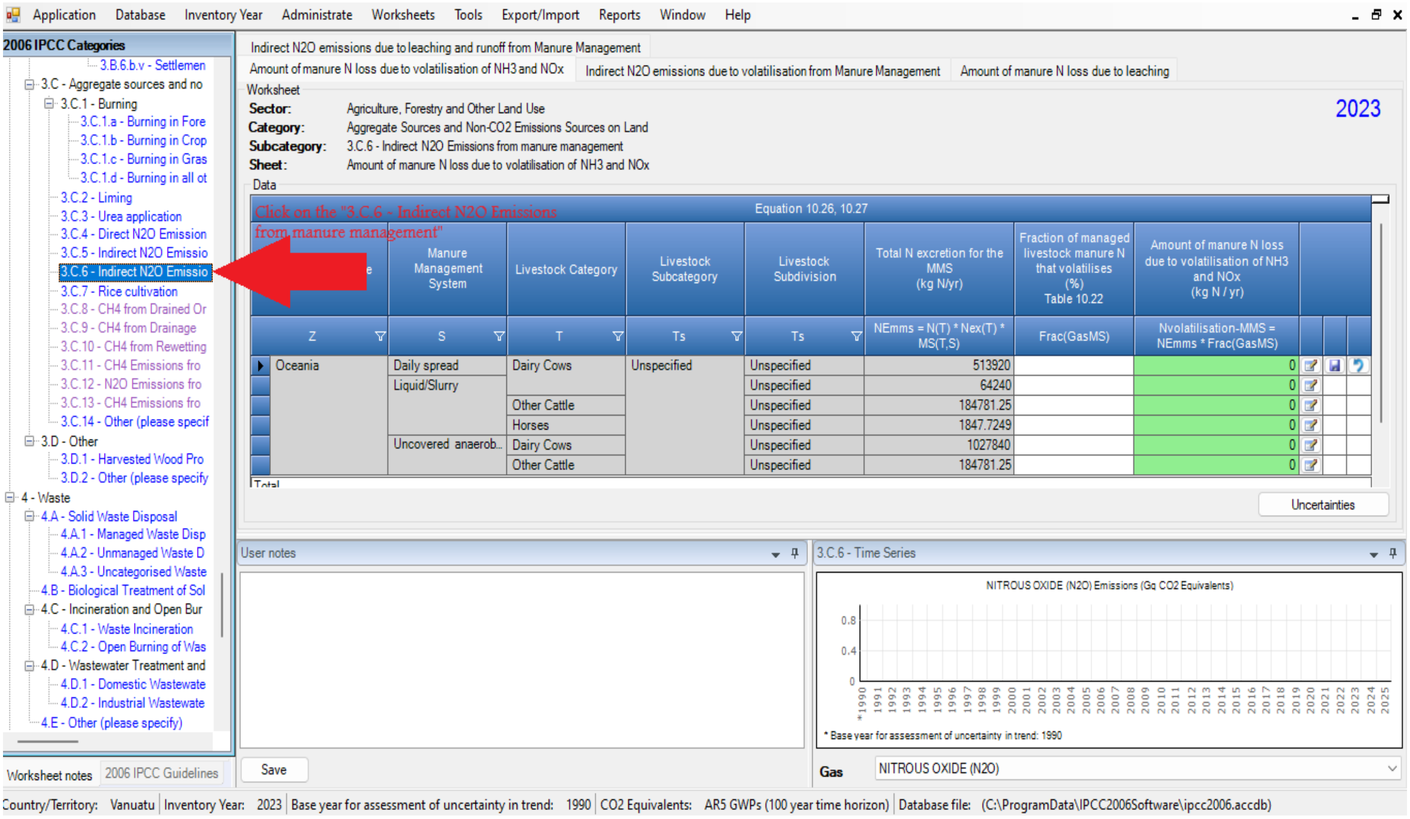
1.13 Type in your password and username.

1.14 Type in the year of your choosing or the current inventory year.

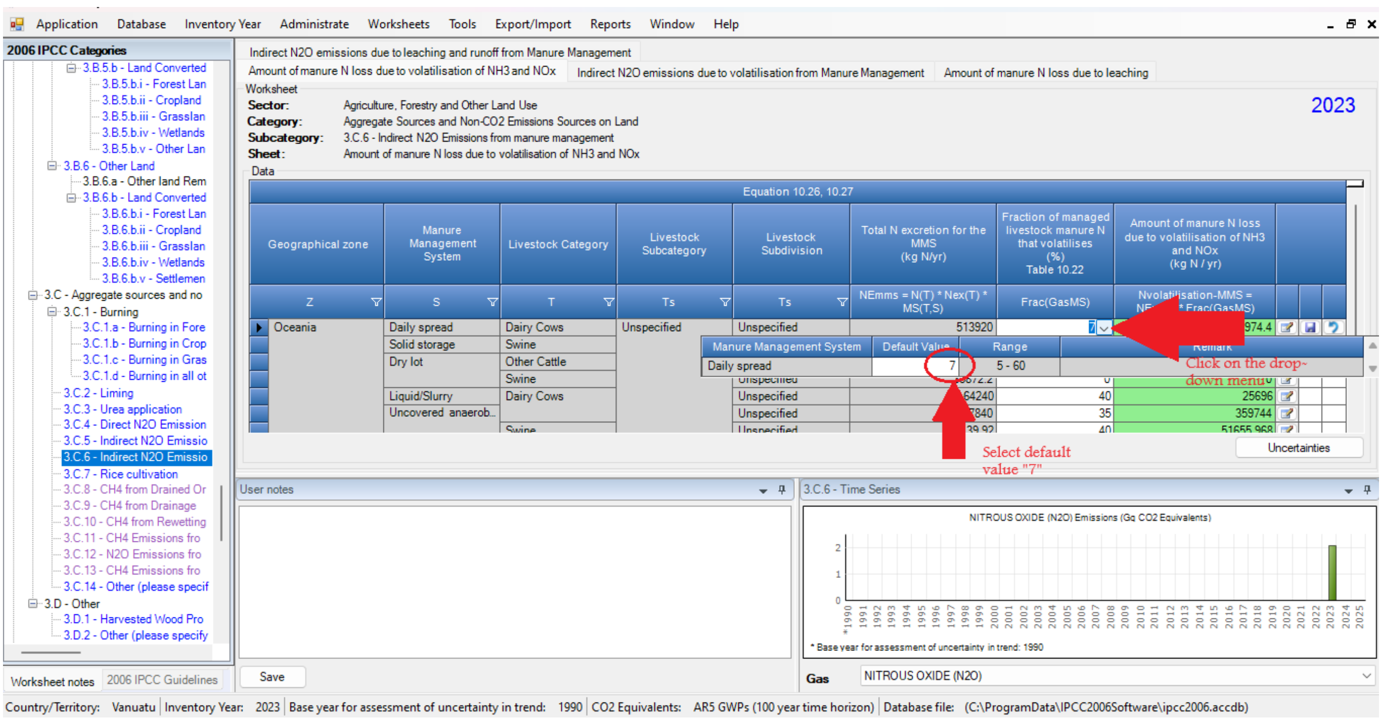
1.4 Locate the bar on the left-hand corner of the page labeled "2006 IPCC categories" (See illustration below)



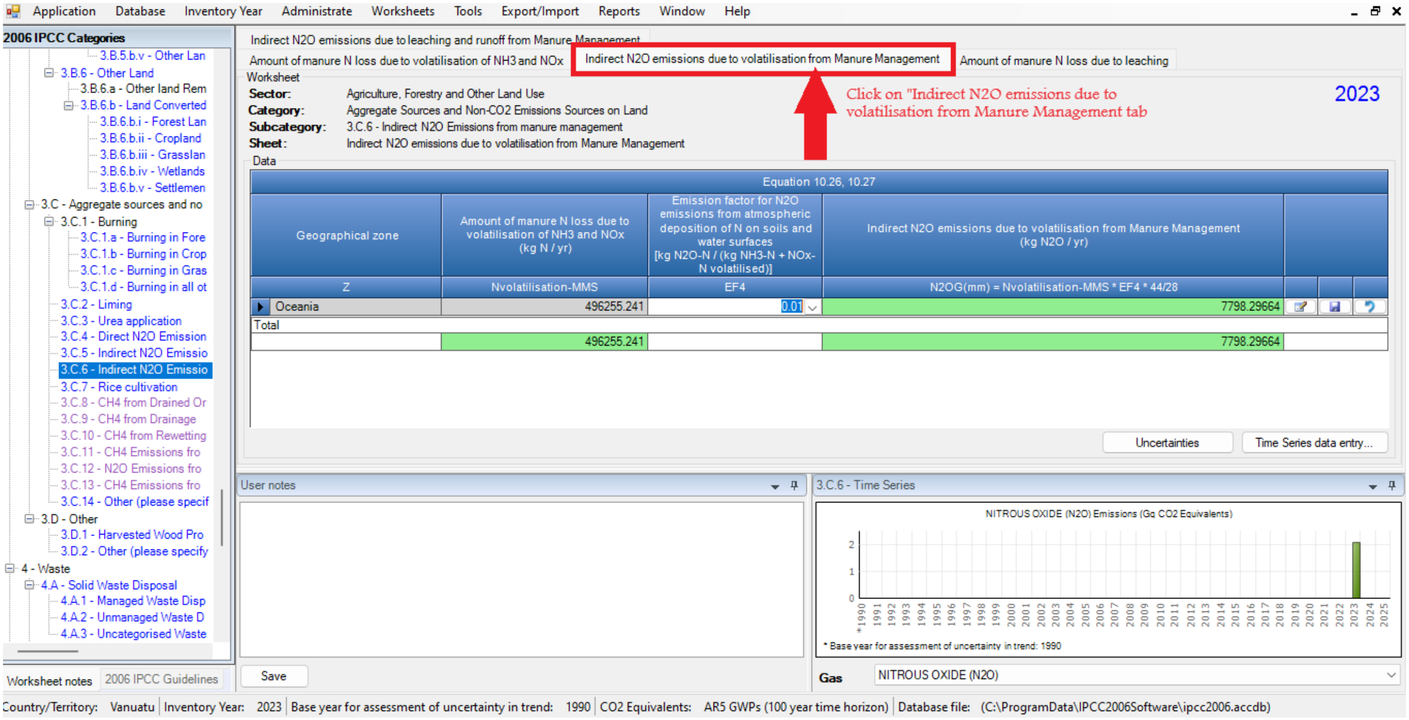
1.5 Click on the subcategory "3.C.6-Indirect N_2O Emissions from Manure Management" (See illustration below)



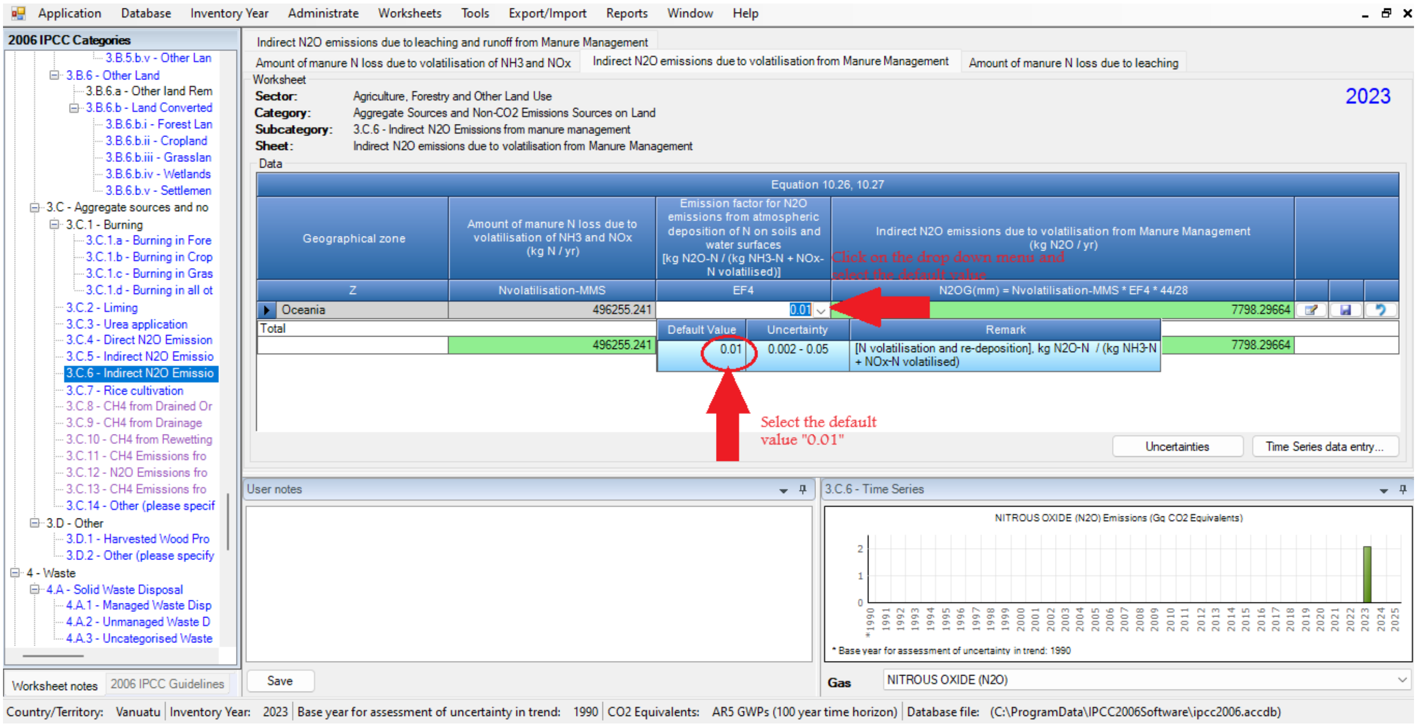
1.6 Under the tab "Fraction of managed livestock manure N that Volatilises (%) table 10.22, click on the drop-down menu and select the default values (Annex table 10.22 for all the different livestock categories) (See illustration below)



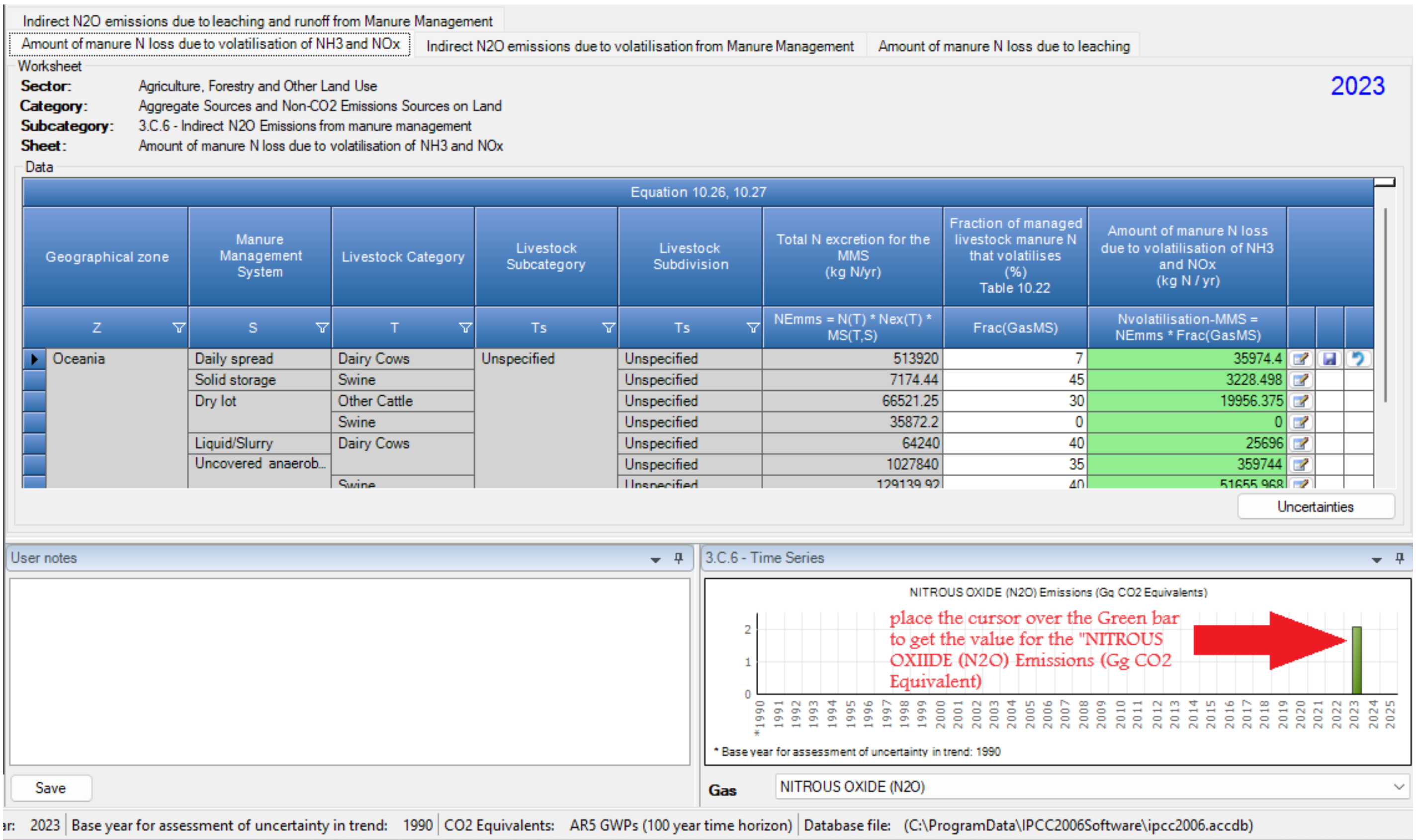
1.7 click the "Indirect N_2O emissions due to volatilization from Manure Management" tab located at the top of the page.



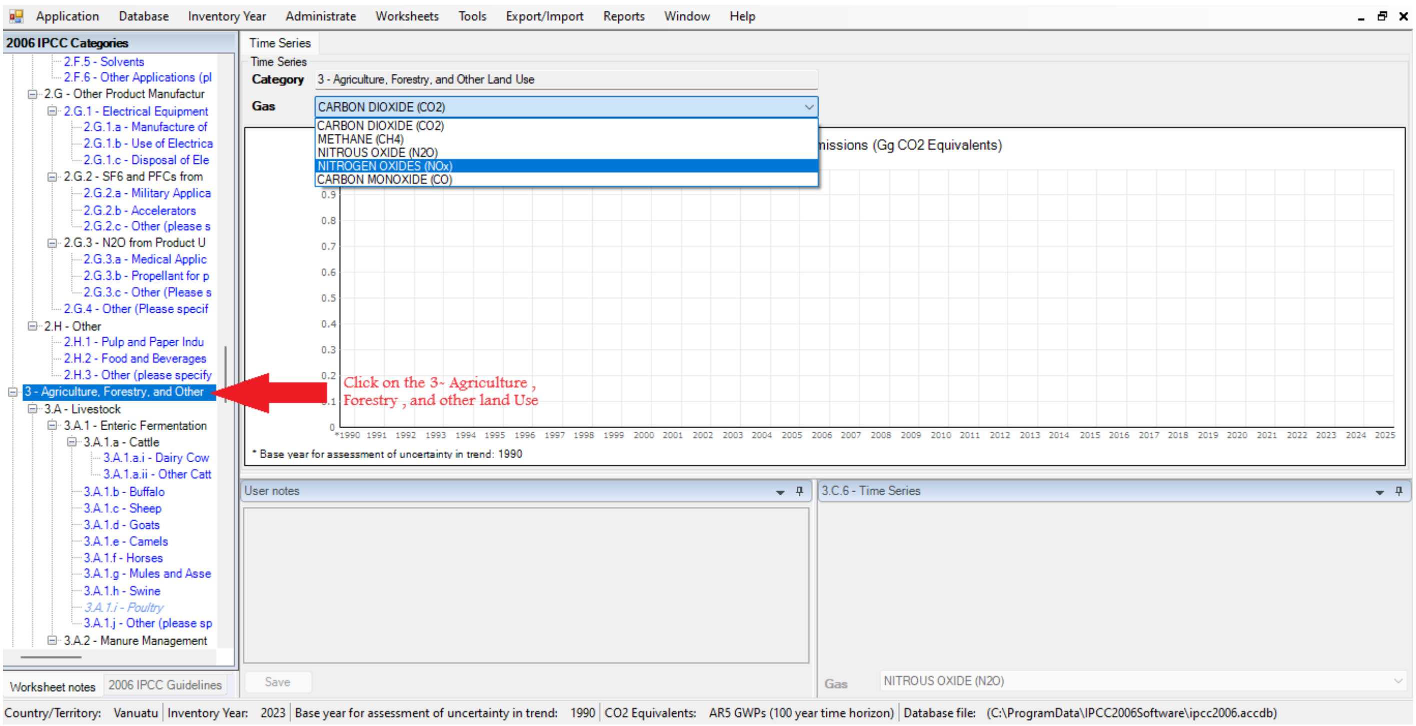
1.8 Under the "Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces [kg N_2O-N / kg NH_3-N + NO_x – N volatilised)] tab, click on the drop-down tab, and select the default value (See Example in the figure below). Cross check the Default value using Table 11.3 in the Annex.



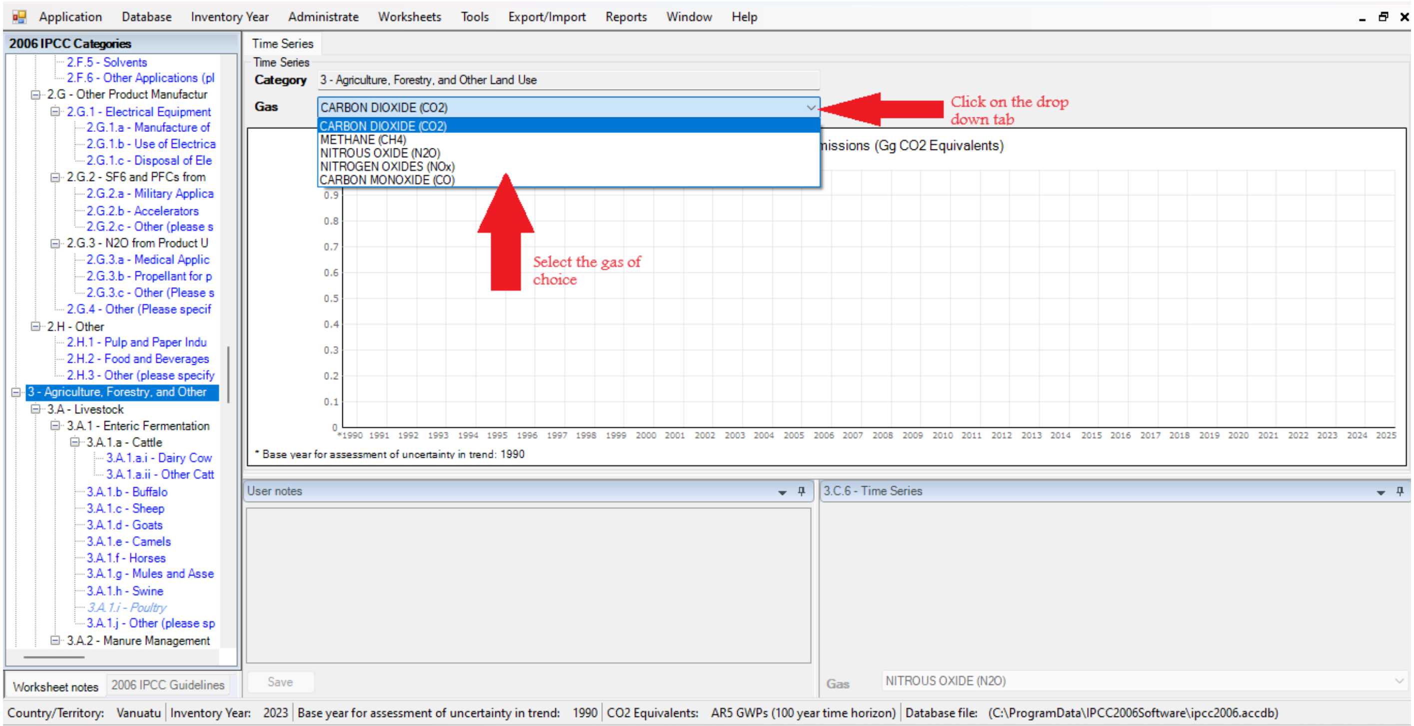
1.9 To find the Gg CO_2 Equivalent produced from the 3.C.6 – Indirect N_2O Emissions from Manure Management place the cursor over the green bar in the graph to generate the value.



2.0 Click on the 3-Agriculture , Forestry, and Other land use from the “2006 IPCC categories” tab (See illustration below)

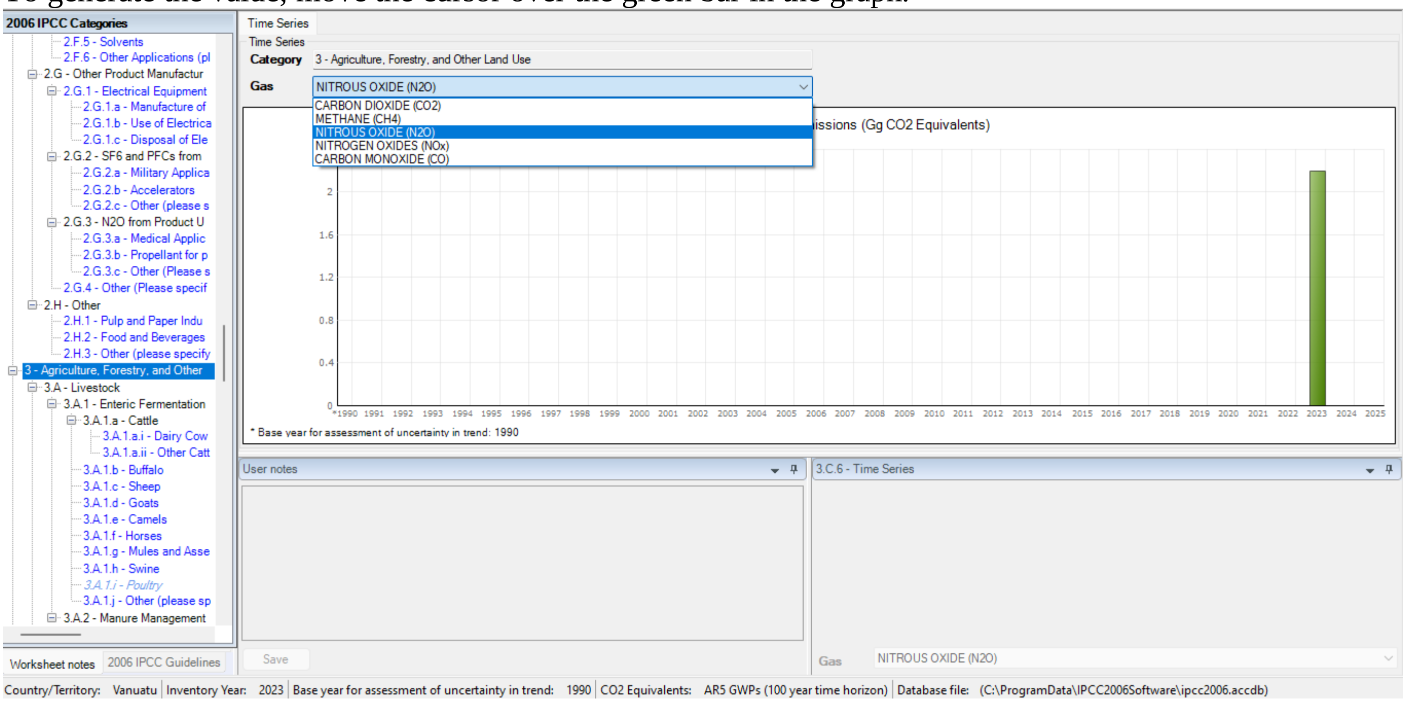


2.1 Click on the drop down bar from the "Gas" tab and select the gas of choice.



2.2 Choose between CH_4 and N_2O from the drop-down option. The resulting graph will show the total amount of CH_4 or N_2O (Gg CO_2 Equivalent) released by Vanuatu's enteric and manure management systems.

To generate the value, move the cursor over the green bar in the graph.



TIME SERIES

Table 2: The N2O emissions (Gg) and emission factors for each of the manure management systems utilized by the livestock in Vanuatu are displayed.

ITEM	UNITS	MANURE MANAGEMENT SYSTEM	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
EF	(Kg N2O-N /(Kg N in MMS)	Uncovered Anaerobic Lagoon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Liquid Slurry	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
		Solid Storage	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
		Dry Lot	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		Pasture / Range / Paddock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Daily Spread	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N2O TOTAL EMISSIONS	NA	NA	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	0.173	0.175	0.121	0.167	0.172	0.174	0	0.177	0.179	NU	NU	NU	NU	NU	NU	NU	NU
METHOD	NA	NA	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1

Where:

NA: Not Applicable

NU: Needs updating

Vanuatu's base year is 1994, even though agricultural practices started far earlier. The most recent national inventory states that only emissions from 2007 to 2015 were computed using the Tier 1 IPCC methodology, default IPCC assumptions, and EF.
The Emissions values require updating.

Table 3: The total CH4 emissions (Gg) and the emission factors for each livestock type under the Vanuatu manure management subsector are displayed.

ITEM	UNITS	LIVESTOCK TYPE	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
EF	[Kg CH4 / (head year)]	Diary	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
		Other Cattle	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
		Horse	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
		Market	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
		Goat	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
		Duck/Poultry	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		sheep	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
CH4 TOTAL EMISSIONS	Gg	NA	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	2.513	2.828	2.516	2.576	2.604	2.631	2.637	2.647	NU	NU	NU	NU	NU	NU	NU	NU
METHOD	NA	NA	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1

Where:

NA: not applicable

NU: Needs updating

Vanuatu's base year is 1994, even though agricultural practices started far earlier. The most recent national inventory states that only emissions from 2007 to 2015 were computed using the Tier 1 IPCC methodology, default IPCC assumptions, and EF. The Emissions values require updating.

Table 4: shows the total CO2 emissions from the 3.A.2 – Manure management.

ITEM	UNIT	Gas	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
EF	CO2 - e	CH4 N2O	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	114.37	116.85	111.27	114.75	117.76	119.09	73.68	120.79	121.47	NU	NU	NU	NU	NU	NU	NU	NU

3.3.3 QUALITY CONTROL / QUALITY CHECK

Completeness, Time series, Quality Assurance/Quality Control and Reporting

Care must be taken to use consistent estimates for the CH4 conversion factors over time. In some cases, there may be reasons to modify methane conversion factors over time. These changes may be due to the implementation of explicit greenhouse gas (GHG) mitigation measures or may be due to changing agricultural practices such as feed conditions or other management factors without regard to GHGs. Regardless of the driver of change, the data and methane conversion factors used to estimate emissions must reflect the change in farm practices. Suppose methane conversion factors over a time series are affected by a change in management practice and/or the implementation of GHG mitigation measures. In that case, the inventory compiler should ensure that the inventory data reflects these practices. The inventory text should thoroughly explain how the changes in management practice and/or implementation of mitigation measures have affected the time series of methane conversion factors [3].

It is good practice to implement quality control checks as outlined in Volume 1, Chapter 6 (Quality Assurance/Quality Control and Verification). In addition to the guidance in Volume 1, specific procedures of relevance to this source category are outlined below:

ACTIVITY DATA CHECK

Inventory Compilers are Expected to:

1. Review the Data collection method and ensure they are aggregated correctly.
2. Cross-check data with previous years to ensure that they are reasonable and consistent with the expected trend.
3. Document the data collection method
4. Identify Potential areas of bias
5. Evaluate the representativeness of the data

REVIEW OF EMISSION FACTORS

• If using Tier 1, the inventory compiler should cross-check default against the IPCC defaults.

EXTERNAL REVIEW

It is important to maintain internal documentation on review results.

To improve transparency, emission estimates from this source category (should be reported along with the activity data and emission factors used to determine the estimates).

The following information should be documented:

1. All activity data including animal population data by category and region.
2. Activity data documentation including:
- The sources of all activity data used in the calculations (i.e., complete citation for the statistical database from which data were collected);

[3] 2006 IPCC Guidelines, Vol.4, Ch. 10.

- The information and assumptions that were used to develop the activity data, in cases where activity data were not directly available from databases; and
- The frequency of data collection, and estimates of accuracy and precision.
- If the Tier 1 method is used, all default emission factors are used to estimate emissions for the specific animal categories.

Table 5: The QC activities and procedures that will be followed are indicated in the table below. The Three consultants will handle the QC and Procedures based on the color in the table, Kay – pink, Florencza Abel – Green, and Zacky Bani – Blue.

QUALITY CONTROL CHECK	PROCEDURES	TIME TAKEN TO COMPLETE PROCEDURE (DAYS)	COMMENTS
Check the Assumptions and criteria for the selection of activity data, emissions factor, and other estimation parameters	• Confirm that estimates are reported for all categories and all years from the appropriate base year to the period of the current inventory.		
	• For subcategories, confirm that the entire category is being covered.		
	• Provide a clear definition of 'Other' type categories.		
	• Check that known data gaps that result in incomplete estimates are documented, including a qualitative evaluation of the importance of the estimate concerning total emissions (e.g., subcategories classified as 'not estimated', see Chapter 8, Reporting Guidance and Tables).		
Check for transcriptions Errors in the data input and references	• Confirm that bibliographical data references are properly cited in the internal documentation.		
	• Cross-check a sample of input data from each category (either measurements or parameters used in calculations) for transcription errors.		
Check that emissions and removals are calculated correctly	• Reproduce a set of emissions and removal calculations.		
	• Use a simple approximation method that gives similar results to the original and more complex calculation to ensure that there is no data input error or calculation error.		

Check that parameters and units are correctly recorded and that appropriate conversion factors are used.	• Check that units are properly labeled in calculation sheets.		
	• Check that units are correctly carried through from beginning to end of calculations.		
	• Check that conversion factors are correct.		
	• Check that temporal and spatial adjustment factors are used correctly.		
Check the integrity of database files	• Examine the included intrinsic documentation (see also Box 6.4) to:		
	1. Confirm that the appropriate data processing steps are correctly represented in the database.		
	2. Confirm that data relationships are correctly represented in the database.		
	3. Ensure that data fields are properly labeled and have the correct design specifications.		
	4. Ensure that adequate documentation of database and model structure and operation are archived.		
Check for consistency in data between categories.	Identify parameters (e.g., activity data, constants) that are common to multiple categories and confirm that there is consistency in the values used for these parameters in the emission/removal calculations.		
Check that the movement of inventory data among processing steps is correct.	• Check that emissions and removal data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries.		
	• Check that emissions and removal data are correctly transcribed between different intermediate products.		

Check that uncertainties in emissions and removals are estimated and calculated correctly.	• Check that the qualifications of individuals providing expert judgment for uncertainty estimates are appropriate.		
	• Check that qualifications, assumptions, and expert judgments are recorded.		
	• Check that calculated uncertainties are complete and calculated correctly.		
	• If necessary, duplicate uncertainty calculations on a small sample of the probability distributions used by Monte Carlo analyses (for example, using uncertainty calculations according to Approach 1).		
Check time series consistency.	• Check for temporal consistency in time series input data for each category.		
	• Check for consistency in the algorithm/method used for calculations throughout the time series.		
	• Check methodological and data changes resulting in recalculations.		
	• Check that the effects of mitigation activities have been appropriately reflected in time series calculations.		
Check Completeness	• Confirm that estimates are reported for all categories and all years from the appropriate base year to the period of the current inventory.		
	For subcategories, confirm that the entire category is being covered.		
	• Provide a clear definition of 'Other' type categories.		

	• Check that known data gaps that result in incomplete estimates are documented, including a qualitative evaluation of the importance of the estimate concerning total emissions (e.g., subcategories classified as 'not estimated', see Chapter 8, Reporting Guidance and Tables)		

Trend Check	• Confirm that estimates are reported for all categories and all years from the appropriate base year to the period of the current inventory.		
	• Check the value of implied emission factors (aggregate emissions divided by activity data) across time series.		
	1. Do any years show outliers that are not explained?		
	2. If they remain static across time series, are changes in emissions or removals being captured?		
	• Check if there are any unusual and unexplained trends noticed for activity data or other parameters across the time series.		
Review of internal documentation and archiving.	• Check that there is detailed internal documentation to support the estimates and enable the reproduction of the emission, removal, and uncertainty estimates.		
	• Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review.		
	• Check that the archive is closed and retained in a secure place following completion of the inventory.		
	• Check the integrity of any data archiving arrangements of outside organizations involved in inventory preparation		

(TABLE 6.1 GENERAL INVENTORY QC PROCEDURES, volume 1, 2006 IPCC Guidelines for National Greenhouse Gas Inventories).

Table 6:below shows the Responsibilities carried out by which particular party and the timeline stating how long it would take for the party to complete the task.

QUALITY CONTROL METHOD	RESPONSIBILITIES	TIMELINE (Time for Completion
GHG INVENTORY TEAM MEMBERS (Consultant)	1. Implement QA/QC at all levels of transparency	2 Months
	2. Collect data, Inventory Preparation and Reporting	
	3. Conduct Checks on the consistency of data and information provided by the different stakeholders to ensure data integrity, correctness, and completeness	
TWGS (Technical Working Groups) Specific group consisting of Experts and Professionals	1. Technical Review of sub-category activity data, Emission Factor, Estimation Parameters, and Calculation method	2 - 3 Weeks
	2. Final Check of the Report	
National Livestock Statistics	Provide activity data	2 Weeks upon request
Agriculture Department	Provide Activity data	2 Weeks upon request

The Director General of the Ministry of Climate Change used office notifications to notify relevant ministries and departments, specified organizations, the public-private sector, and other institutions to collect data for the last inventory period. The Department of Climate Change is responsible for maintaining the gathered data, database repository, and archives [1].

Tier 1 method was used in the last National Inventory report. Since Vanuatu has no country-specific values, default values, and default activity data and parameters were used instead hence the Tier 1 method approach was adopted.

Following The (2006 IPCC Guidelines, Vol. 4, Ch. 10, Pg. 25, FIGURES 10.2, 10.3, 10.4) the Tier 1 Method will be used for this inventory. Estimated Emissions will be calculated using historical data and present up-to-date data.

To collect information, the Project Coordinator and the Consultants will notify Offices relevant to ministries and stakeholders such as the:

The channels for requesting activity data meetings are the Electronic Single Window, emails, dialogues, and interviews. Consultants may ask the Prime Minister's Office for a Confidential Agreement or Right to Information (RTI) in specific situations where data is unavailable.

To collect information, the Project Coordinator and the Consultants will notify Offices relevant to ministries and stakeholders such as the:

1. National Livestock Statistics
2. Department of Agriculture

Table 7 below shows the times series of total Emissions (CO_2 Equivalent) calculated from the 4 types of livestock present in Vanuatu starting from the base year (1994) to 2023[4]

ITEMS	LIVESTOCK	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
EF ([Kg CH4/ (head year)]	Diary	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Cattle	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
	Horse	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Swine	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Goat	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Total Emission (CO2-e)	Diary , Cattle , Horse, Swine	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	298.25	301.49	187.085	285.824	294.56	298.088	299.897	303.548	306.619	NU	NU	NU	NU	NU	NU	NU	NU
METHOD	Diary , Cattle , Horse, Swine	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1	TIER 1

Where :

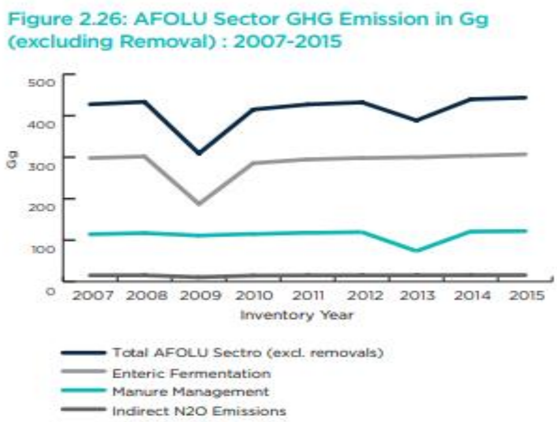
NU: Needs Updating

Agricultural practices in Vanuatu have continued well beyond the 1994 baseline year. Using the default IPCC parameters and EF, the Tier 1 Method Approach was used to calculate emissions from 1994 to 2023. The years from 1994 to 2006 and from 2026 to 2023 have no information included, but the years from 2007 to 2015 emissions (CO2-e) have been included in the table. This is because the values in the emissions need to be updated.

[4] *The Republic of Vanuatu Third National Communication to the The United Nations Framework Convention on Climate Change | Vanuatu Environment Data Portal*. (2020, December). Vanuatu-Data.sprep.org. https://vanuatu-data.sprep.org/dataset/republic-vanuatu-third-national-communication-united-nations-framework-convention-climate

Identifying Trends, Big Variations, And Outliers with A Transparent Explanation

Figure 6 displays the findings of the AFOLU Sector Emissions in Gg from 2007 to 2015, as reported in The Republic of Vanuatu's Third National Communication to the United Nations Framework Convention on Climate Change | Vanuatu Environment Data Portal, 2020.



Methane and nitrous oxide are the main emissions coming from the agriculture sector. Indirect GHG emissions, on the other hand, like CO and NOx, are not calculated and are thought to be insignificant [1].

The majority of greenhouse gas emissions from the AFOLU industry are attributed to livestock farming, specifically enteric fermentation (69%) and manure management (27%). The remaining 4% are attributed to indirect nitrogen dioxide emissions from land management and manure. This is because Vanuatu engages in extensive livestock husbandry as well as animal gazing. [1]

The graph shows that there is an outlier in 2009 and that the amount of CH_4 emissions has decreased statistically. Other anomalies that might exist include the COVID-19 lockdown in 2020 and the government system hack in 2022 that resulted in the deletion of all data that had been stored on the system.

3.3.4 UNCERTAINTIES

Emissions Factors

Since the emission factors used in the Tier 1 technique are not derived from country-specific data, it is possible that they may not be an accurate representation of the characteristics of that country's livestock and will instead be highly uncertain. It is not likely that emission factors predicted with the Tier 1 approach will be known with greater accuracy than +30%, and they may be uncertain up to +50% (2006 IPCC guidelines) [1].

Table 8: showing the Tier 1 enteric fermentation emission factors for cattle1.

REGION	Cattle Category	EF (Kg CH4 Head-1 Year-1	Comments
Oceania	Diary	100	Average mild produced of 2,200 kg head-1 yr-1
	Other Cattle	60	Includes Beef, Cows, Bulls and young

(See Annex Table 1)

Table 9:Depicts the different livestock types, their live weight, and the Enteric Fermentation Emission Factors for Tier 1 Method1 (KG CH4 HEAD-1 YR-1) Developing countries (2006 IPCC Software, Vol. 4, Ch. 10, pg. 28) .

LIVESTOCK	DEVELOPING COUNTRIES	LIVEWEIGHT
Sheep	5	45kg
Goats	5	40kg
Horses	18	550kg
Swine	1	
Poultry	Insufficient data for calculations	

(See Annex Table 2)

Table 10: Shows the data for estimation TIER 1 Enteric Fermentation CH4 Emission CH4 Emission Factors for Dairy Cows, their weight, Vanuatu will be using the "Oceania" Region. (See 2006 IPCC guidelines, Vol. 4, Ch. 10, Pg. 72, TABLE 10A.1).

REGIONS	LIVESTOCK TYPE	WEIGHT, Kg	EMISSION FACTOR
OCEANIA	Dairy Cow	500	100
	Other Cattle		60
	1. Mature Females	400	71
	2. Mature Males	450	61
	3. Young	200	46

(See Annex table 3 and 4)

Activity Data

The following are the list of some of the uncertainties that may be present in the activity data.

- Livestock Characterization – Animal types
- Population data
- For cattle, where possible:
  - Average Milk Production
  - Typical Animal Mass (TAM- liveweight, kg)
- For other animal types: (TAM- Liveweight, kg)
- Region (Oceania)- to select appropriate default emission factors from tables 10.10 and 10.11. (*See 2006 IPCC Guideline, Volume 4, Chapter 10 EMISSIONS FROM LIVESTOCK AND MANURE MANAGEMENT, Section 10.3.2 Choice of emission factors*)
- Data Sources and time of sourcing
- Frequency of data recording; are the data provisional or actual?

METHANE EMISSIONS FROM MANURE MANAGEMENT

Emission Factors

The default emission factors for Tier 1 contains high uncertainties. The default factors are expected to have an uncertainty range of +30% [1].

Because the default values might not accurately represent a distinctive manure management system in a specific country, this could lead to a great deal of uncertainty [1].

Table 11:Shows the CH4 Emissions factors for each of the Livestock under the Manure management category (See 2006 IPCC Guideline, table 10.14 and table 10.15).

ITEM	UNITS	LIVESTOCK TYPE	EF VALUE
EF	[Kg CH_4 / (head year)]	Diary	30
		Other Cattle	2
		Horse	1.64
		Market Swine	13
		Goat	0.17
		Duck/Poultry	0.02
		sheep	0.15

(See Annex table 10.14 and table 10.15)

Activity Data

The following are some of the list of activity data that may lead to high uncertainties

- Tier 1 Activity Data (AD) requirement to estimate Methane (CH_4) in Manure Management
- To calculate CH_4 emissions using Tier 1 in Manure management, the following AD are mandatory:
- - Livestock population data according to basic characterization. (Same data for enteric fermentation can be used).
- Average annual temperature for the country or region to select the EFs (for Vanuatu it's ~25oC), the geographical zone (for Vanuatu = tropical moist).

N_2O EMISSIONS FROM MANURE MANAGEMENT

Emission Factors

EMISSION FACTORS – DIRECT N2O EMISSIONS There are large uncertainties associated with the default emission factors for this source category (–50% to +100%). Accurate and well-designed emission measurements from well-characterized types of manure and manure management systems can help reduce these uncertainties. These measurements must account for temperature, moisture conditions, aeration, manure N content, metabolizable carbon, storage duration, and other treatment aspects[1].

Table 12: Shows the manure management systems and their N2O Emission factors.

ITEM	UNITS	MANURE MANAGEMENT SYSTEM	EF VALUE
EF	(Kg N2O-N /(Kg N in MMS)	Uncovered Anaerobic Lagoon	0
		Liquid Slurry	0.005
		Solid Storage	0.005
		Dry Lot	0.02
		Pasture / Range / Paddock	0
		Daily Spread	0

Activity Data – Manure Management System Usage

The features of each country's livestock industry and the methods used to gather data on manure management will determine how unreliable the manure management system's information on utilization is (2006, IPCC Guidelines)[5].

For instance, in countries that solely rely on pasture and range management systems, the uncertainty associated with their application may be less than 10% [1].

However, the uncertainty range in management system usage data can be much higher, ranging from 25% to 50%, when a wide variety of management systems are used with locally distinct operating practices. This is dependent on the availability of reliable and representative survey data that separates animal populations in accordance with system usage. (Cite using IPCC guideline) [1].

The following is the list of activity data that may lead to high uncertainties.

To calculate direct N2O emission using Tier 1 in Manure Management, the following AD are

- 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 (TAM).

INDIRECT N_2O EMISSIONS

Uncertainty ranges for default N losses due to volatilization of NH3 and NOx and total N losses from manure management systems are presented in the Tables 10.22 and 10.23, respectively [1].

The uncertainty associated with default emission factor for nitrogen volatilization and re-deposition (EF4) is 0.01 [1]. The value is given in Table 11.3 of Chapter 11 (See annex table 11.3)

3.4 IMPROVEMENT PLAN

3.4.1 Vanuatu's Current Inventory Process

The agriculture sector is the major contributor of methane emissions in Vanuatu and is also the top contributor of GHG emissions in Vanuatu. However, the forestry sector is the net carbon sink and makes the Vanuatu net carbon emissions negative.

Emissions in this sector are estimated for following categories:

• Livestock Farming

• Enteric Fermentation

• Manure Management

• N2O Emissions from managed soils

• Forestry Sector (net removal)

Emissions due to rice cultivation and burning of Savannas do not occur in Vanuatu while emissions from field burning of agricultural residues have not been estimated due to lack of data. Data used for estimating GHG emissions from agriculture sector were from national livestock statistics and Department of Agriculture. These were also crosschecked and confirmed with FAO data.

Since use of fertilizers in Vanuatu is very limited and records are not available for GHG Inventory years 2007-2015, emissions from use of fertilizer are not estimated under the agriculture sector. The emissions from agriculture sector in Vanuatu is the largest contributor and account for average about 74% of Vanuatu's total GHG emissions for the year 2007 2015. It can be observed from Table below, that GHG emissions from agriculture sector have increased since 2007. This increase is primarily due to increase in livestock farming and N2O emissions from managed soils were not estimated under the Initial National Communication.[6]

	2007	2008	2009	2010	2011	2012	2013	2014	2015
3 - Agriculture, Forestry, and Other Land Use (AFOLU)									
3.A - Livestock	412.6	418.3	298.4	400.6	412.3	417.2	373.6	424.3	428.1
3.A.1 - Enteric Fermen-tation	298.3	301.5	187.1	285.8	294.6	298.1	299.9	303.5	306.6
3.A.2 - Manure Man-agement	114.4	116.8	111.3	114.8	117.8	119.1	73.7	120.8	121.5
3.B - Land	-7021.2	-7021.2	-7021.2	-6973.7	-6973.7	-6973.7	-6973.7	-6973.7	-6973.7
3.B.1 - Forest land	-7021.2	-7021.2	-7021.2	-6973.7	-6973.7	-6973.7	-6973.7	-6973.7	-6973.7
3.C - Aggregate sources and non-CO2 emissions sources on land	14.8	15.0	10.9	14.3	14.8	14.9	15.0	15.2	15.3
3.C.6 - Indirect N2O Emis-sions from ma-nure management	14.8	15.0	10.9	14.3	14.8	14.9	15.0	15.2	15.3
AFOLU Sector Total (Excl. Re-movals)	427.4	433.3	309.2	414.9	427.1	432.1	388.6	439.5	443.4
AFOLU Sector (Incl. Removals)	-6593.7	-6587.8	-6711.9	-6558.8	-6546.6	-6541.6	-6585.1	-6534.2	-6530.3

Source: Vanuatu's Third National Inventory (2020).

The livestock sector is a major contributor to food security and an is essential component of livelihood for a vast majority of the people of the Republic of Vanuatu. The sector plays an important role in local cultures

[6] https://unfccc.int/sites/default/files/resource/Vanuatu%20Third%20National%20Communication%20Report.pdf

and the economic development of Vanuatu. Vanuatu has large livestock population; however, yet to realize its full potential in the livestock sector. The data and information on the total livestock population and livestock farming practices are very limited in Vanuatu.

The major information available on the livestock and beef export. The data used for the inventory year 2007-2015 is based on the national agriculture census-2007, Census of Population and Housing 2009, and FAO published data. The following table present the data used for estimation of GHG emissions from the livestock sector.

Livestock Population	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cattle	1,74,152	1,75,000	1,05,051	1,65,000	1,70,000	1,72,000	1,73,000	1,75,000	1,76,674
Goats	8,792	19,500	34,086	22,000	24,000	25,000	25,000	26,000	26,803
Horses	4,000	4,500	5,559	6,000	6,000	6,000	6,200	6,500	6,778
Swine	86,698	89,000	1,08,056	90,000	92,000	93,000	94,000	94,000	94,216
Poultry	3,68,251	8,04,000	4,68,779	6,00,000	7,00,000	7,00,000	7,50,000	8,00,000	8,19,000
Total	**6,41,893**	**10,92,000**	**7,21,531**	**8,83,000**	**9,92,000**	**9,96,000**	**10,48,200**	**11,01,500**	**11,23,471**

Source: Vanuatu's Third National Inventory (2020).

3.4.2 Areas Identified for Improvement and Identified Gaps

The livestock emission both enteric fermentation and manure management are key category; hence more frequent and granular data will be obtained from the Animal farming department. In the future inventory the applicability of higher tier method (Tier 2- method) will be adopted for this subcategory if subjective to the data availability.[7]

[7] https://unfccc.int/sites/default/files/resource/Vanuatu%20Third%20National%20Communication%20Report.pdf

3.4.3: Proposed Improvement Actions

These are the outlined improvement actions the consultant needs to take into consideration while conducting the GHG inventory. This table shows detailed information on the data sources, how to access it, who is responsible and the relevant time it needs to collect data sets, thus, will result in accurate GHG inventory.

Department/ Organization	Roles and Responsibility	Dates	Relevant Governing Arrangement	Contact Person	Comments
Department of Livestock (MALFFB)	It is responsible to provide data on livestock populations, management practices, and productivity	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between Department of Livestock and DOCC	Department of Livestock Sergio Email: Tel: Sylvia Email: Tel:	For significant information and data requirements, DOCC needs to send a prompt letter to the Department of livestock two months prior. A follow-up email or call is crucial as well.
Vanuatu Bureau of Statistics (VBoS)	VBoS is responsible for providing data relevant to greenhouse gas emissions estimation	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between VBoS and DOCC	KWARI Linda *Statistician - Agriculture (Economics)* Email: Tel: VBoS contact E-mail: stats@vanuatu.gov.vu Tel: (678) 22110 / 22111 / 33040	For significant information and data collection, DOCC needs to send a prompt letter to VBoS two months prior. A follow-up email or call is crucial as well.
Vanuatu Abattoir	To provide data on livestock slaughter numbers and carcass weights. This information can be useful for estimating livestock	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between Abattoir and DOCC	Vanuatu Abattoir Tel: 7722961	For significant information and data collection, DOCC needs to send a prompt letter to Abattoir two months prior.

	populations and meat production, which are relevant factors in emissions calculations.				A follow-up email or call is crucial as well.
Farm	To provide ground data related to livestock management practices and manure management. And to provide information on their livestock populations, feeding practices, and waste management methods.	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between the Farmers and DOCC		For significant information and data collection, DOCC needs to send a prompt letter to the farms two months prior. A follow-up email or call is crucial as well.
Department of Climate Change (DOCC)	DOCC is responsible to send a formal letter requesting relevant data and information on manure management and enteric fermentation to Department of livestock, VBoS, Vanuatu Abattoir and farms.	February – March every year	Provide a Memorandum of understanding or Right to Information (RTI) to the Department of livestock, VBoS, Vanuatu Abattoir and farms.	Name: Nelson Kalo Director of Climate Change Email: nekalo@vanuatu.gov.vu	DOCC is responsible for doing a follow-up to the departments or organization for the required data to be delivered upon schedule.

REFERENCE

Goodwin, J., Woodfield, M., Ibnoaf, M., Koch, M., & Yan, H. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 2: Approaches to Data Collection.* Institute for Global Environmental Strategies (IGES).

Dong, H., Joe, M., & McAllister, T. (2006). CHAPTER 4: EMISSIONS FROM LIVESTOCK AND MANURE MANAGEMENT. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, *4*.

ANNEX

ENTERIC FERMENTATION ANNEX

Table 1 below shows the Enteric fermentation emissions factors for the different cattle category and their regional characteristics together with Comments including the milk production and beef cows, bulls, calves, growing steers/heifers, and feedlot cattle. (2006 IPCC Guidelines, Vol. 4, Ch. 10, Pg. 29, TABLE 10.11)

TABLE 10.11
TIER 1 ENTERIC FERMENTATION EMISSION FACTORS FOR CATTLE[1]

Regional characteristics	Cattle category	Emission factor [2,3] (kg CH_4 $head^{-1}$ yr^{-1})	Comments
North America: Highly productive commercialized dairy sector feeding high-quality forage and grain. Separate beef cow herd, primarily grazing with feed supplements seasonally. Fast-growing beef steers/heifers finished in feedlots on grain. Dairy cows are a small part of the population.	Dairy	128	Average milk production of 8,400 kg $head^{-1}$ yr^{-1}.
	Other Cattle	53	Includes beef cows, bulls, calves, growing steers/heifers, and feedlot cattle.
Western Europe: Highly productive commercialized dairy sector feeding high-quality forage and grain. Dairy cows are also used for beef calf production. Very small dedicated beef cow herd. A minor amount of feedlot feeding with grains.	Dairy	117	Average milk production of 6,000 kg $head^{-1}$ yr^{-1}.
	Other Cattle	57	Includes bulls, calves, and growing steers/heifers.
Eastern Europe: Commercialized dairy sector feeding mostly forages. Separate beef cow herd, primarily grazing. A minor amount of feedlot feeding with grains.	Dairy	99	Average milk production of 2,550 kg $head^{-1}$ yr^{-1}.
	Other Cattle	58	Includes beef cows, bulls, and young.
Oceania: Commercialized dairy sector based on grazing. Separate beef cow herd, primarily grazing rangelands of widely varying quality. A growing amount of feedlot feeding with grains. Dairy cows are a small part of the population.	Dairy	100	Average milk production of 2,200 kg $head^{-1}$ yr^{-1}.
	Other Cattle	60	Includes beef cows, bulls, and young.
Latin America: Commercialized dairy sector based on grazing. Separate beef cow herd grazing pastures and rangelands. A minor amount of feedlot feeding with grains. Growing non-dairy cattle comprise a large portion of the population.	Dairy	72	Average milk production of 800 kg $head^{-1}$ yr^{-1}
	Other Cattle	56	Includes beef cows, bulls, and young.
Asia: Small commercialized dairy sector. Most cattle are multi-purpose, providing draft power and some milk within farming regions. Small grazing population. Cattle of all types are smaller than those found in most other regions.	Dairy	68	Average milk production of 1,650 kg $head^{-1}$ yr^{-1}
	Other Cattle	47	Includes multi-purpose cows, bulls, and young

Africa and Middle East: Commercialized dairy sector based on grazing with low production per cow. Most cattle are multi-purpose, providing draft power and some milk within farming regions. Some cattle graze over very large areas. Cattle are smaller than those found in most other regions.	Dairy Other Cattle	46 31	Average milk production of 475 kg $head^{-1}$ yr^{-1} Includes multi-purpose cows, bulls, and young
Indian Subcontinent: Commercialized dairy sector based on crop by-product feeding with low production per cow. Most bullocks provide draft power and cows provide some milk in farming regions. Small grazing population. Cattle in this region are the smallest compared to cattle found in all other regions.	Dairy Other Cattle	58 27	Average milk production of 900 kg $head^{-1}$ yr^{-1} Includes cows, bulls, and young. Young comprise a large portion of the population

1 Emission factors should be derived based on the characteristics of the cattle and feed of interest and need not be restricted solely to regional characteristics.

2 IPCC Expert Group, values represent averages within region, where applicable the use of more specific regional milk production data is encouraged. Existing values were derived using the Tier 2 method and the data in Tables 10 A.1 and 10A. 2. 3

The following assumptions have been made in deriving these values: i) mature weights of animals have been used; ii) cows have been assumed to be non-lactating as lactation levels were low and, iii) the mix of bulls and castrates among "males" was undetermined as Cfi value for castrates was not specified.

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Table 2: Depicts the different livestock types, their live weight, and the Enteric Fermentation Emission Factors for Tier 1 Method[1] (KG CH_4 $HEAD^{-1}$ YR^{-1}) for Developed countries and Developing countries (2006 IPCC Software, Vol. 4, Ch. 10, pg. 28)

TABLE 10.10
ENTERIC FERMENTATION EMISSION FACTORS FOR TIER 1 METHOD[1]
(KG CH_4 $HEAD^{-1}$ YR^{-1})

Livestock	**Developed countries**	**Developing countries**	**Liveweight**
Buffalo	55	55	300 kg
Sheep	8	5	65 kg - developed countries; 45 kg - developing countries
Goats	5	5	40 kg
Camels	46	46	570 kg
Horses	18	18	550 kg
Mules and Asses	10	10	245 kg
Deer	20	20	120 kg

Alpacas	8	8	65 kg
Swine	1.5	1.0	
Poultry	Insufficient data for calculation	Insufficient data for calculation	
Other (e.g., Llamas)	To be determined[1]	To be determined[1]	

All estimates have an uncertainty of ±30-50%.

Sources: Emission factors for buffalo and camels from Gibbs and Johnson (1993). Emission factors for other livestock from Crutzen *et al*., (1986), Alpacas from Pinares-Patino *et al.*, 2003; Deer from Clark *et al.*, 2003. 1

One approach for developing the approximate emission factors is to use the Tier 1 emissions factor for an animal with a similar digestive system and to scale the emissions factor using the ratio of the weights of the animals raised to 0.75 power. Liveweight values have been included for this purpose. Emission factors should be derived based on the characteristics of the livestock and feed of interest and should not be restricted solely to regional characteristics.

TABLE 3: Shows the data for estimation TIER 1 Enteric Fermentation CH_4 Emission CH_4 Emission Factors for Dairy Cows, their weight, weight gain (kg/day), Feeding situation, Milk kg/day, work Hr/day, %pregnant, Digestibility of Feed (DE%), CH_4 conversion factor (Y_m). Vanuatu will be using the "Oceania" Region. (See 2006 IPCC guidelines, Vol. 4, Ch. 10, Pg. 72, TABLE 10A.1)

TABLE 10A.1
DATA FOR ESTIMATING TIER 1 ENTERIC FERMENTATION CH4 EMISSION FACTORS FOR DAIRY COWS IN TABLE 10.11

Regions	Weight, kg	Weight gain, kg day^{-1}	Feeding Situation	Milk, kg day^{-1}	Work, hr day^{-1}	%Pregnant	Digestibility of feed (DE%)	CH_4 conversion factor (Y_m)
North America	600	0	Stall-fed	23.0	0	90%	75%	6.5%
Western Europe	600	0	Stall-fed	16.4	0	90%	70%	6.5%
Eastern Europe[b]	550	0	Stall fed	7.0	0	80%	60%	6.5%
Oceania[c]	500	0	Pasture/Range	6.0	0	80%	60%	6.5%
Latin America[d]	400	0	Pasture/Range	2.2	0	80%	60%	6.5%
Asia[e]	350	0	Stall fed	4.5	0	80%	60%	6.5%
Africa & Middle East	275	0	Stall fed	1.3	0	67%	60%	6.5%
Indian Subcontinent[f]	275	0	Stall fed	2.5	0	50%	55%	6.5%

a- Based on estimates for the United States.
b- Based on estimates for the former USSR.
c- Based on average estimate for the region.
d- Based on estimates for Brazil.
e- Based on estimates for China.
f- Based on estimates for India.

Source: Gibbs and Johnson (1993).

Table 4: shows the data for estimating tier 1 enteric fermentation CH_4 emission factors for other cattle in Table 10.11. Vanuatu will be using the "Oceanic". (See 2006 IPCC guidelines, Vol. 4, Ch. 10, Pg. 73, TABLE 10A.2)

TABLE 10A.2 DATA FOR ESTIMATING TIER 1 ENTERIC FERMENTATION CH4 EMISSION FACTORS FOR OTHER CATTLE IN TABLE 10.11										
Subcategory	**Weight, kg**	**Weight gain, kg day^{-1}**	**Feeding situation**	**Milk, kg day^{-1}**	**Work, hr day^{-1}**	**%Pregnant**	**Digestibility of feed (DE%)**	**CH_4 conversion factor (Y_m)**	**Day weighted population mix %**	**Emission factors, kg CH4 head-1 yr-1**
North Americaa										
Mature females	500	0.0	Pasture/Range	3.3	0.0	80%	60%	6.5%	36%	76
Mature males	800	0.0	Pasture/Range	0.0	0.0	0%	60%	6.5%	2%	81
Calves on milk	100	0.9	Pasture/Range	0.0	0.0	0%	NA	0.0%	16%	0
Calves on forage	185	0.9	Pasture/Range	0.0	0.0	0%	65%	6.5%	8%	48
Growing heifers/steers	265	0.7	Pasture/Range	0.0	0.0	0%	65%	6.5%	17%	55
Replacement/growing	375	0.4	Pasture/Range	0.0	0.0	0%	60%	6.5%	11%	66
Feedlot cattle	415	1.3	Stall fed	0.0	0.0	0%	75%	3.0%	11%	33
Western Europe										
Mature males	600	0.0	Pasture/Range	0.0	0.0	0%	60%	6.5%	22%	66
Replacement/growing	400	0.4	Pasture/Range	0.0	0.0	0%	60%	6.5%	54%	73
Calves on milk	230	0.3	Pasture/Range	0.0	0.0	0%	65%	0.0%	15%	0
Calves on forage	230	0.3	Pasture/Range	0.0	0.0	0%	65%	6.5%	8%	35
Eastern Europeb										
Mature females	500	0.0	Pasture/Range	3.3	0.0	67%	60%	6.5%	30%	75
Mature males	600	0.0	Pasture/Range	0.0	0.0	0%	60%	6.5%	22%	66
Young	230	0.4	Pasture/Range	0.0	0.0	0%	60%	6.5%	48%	45

Oceanic										
Mature females	400	0.0	Pasture/Range	2.4	0.0	67%	55%	6.5 %	51%	71
Mature males	450	0.0	Pasture/Range	0.0	0.0	0%	55%	6.5%	11%	61
Young	200	0.3	Pasture/Range	0.0	0.0	0%	55%	6.5%	38%	46
[a] Based on estimates for the United States; . [b] Based on estimates for the former USSR; [c] Based on average estimate for the region.										

MANURE MANAGEMENT ANNEX

Table 10.15 shows the manure management methane emission factors by temperature for sheep, goats, camels, horses, mules and asses, and poultry (kg ch4 head-1 yr-1)

TABLE 10.15
MANURE MANAGEMENT METHANE EMISSION FACTORS BY TEMPERATURE FOR SHEEP, GOATS, CAMELS, HORSES, MULES AND ASSES, AND POULTRY[a] (KG CH_4 $HEAD^{-1}$ YR^{-1})

Livestock	CH_4 emission factor by average annual temperature (°C)		
	Cool (<15˚C)	Temperate (15 to 25˚C)	Warm (>25˚C)
Sheep			
Developed countries	0.19	0.28	0.37
Developing countries	0.10	0.15	0.20
Goats			
Developed countries	0.13	0.20	0.26
Developing countries	0.11	0.17	0.22
Camels			
Developed countries	1.58	2.37	3.17
Developing countries	1.28	1.92	2.56
Horses			
Developed countries	1.56	2.34	3.13
Developing countries	1.09	1.64	2.19
Mules and Asses			
Developed countries	0.76	1.10	1.52
Developing countries	0.60	0.90	1.20
Poultry			
Developed countries			
Layers (dry)[b]	0.03	0.03	0.03
Layers (wet)[c]	1.2	1.4	1.4
Broilers	0.02	0.02	0.02
Turkeys	0.09	0.09	0.09
Ducks	0.02	0.03	0.03
Developing countries	0.01	0.02	0.02

The uncertainty in these emission factors is ±30 %. Sources: Emission factors developed from: feed intake values and feed digestibilities used to develop the enteric fermentation emission factors (see Annex 10A.1); Except for poultry in developed countries, methane conversion factor (MCF), and maximum methane producing capacity (B_o) values reported in Woodbury and Hashimoto (1993). Poultry for developed countries was subdivided into five categories. Layers (dry) represent layers in a "without bedding" waste management system; layers (wet) represent layers in an anaerobic lagoon waste management system. For layers, volatile solids (VS) are values reported in USDA (1996); typical animal mass values are from ASAE (1999); and B_o values for Layers are values reported by Hill (1982). For broilers and turkeys, B_o values are from Hill (1984); typical animal mass values are from ASAE (1999); and VS values are those reported in USDA (1996). B_o values for ducks were transferred from broilers and turkeys; typical animal mass values are from MWPS-18; and VS values are from USDA, AWMFH. Typical mass of sheep, goats and horses, and VS and B_o values of goats and horses for developed countries updated according to the analysis of GHG inventories of Annex I countries. All manure, with the exception of Layers (wet), is assumed to be managed in dry systems, which is consistent with the manure management system usage reported in Woodbury and Hashimoto (1993). a When selecting a default emission factor, be sure to consult the supporting tables in Annex 10A.2 for the distribution of manure management systems and animal waste characteristics used to estimate emissions. Select an emission factor for a region that most closely matches your own in these characteristics. b Layer operations that manage dry manure. c Layer operations that manage manure as a liquid, such as stored in an anaerobic lagoon.

INDIRECT N2O EMISSIONS

Table 10.23 shows that manure management system for each livestock type and the Total N loss from MMS b FracLossMS (Range of FracLossMS).

TABLE 10.23
DEFAULT VALUES FOR TOTAL NITROGEN LOSS FROM MANURE MANAGEMENT

Animal category	Manure management system [a]	Total N loss from MMS [b] FracLossMS (Range of FracLossMS)
Swine	Anaerobic lagoon	78% (55 – 99)
	Pit storage	25% (15 – 30)
	Deep bedding	50% (10 – 60)
	Liquid/Slurry	48% (15 – 60)
	Solid storage	50% (20 – 70)
Dairy Cow	Anaerobic lagoon	77% (55 – 99)
	Liquid/Slurry	40% (15 – 45)
	Pit storage	28% (10 – 40)
	Dry lot	30% (10 – 35)
	Solid storage	40% (10 – 65)
	Daily spread	22% (15 – 60)

Poultry	Poultry without litter	55% (40 – 70)
	Anaerobic lagoon	77% (50 – 99)
	Poultry with litter	50% (20 – 80)
Other Cattle	Dry lot	40% (20 – 50)
	Solid storage	50% (20 – 70)
	Deep bedding	40% (10 – 50)
Other [c]	Deep bedding	35% (15 – 40)
	Solid storage	15% (5 – 20)

a
Manure Management System here includes associated N losses at housing and final storage system.

b
Total N loss rates based on judgement of IPCC Expert Group and following sources: Rotz (2003), Hutchings *et al.* (2001), and U.S EPA (2004). Rates include losses in forms of NH_3, NO_x, N_2O, and N_2 as well from leaching and runoff from solid storage and dry lots. Values represent average rates for typical housing and storage components without any significant nitrogen control measures in place. Ranges reflect values that appear in the literature. Where measures to control nitrogen losses are in place, alternative rates should be developed to reflect those measures.

c
Other includes sheep, horses, and fur-bearing animals.

TABLE 10.19 shows the Default values for nitrogen excretion rate, Vanuatu is categorized under the region “Oceania”.

TABLE 10.19
DEFAULT VALUES FOR NITROGEN EXCRETION RATE [a] (KG N (1000 KG ANIMAL MASS)$^{-1}$ DAY^{-1})

Category of animal	Region							
	North America	Western Europe	Eastern Europe	Oceania	Latin America	Africa	Middle East	Asia
Dairy Cattle	0.44	0.48	0.35	0.44	0.48	0.60	0.70	0.47
Other Cattle	0.31	0.33	0.35	0.50	0.36	0.63	0.79	0.34
Swine	0.40	0.50	0.54	0.52	1.47	1.47	1.47	0.40
Market	0.42	0.51	0.55	0.53	1.57	1.57	1.57	0.42
Breeding	0.24	0.42	0.46	0.46	0.55	0.55	0.55	0.24
Poultry	0.83	0.83	0.82	0.82	0.82	0.82	0.82	0.82
Hens >/= 1 yr	0.83	0.96	0.82	0.82	0.82	0.82	0.82	0.82
Pullets	0.62	0.55	0.60	0.60	0.60	0.60	0.60	0.60
Other Chickens	0.83	0.83	0.82	0.82	0.82	0.82	0.82	0.82
Broilers	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Turkeys	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Ducks	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Sheep	0.42	0.85	0.90	1.13	1.17	1.17	1.17	1.17
Goats	0.45	1.28	1.28	1.42	1.37	1.37	1.37	1.37
Horses (and mules, asses)	0.30	0.26	0.30	0.30	0.46	0.46	0.46	0.46
Camels[c]	0.38	0.38	0.38	0.38	0.46	0.46	0.46	0.46
Buffalo	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32

Mink and Polecat (kg N head^{-1} yr^{-1})d	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59
Rabbits (kg N head^{-1} yr^{-1})	8.10	8.10	8.10	8.10	8.10	8.10	8.10	8.10
Fox and Racoon (kg N head^{-1} yr^{-1})[d]	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09

The uncertainty in these estimates is ±50%.

a
Summarized from *1996 IPCC Guidelines*, 1997; European Environmental Agency, 2002; USA EPA National NH_3 Inventory Draft Report, 2004; and data of GHG inventories of Annex I Parties submitted to the Secretariat UNFCCC in 2004.

b
Nitrogen excretion for swine is based on an estimated country population of 90% market swine and 10% breeding swine.

c
Modified from European Environmental Agency,
2002. d
Data of Hutchings *et al.*, 2001.

TABLE 10.14 shows the Manure Methane Emission factors by temperature for cattle, swine, and Buffalo. Vanuatu is characterized under the “Oceania” Regional Characteristic.

TABLE 10.14
MANURE MANAGEMENT METHANE EMISSION FACTORS BY TEMPERATURE FOR CATTLE, SWINE, AND BUFFALO[a]
($KG\ CH_4\ HEAD^{-1}\ YR^{-1}$)

Regional characteristics	Livestock species	CH_4 emission factors by average annual temperature (°C)[b]																		
		Cool					Temperate											Warm		
		≤ 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	≥ 28
North America: Liquid-based systems are commonly used for dairy cows and swine manure. Other cattle manure is usually managed as a solid and deposited on pastures or ranges.	Dairy Cows	48	50	53	55	58	63	65	68	71	74	78	81	85	89	93	98	105	110	112
	Other Cattle	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Market Swine	10	11	11	12	12	13	13	14	15	15	16	17	18	18	19	20	22	23	23
	Breeding Swine	19	20	21	22	23	24	26	27	28	29	31	32	34	35	37	39	41	44	45
Western Europe: Liquid/slurry and pit storage systems are commonly used for cattle and swine manure. Limited cropland is available for spreading manure.	Dairy Cows	21	23	25	27	29	34	37	40	43	47	51	55	59	64	70	75	83	90	92
	Other Cattle	6	7	7	8	8	10	11	12	13	14	15	16	17	18	20	21	24	25	26
	Market Swine	6	6	7	7	8	9	9	10	11	11	12	13	14	15	16	18	19	21	21
	Breeding Swine	9	10	10	11	12	13	14	15	16	17	19	20	22	23	25	27	29	32	33
	Buffalo	4	4	5	5	5	6	7	7	8	9	9	10	11	12	13	14	15	16	17
Eastern Europe: Solid-based systems are used for the majority of manure. About one-third of livestock manure is managed in liquid-based systems.	Dairy Cows	11	12	13	14	15	20	21	22	23	25	27	28	30	33	35	37	42	45	46
	Other Cattle	6	6	7	7	8	9	10	11	11	12	13	14	15	16	18	19	21	23	23
	Market Swine	3	3	3	3	3	4	4	4	4	5	5	5	6	6	6	7	10	10	10

	Breeding Swine	4	5	5	5	5	6	7	7	7	8	8	9	9	10	11	12	16	17	17
	Buffalo	5	5	5	6	6	7	8	8	9	10	11	11	12	13	15	16	17	19	19
Oceania: Most cattle manure is managed as a solid on pastures and ranges, except dairy cows where there is some usage of lagoons. About half of the swine manure is managed in anaerobic lagoons.	Dairy Cows	23	24	25	26	26	27	28	28	28	29	29	29	29	29	30	30	31	31	31
	Other Cattle	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Market Swine	11	11	12	12	12	13	13	13	13	13	13	13	13	13	13	13	13	13	13
	Breeding Swine	20	20	21	21	22	22	23	23	23	23	23	24	24	24	24	24	24	24	24
Latin America: Almost all livestock manure is managed as a solid on pastures and ranges. Buffalo manure is deposited on pastures and ranges.	Dairy Cows	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
	Other Cattle	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Swine	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
	Buffalo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2

TABLE 3: shows the livestock type and their MMS Use default values.

Oceania Default Values - MMS Use					*Expert Judgement	
	Lagoon	Liquid Slurry	Solid Storage	Dry Lot	Pasture/Range/Paddock	Daily Spread
Dairy Cows	16%	1%			75%	8%
Other Cattle				9%	91%	
Swine (pigs)- Market Swine	54%	14%	17%	15%		
Sheep					100%	
Goats					100%	
Poultry/Ducks*			100%			
Horses*					100%	

Table 4: Shows the default emission factors for direct N_2O emissions from each of the different manure management systems.

TABLE 10.21
DEFAULT EMISSION FACTORS FOR DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT

System	Definition	EF_3 [kg N_2O-N (kg Nitrogen excreted)$^{-1}$]	Uncertainty ranges of EF_3	Source[a]
Pasture/Range/ Paddock	The manure from pasture and range grazing animals is allowed to lie as is and is not managed.	Direct and indirect N_2O emissions associated with the manure deposited on agricultural soils and pasture, range, and paddock systems are treated in Chapter 11, Section 11.2, N_2O emissions from managed soils.		
Daily Spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion. N_2O emissions during storage and treatment are assumed to be zero. N_2O emissions from land application are covered under the Agricultural Soils category.	0	Not applicable	Judgment by IPCC Expert Group (see Co-chairs, Editors and Experts; N_2O emissions from Manure Management).
Solid storage[b]	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.	0.005	Factor of 2	Judgement of IPCC Expert Group in combination with Amon *et al.* (2001), which shows emissions ranging from 0.0027 to 0.01 kg N_2O-N (kg N)$^{-1}$.

Dry lot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically. Dry lots are most typically found in dry climates but also are used in humid climates.		0.02	Factor of 2	Judgement of IPCC Expert Group in combination with Kulling (2003).
Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water to facilitate handling and is stored in either tanks or earthen ponds.	With natural crust cover	0.005	Factor of 2	Judgement of IPCC Expert Group in combination with Sommer *et al.* (2000).
		Without natural crust cover	0	Not applicable	Judgement of IPCC Expert Group in combination with the following studies: Harper *et al.* (2000), Lague *et al.* (2004), Monteny *et al.* (2001), and Wagner-Riddle and Marinier (2003). Emissions are believed negligible based on the absence of oxidized forms of nitrogen entering systems in combination with low potential for nitrification and denitrification in the system.
Uncovered anaerobic lagoon	Anaerobic lagoons are designed and operated to combine waste stabilization and storage. Lagoon supernatant 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 fertilise fields.		0	Not applicable	Judgement of IPCC Expert Group in combination with the following studies: Harper *et al.* (2000), Lague *et al.* (2004), Monteny *et al.* (2001), and Wagner-Riddle and Marinier (2003). Emissions are believed negligible based on the absence of oxidized forms of nitrogen entering systems in combination with low potential for nitrification and denitrification in the system.
Pit storage below animal confinements	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility.		0.002	Factor of 2	Judgement of IPCC Expert Group in combination with the following studies: Amon *et al.* (2001), Kulling (2003), and Sneath *et al.* (1997).

TABLE 10.21 (CONTINUED)
DEFAULT EMISSION FACTORS FOR DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT

System	Definition		EF_3 [kg N_2O-N (kg Nitrogen excreted)$^{-1}$]	Uncertainty ranges of EF_3	Source[a]
Anaerobic digester	Anaerobic digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to CH_4 and CO_2, which is captured and flared or used as a fuel.		0	Not applicable	Judgement of IPCC Expert Group in combination with the following studies: Harper *et al.* (2000), Lague *et al.* (2004) Monteny *et al.* (2001), and Wagner-Riddle and Marinier (2003). Emissions are believed negligible based on the absence of oxidized forms of nitrogen entering systems in combination with low potential for nitrification and denitrification in the system.
Burned for fuel or as waste	The dung is excreted on fields. The sun dried dung cakes are burned for fuel.		The emissions associated with the burning of the dung are to be reported under the IPCC category 'Fuel Combustion' if the dung is used as fuel and under the IPCC category 'Waste Incineration' if the dung is burned without energy recovery.		
	Urine N deposited on pasture and paddock		Direct and indirect N_2O emissions associated with the urine deposited on agricultural soils and pasture, range, paddock systems are treated in Chapter 11, Section 11.2, N_2O emissions from managed soils.		
Cattle and swine deep bedding	As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 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.	No mixing	0.01	Factor of 2	Average value based on Sommer and Moller (2000), Sommer (2000), Amon *et al.* (1998), and Nicks *et al.* (2003).
		Active mixing	0.07	Factor of 2	Average value based on Nicks *et al.* (2003) and Moller *et al.* (2000). Some literature cites higher values to 20% for well maintained, active mixing, but those systems included treatment for ammonia which is not typical.
Composting - In-Vessel[c]	Composting, typically in an enclosed channel, with forced aeration and continuous mixing.		0.006	Factor of 2	Judgement of IPCC Expert Group. Expected to be similar to static piles.
Composting - Static Pile[c]	Composting in piles with forced aeration but no mixing.		0.006	Factor of 2	Hao *et al.* (2001).
Composting - Intensive Windrow[c]	Composting in windrows with regular turning for mixing and aeration.		0.1	Factor of 2	Judgement of IPCC Expert Group. Expected to be greater than passive windrows and intensive composting operations, as emissions are a function of the turning frequency.
Composting - Passive Windrow[c]	Composting in windrows with infrequent turning for mixing and aeration.		0.01	Factor of 2	Hao *et al.* (2001).

Poultry manure with litter	Similar to deep bedding systems. Typically used for all poultry breeder flocks and for the production of meat type chickens (broilers) and other fowl.	0.001	Factor of 2	Judgement of IPCC Expert Group based on the high loss of ammonia from these systems, which limits the availability of nitrogen for nitrification/denitrification.
Poultry manure without litter	May be similar to open pits in enclosed animal confinement facilities or may be designed and operated to dry the manure as it accumulates. The latter is known as a high-rise manure management system and is a form of passive windrow composting when designed and operated properly.	0.001	Factor of 2	Judgement of IPCC Expert Group based on the high loss of ammonia from these systems, which limits the availability of nitrogen for nitrification/denitrification.

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TABLE 10.21 (CONTINUED)
DEFAULT EMISSION FACTORS FOR DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT

System	Definition		EF_3 [kg N_2O-N (kg Nitrogen excreted)$^{-1}$]	Uncertainty ranges of EF_3	Source[a]
Aerobic treatment	The biological oxidation of manure collected as a liquid with either forced or natural aeration. Natural aeration is limited to aerobic and facultative ponds and wetland systems and is due primarily to photosynthesis. Hence, these systems typically become anoxic during periods without sunlight.	Natural aeration systems	0.01	Factor of 2	Judgment of IPCC Expert Group. Nitrification-denitrification is used widely for the removal of nitrogen in the biological treatment of municipal and industrial wastewater with negligible N_2O emissions. Limited oxidation may increase emissions compared to forced aeration systems.
		Forced aeration systems	0.005	Factor of 2	Judgment of IPCC Expert Group. Nitrification-denitrification is used widely for the removal of nitrogen in the biological treatment of municipal and industrial wastewater with negligible N_2O emissions.

[a] Also see Dustan (2002), which compiled information from some of the original references cited.

[b] Quantitative data should be used to distinguish whether the system is judged to be a solid storage or liquid/slurry. The borderline between dry and liquid can be drawn at 20% dry matter content.

[c] Composting is the biological oxidation of a solid waste including manure usually with bedding or another organic carbon source typically at thermophilic temperatures produced by microbial heat production.