Livestock
3A1Enteric Fermentation

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Outline

- Background
- Step to estimate emissions
- Tier.1 Methodology
- Tier.2 Methodology
- Exercise by using the IPCC Software

Background

- Methane (CH_4) is a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream as a source of energy.

- CH_4 is produced during the process and may be released to the atmosphere.

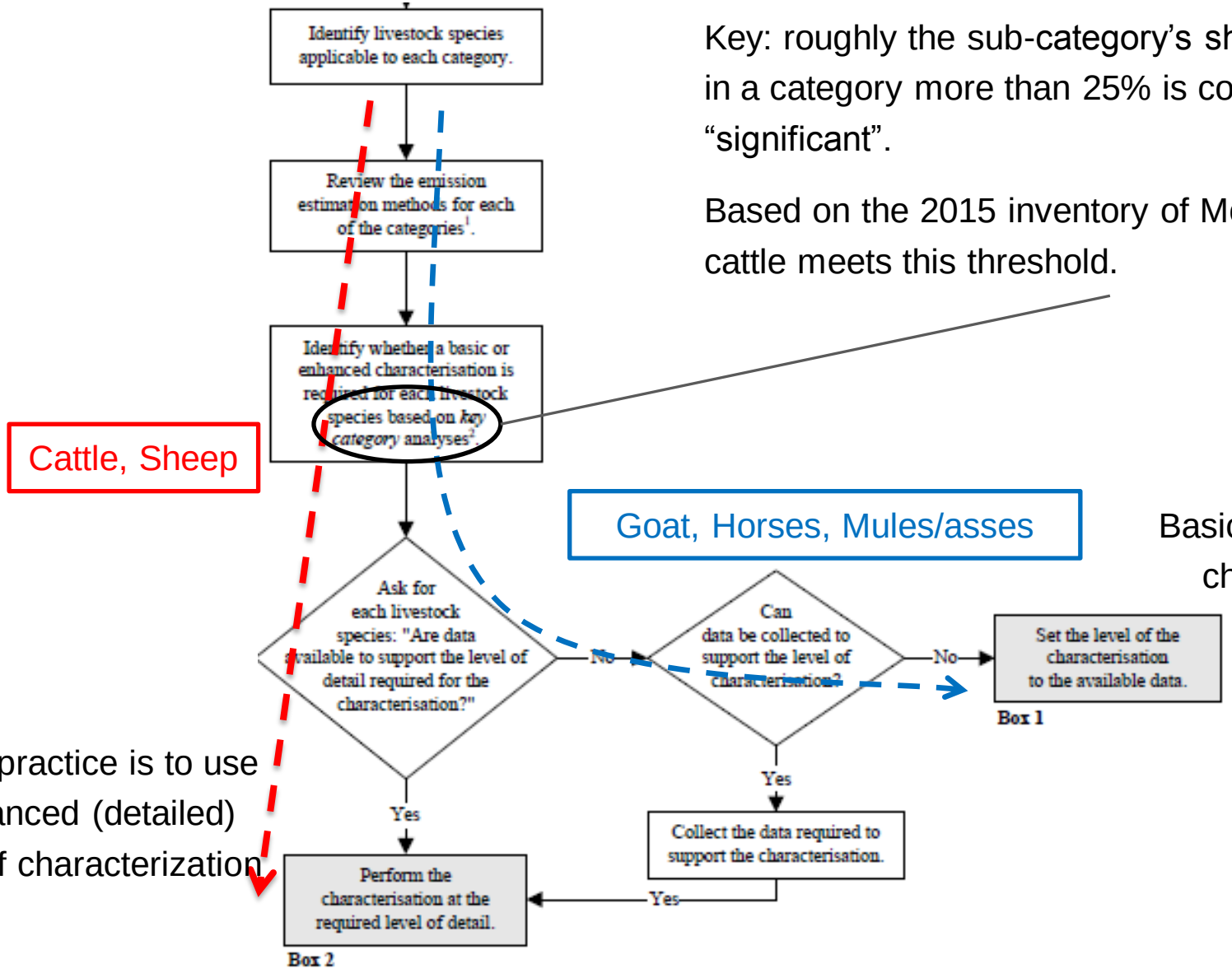
- The amount of CH_4 produced and excreted by an individual animal is primarily dependent on the type of digestive system and the quantity and quality of feed consumed (which relates to the energy expenditure of the animal).

Step to estimate emissions

- Identify livestock subcategories (for both 3A1 and 3A2)
  - Emission pathway slightly differ in each livestock species. (ex. ruminant vs. non-ruminant)
  - Different tier may apply (ex. Higher tier for dominant species)
- Review the emission estimation method in each livestock level
  - Taking into account the decision trees and the relevant explanation in the IPCC GL
  - The suggested methods for enteric fermentation are as follows (from Table 10.9, 2006GL-AFOLU)

Livestock	Suggested methods in 2006GL	2015 inv. Moldova
Dairy Cow, Other Cattle	Tier.2/Tier.3	Tier.2
Buffalo, Sheep	Tier.1/Tier.2	Tier.2 (sheep)
Goats, Camels, Horses, Mules/Asses, Swine	Tier.1	Tier.2 (goats) Tier.1 (other)
Poultry	Not developed	-
Other	Tier.1	Tier.1

Decision tree: Livestock characterization



Key: roughly the sub-category's share of emission in a category more than 25% is considered "significant".

Based on the 2015 inventory of Moldova, only dairy cattle meets this threshold.

Basic (single) level of characterization

Good practice is to use Enhanced (detailed) level of characterization

Tier.1 methodology for Enteric Fermentation

- Equation
  - Simply multiplying “animal population” and “EF (annual CH_4 emission per head)

    Total $CH_{4Enteric} = \Sigma [EF_{(T)} * N_{(T)}/10^6]$

    $EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

    $N_{(T)}$ = the number of head of livestock species / Category T

- How to identify appropriate default EF
  - Refer the appropriate livestock category and region characteristics
  - As animal size is important determinants of EF, live-weight or average milk production should also be taken into account.
- How to collect the number of head of each livestock
  - Can use statistical information
  - Important note is that the number here means “annual average”. For instance, broiler chicken are typically grown 60 days, thus the annual average number is estimated through,

    (total chicken produced annually) / 365 *60 (see equation 10.1 in 2006GL)

Tier.2 methodology for Enteric Fermentation

- Basic Equation
  - The equation for Tier.2 is also multiplying “animal population” and “EF (annual CH_4 emission per head).
  - But EF itself must be developed from other parameters which reflect the feed intake situation. Generally, the higher the feed intake, the higher the methane emission. Amount of diet may also affect methane production.
  - So for tier.2, animal population should also be divided into appropriate subgroup.

- Development EF
  - The Methane conversion factor (V_m : per cent of gross energy (Carbon) in feed converted to methane) and Gross energy intake (GE: MJ $head^{-1}$ day^{-1}) is necessary for EF under Tier.2.

    EF = [GE * (Y_m/100) *365 / 55.65]
    - The factor 55.65 (MJ/kg CH_4) is the energy content in methane
    - If feeding period is limited, 365 can be replaced by the number of days in feeding period.

Tier.2 methodology for Enteric Fermentation

- Development EF
  - V_m
    - The default Methane conversion factors(V_m) are provided in the 2006GL for Cattle and sheep (Table 10.12 and 10.13). Refinement of CS V_m factors needs scientific research.
  - GE
    - The accumulation of the total amount of energy (MJ/day) needs for maintenance, activity, growth, location, draft power (for cattle only), wool production (for sheep only), and pregnancy is the parameter required here.
    - In the 2006GL, calculation methods of net energy required for each metabolic function are provided.
    - The estimated net energy (really used for maintenance or growth) are converted to gross energy (total energy from feed including one goes to feces) by using digestible ratio of feed (through empirical equation). This is because amount of CH_4 generation is relating to amount of feed they eat.
    - Equations and necessary coefficients are provided in the 2006GL

Tier.2 methodology for Enteric Fermentation (GE)

Metabolic function	Applicability	Necessary data	Equation & Table
Maintenance (NE_m)	All in equilibrium	Live-weight of animal	Eq. 10.3, Table 10.4
Activity(NE_a)	All cattle	NE_m	Eq. 10.4, Table 10.5
	All sheep	Live-weight of animal	Eq. 10.5, Table 10.5
Growth (NE_g)	Growing cattle	Manure live body weight Average body weight of population Average daily weight gain	Eq. 10.6, Table 10.6
	Growing sheep	Live body weight at weaning Live body weight at 1-yr old or slaughter	Eq. 10.7, Table 10.6
Lactation (NE_l)	Female cattle in lactation	Amount of milk produced Fat content of milk	Eq. 10.8
	Female Sheep (milk production known)	Amount of milk production	Eq. 10.9
	Female Sheep (milk production known)	Weight gain of the lamb between birth and weaning	Eq. 10.10

Tier.2 methodology for Enteric Fermentation (GE)

Metabolic function	Applicability	Necessary data	Equation & Table
Work (NE_{work})	Only for cattle used as worker	NE_m Number of hours of work/day	Eq. 10.11
Wool Production (NE_{wool})	Only for sheep	Annual wool production per sheep	Eq. 10.12
Pregnancy (NE_p)	All pregnancy	NE_m Live product produced by a female for sheep	Eq. 10.12, Table 10.7

parameter	Applicability	Necessary data	Equation & Table
Ratio of net energy available in diet for maintenance to digestible energy consumed	All for maintenance function	DE%	Eq. 10.15
Ratio of net energy available in diet for growth to digestible energy consumed	All for growth function	DE%	Eq. 10.16

Exercise of using the IPCC Software

- Objective
  - Reproduction of CH_4 emission from enteric fermentation for the year 2013 in Republic of Moldova, by using the IPCC Software.

- Materials used
  - IPCC Software
  - IPCC Software Manual p28-
  - 2006GL, AFOLU, chapter 10 around page 10.8 – 10.31
  - NIR of Republic of Moldova submitted in 2015 (The 2015 inv.), page 219-232

- Tiers to apply: The same tiers in the 2015 inv.
  - Tier.1 : Horse, Camels, Mules/asses, Rabbit
  - Tier.2: Cattle (Dairy Cows, Other Cattle), Sheep ,Goats
  - NO: Buffalo, Camels, Poultry (Chickens, Geese, Ducks, Turkeys),

Exercise by using the IPCC Software

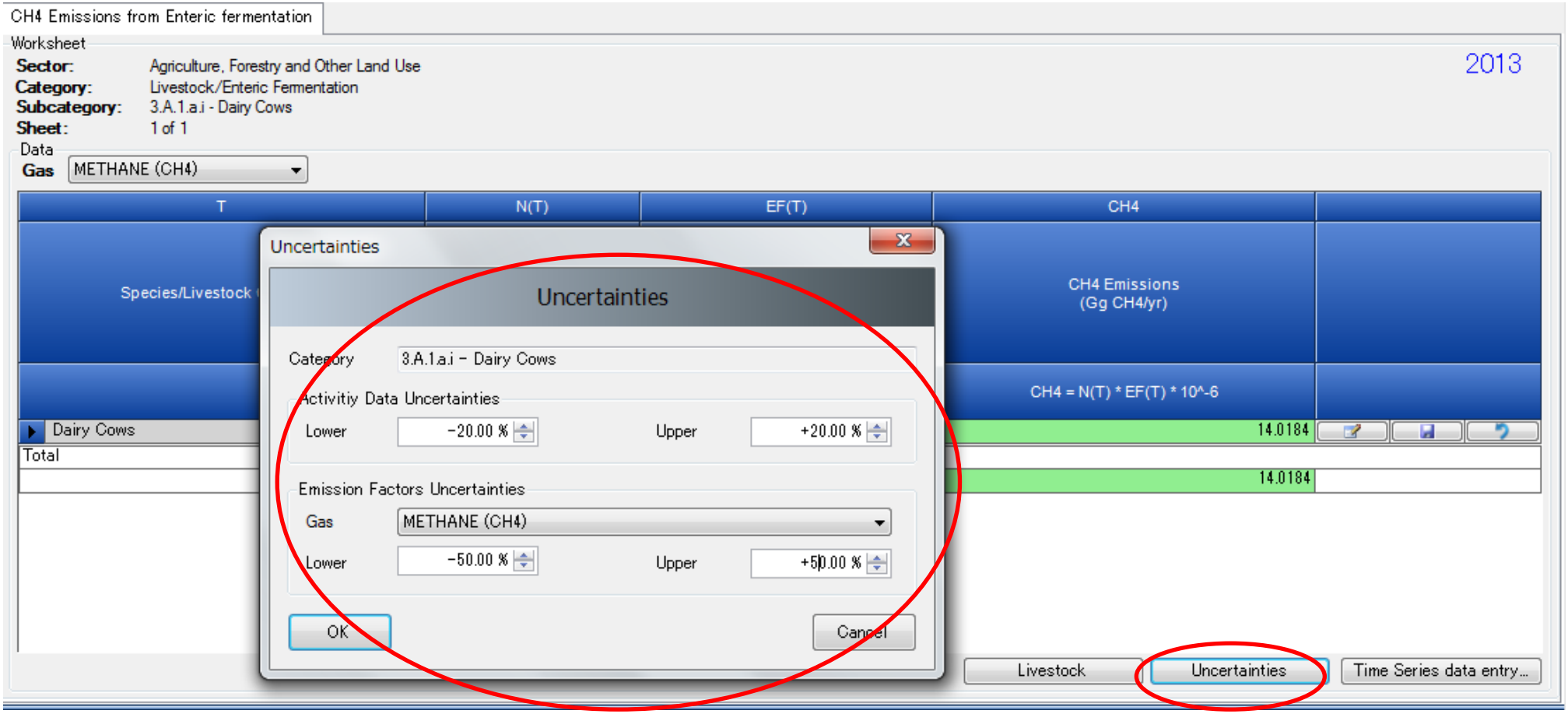
- NOs
  - Currently, entering notation keys are not possible in the IPCC Software ver2.17 (p42, 5.5 of User Manual) unfortunately.
- Tier.1
  - Can be estimated directly through the software.
  - Entering numbers of head of animals from Table 6-9 in the NIR to Horses, Mules and Asses, Swine and other (rabbit), through “Livestock Manager”.
  - Chose the proper default EFs in the worksheet to Horses, Mules and Asses, Swine. For rabbit, EF can be entered directly.
- Tier.2
  - Numbers of head of animals can be entered by the “Livestock Manager” with adding new subcategories for Other cattle, sheep, goats.
  - Ter.2 EF calculation (the most difficult point) is not covered by the software. But allowed to enter the calculated EF in the software.

Uncertainty assessment

- The 2006GL provides the relevant uncertainties (not explicitly very much).
  - Animal population: “vary widely depending on source, but should be known within ±20%
  - Gross Energy intake: almost 20%
  - EF for Tier.1: 30-50%
  - EF for Tier.2: likely to 20%
- The IPCC inventory software has uncertainty estimate equipment.
  - The numbers are able to enter for AD and EF at the sub-category level.

Uncertainty assessment

- In the IPCC inventory software, click “Uncertainty” and enter the data of uncertainty at the Uncertainties window.



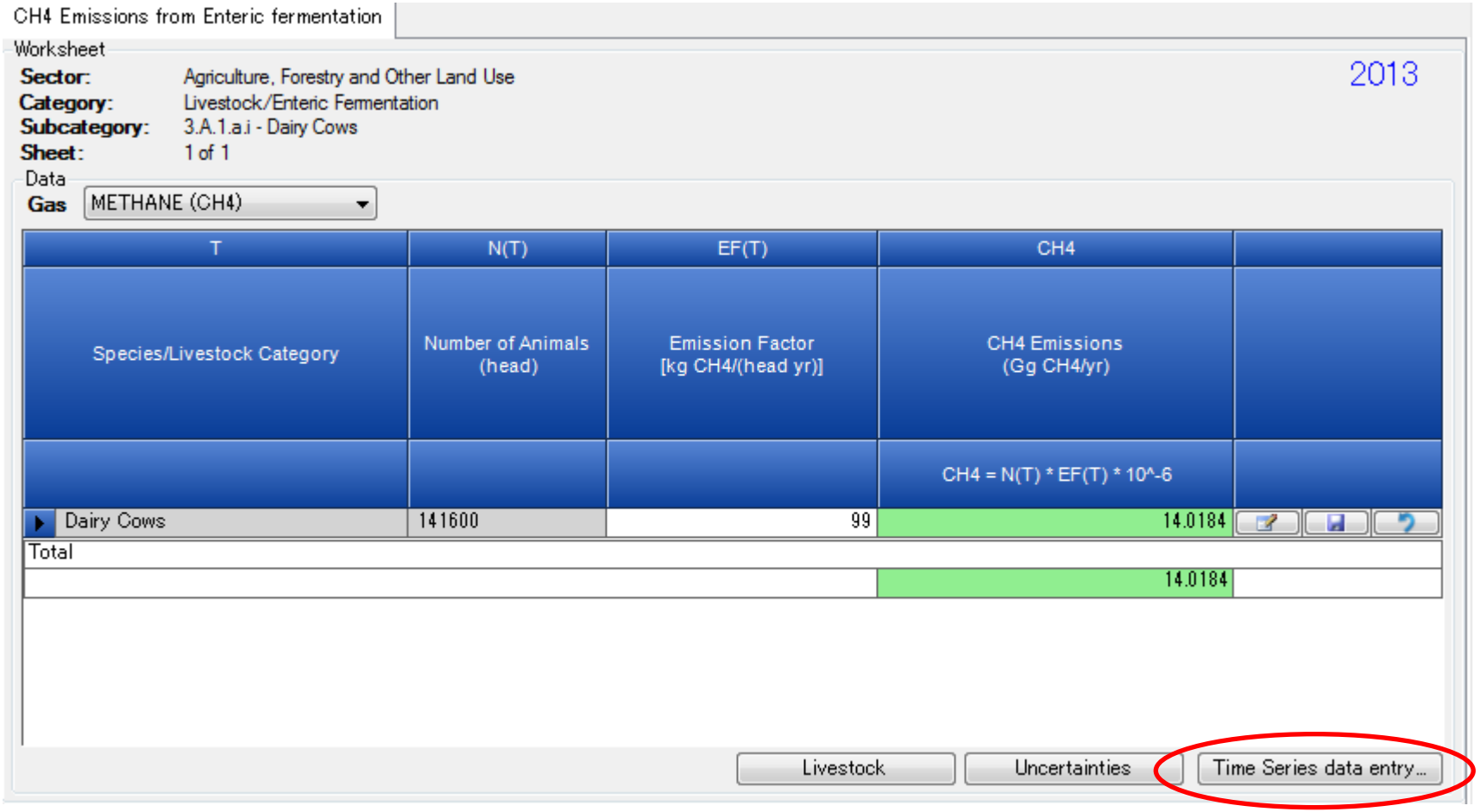
Time series data entry

- Majority of worksheets supports time series data entry, including 3.A.
- For implementation of time series data entry, all time series Inventory year must be created in advance. Creating new inventory year can be done by “Inventory Year” (See, page 18 of the manual for this procedure)
- The timing of creating new inventory years might need consideration because you can select Copy of existing inventory year or Create empty inventory year.

- In the Inventory Software ver 2.17 Manual, section 4.4 (p39-40) covers this procedure

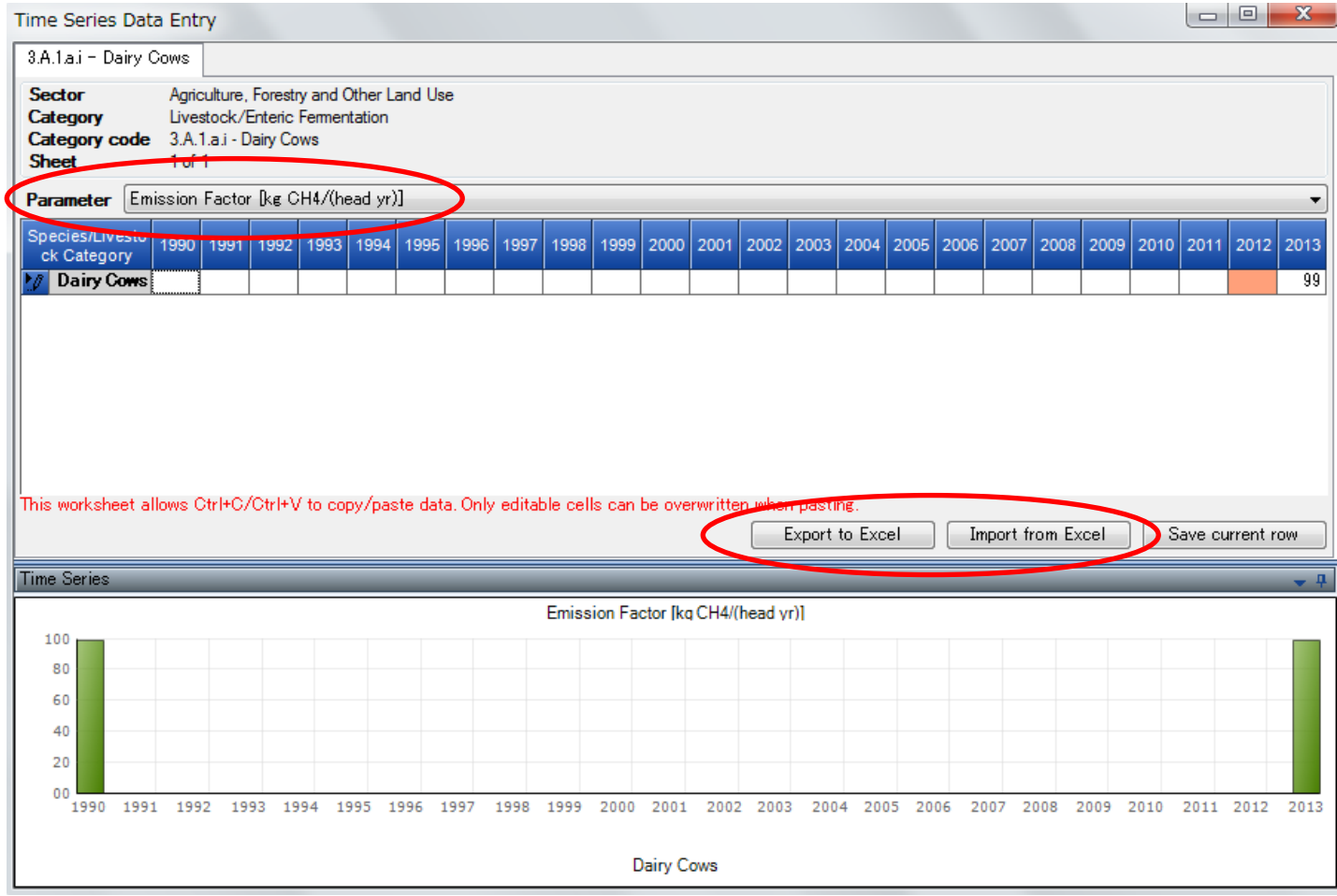
Time series data entry

- Majority of worksheets supports time series data entry, including 3.A. Time series data entry worksheet can be activated by pressing the “Time series Data Entry” button located under the grid.



Time series data entry

- Parameter list contains the list of all editable parameters contained in the worksheet.
- Values in white cells are editable.
- Editing by excel sheet is also possible.



Time series data entry

- Data for that parameter then can be modified in Excel and imported back into the software.
- Data transfer from Excel to the software can be done by “import” function or just normal Copy and Paste.

2	**Country:**	Republic of Moldova							
3	**Sector:**	Agriculture, Forestry and Other Land Use							
4	**Category:**	Livestock/Enteric Fermentation							
5	**Subcategory:**	3.A.1.a.i - Dairy Cows							
6	**Sheet:**	1 of 1							
7	**Parameter:**	Emission Factor [kg CH4/(head yr)]							
8									
9	**Species/Livestock Category**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
10	Dairy Cows	104.8	97.6	97	93.7	92.8	90	90.3	90.1