MODULE NAME:

ACCOUNTING MODULE FOR EMISSIONS FROM ENTERIC FERMENTATION

MODULE CODE:

A-ENTERIC

Contents

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1. Parameters, Purpose and Applicability

1.1 Output Parameters(s):

Parameter Name	Parameter Description
S_ENT	Net enteric emissions (t CO_2e)

1.2 Key Input Data:

Parameter Name	Parameter Description
BW_m	Body weight of livestock under management m; kg
DEE_x	Dietary ether extract for feed x; %
GEI_x	Gross energy intake for feed x; Mcal/d
NDF_x	Dietary neutral detergent fiber for feed x; %
$Prop_x$	Proportion of total diet made up of feed x; dimensionless

1.3 Purpose

- To estimate emissions and net emission reductions from enteric fermentation as part of grazing land and livestock management greenhouse gas mitigation activities.
- The module is for large scale emissions.
- The module estimates both emissions in the baseline case and with project implementation.

1.4 Applicability Conditions

- The module is applicable to all projects implemented for grazing land and livestock management.
- Where with-project emissions are significantly elevated (see T-XANTE) the module shall be used, in all other cases it is optional.

2. Calculation Procedure

2.1 Calculation approach

The calculation approach is based on empirical equations developed by Professor Ermias Kebreab and others[1]. The equations were developed using animal and feed data from 1963 to 1995. The data were collected in the Beltsville open-circuit respiration chambers at the United States Department of Agriculture, Agricultural Research Center, Beltsville, MD. The equations are applicable to cows under all production systems.

The baseline shall be dynamic to allow for changes in livestock numbers. Ex ante, an estimate will be made of both baseline and with-project emissions. Ex post at the time of reporting, baseline and project emissions shall be calculated based on livestock population, climatic conditions and other factors specific to the project and time period.

2.2 Calculations

Enteric emissions are derived from data on feed and on the body weight of livestock. Equations are divided into three categories:

- Lactating cows
- Dry cows
- Heifers and steers

Lactating cows:

$$E\_ENT_{LC,m,t} = 0.3743 + \sum_x \left(0.0392 * GEI_x * \text{Prop}_x\right) + \sum_x \left(0.0189 * NDF_x * \text{Prop}_x\right) - \sum_x \left(0.1555 * DEE_x * \text{Prop}_x\right) + \left(0.0014 * BW_m\right) \quad \textbf{(1)}$$

Dry cows:

$$E\_ENT_{DC,m,t} = 0.4535 + \sum_x \left(0.0503 * GEI_x * \text{Prop}_x\right) - \sum_x \left(0.0546 * DEE_x * \text{Prop}_x\right) + \left(0.0008 * BW_m\right) \quad \textbf{(2)}$$

[1] Hristov, A.N., Oh, J., Lee, C., Meinen, R., Montes, F., Ott, T., Firkins, J., Rotz, A., Dell, C., Adesogan, A., Yang, W., Tricarico, J., Kebreab, E., Waghorn, G., Dijkstra, J. & Oosting, S. 2013. *Mitigation of greenhouse gas emissions in livestock production – A review of technical options for non-CO2 emissions.* Edited by Pierre J. Gerber, Benjamin Henderson and Harinder P.S. Makkar. FAO Animal Production and Health Paper No. 177. FAO, Rome, Italy.

Heifers and steers:

$$E\_ENT_{HS,m,t} = -0.0558 + \sum_x (0.0447 * GEI_x * \mathrm{Prop}_x) + \sum_x (0.0039 * NDF_x * \mathrm{Prop}_x) - \sum_x (0.0332 * DEE_x * \mathrm{Prop}_x) + (0.0014 * BW_m) \quad \textbf{(3)}$$

Where:

$E\_ENT_{LC,m,t}$	Enteric emissions from lactating cows under management *m* at time *t*; CH_4 GE Mcal.day^{-1}
$E\_ENT_{DC,m,t}$	Enteric emissions from dry cows under management *m* at time *t*; CH_4 GE Mcal.day^{-1}
$E\_ENT_{HS,m,t}$	Enteric emissions from heifers and steers under management *m* at time *t*; CH_4 GE Mcal.day^{-1}
BW_m	Mass of livestock under management *m*; kg
DEE_x	Dietary ether extract for feed *x*; %
GEI_x	Gross energy intake for feed *x*; Mcal.day^{-1}
NDF_x	Dietary neutral detergent fiber for feed *x*; %
$Prop_x$	Proportion of total diet made up of feed *x*; dimensionless

Emissions in Mcal/day are converted to t CO_2 equivalent per year:

$$E\_ENT_{LC,t} = \left(\frac{\left(\sum_m (E\_ENT_{LC,m,t} * Num_m)\right) * \#days}{13.29} \Big/ 1000 \right) * 21 \quad \textbf{(4)}$$

$$E\_ENT_{DC,t} = \left(\frac{\left(\sum_m (E\_ENT_{DC,m,t} * Num_m)\right) * \#days}{13.29} \Big/ 1000 \right) * 21 \quad \textbf{(5)}$$

$$E\_ENT_{HS,t} = \left(\frac{\left(\sum_m (E\_ENT_{HS,m,t} * Num_m)\right) * \#days}{13.29} \Big/ 1000 \right) * 21 \quad \textbf{(6)}$$

Where:

$E\_ENT_{LC,t}$	Enteric emissions from lactating cows at time *t*; t CO_2-e
$E\_ENT_{DC,t}$	Enteric emissions from dry cows at time *t*; t CO_2-e
$E\_ENT_{HS,t}$	Enteric emissions from heifers and steers at time *t*; t CO_2-e
$E\_ENT_{LC,m,t}$	Enteric emissions from lactating cows under management *m* at time *t*; CH_4 GE Mcal.day^{-1}
$E\_ENT_{DC,m,t}$	Enteric emissions from dry cows under management *m* at time *t*; CH_4 GE Mcal.day^{-1}
$E\_ENT_{HS,m,t}$	Enteric emissions from heifers and steers under management *m* at time *t*; CH_4 GE Mcal.day^{-1}
Num_m	Number of livestock (by category) under management *m*; dimensionless
#days	Number of days since previous verification (or start of project if no verification has occurred to date); dimensionless
13.29	Mcal.kg CH_4^{-1}
21	Global warming potential of methane (SAR-100 value in IPCC AR4 2007)

The total enteric emissions are equal to the sum of the three categories:

$$E\_ENT_t = E\_ENT_{LC,t} + E\_ENT_{DC,t} + E\_ENT_{HS,t} \quad \textbf{(7)}$$

Where:

E_ENT_t	Enteric emissions from livestock at time *t*; t CO_2-e
$E\_ENT_{LC,t}$	Enteric emissions from lactating cows at time *t*; t CO_2-e
$E\_ENT_{DC,t}$	Enteric emissions from dry cows at time *t*; t CO_2-e
$E\_ENT_{HS,t}$	Enteric emissions from heifers and steers at time *t*; t CO_2-e

2.3 Baseline

The same equations given in Section 1.2 are applicable in both the baseline and project case. The emission in the baseline case shall be equal to:

$E\_ENT_{BSL,t} = E\_ENT_t$ where *t* is year *t* in the baseline case.

2.4 With-project

The same equations given in Section 1.2 are applicable in both the baseline and project case. The emission in the project case shall be equal to:

$E\_ENT_{P,t} = E\_ENT_t$ where *t* is year *t* in the project case.

2.5 Summation

Total net emission reduction (or increase) from changes in practices impacting enteric emissions will be equal to baseline minus the project:

$$E\_ENT_{prelim} = E\_ENT_{BSL,t} - E\_ENT_{P,t} \quad \textbf{(8)}$$

Where:

E_ENT_{prelim}	Net enteric emissions prior to uncertainty deductions; t CO_2-e
$E\_ENT_{BSL,t}$	Enteric emissions from livestock in the baseline case at time *t*; t CO_2-e
$E\_ENT_{P,t}$	Enteric emissions from livestock in the project case at time *t*; t CO_2-e

2.6 Uncertainty

Uncertainty shall be quantified by means of a Monte Carlo simulation. The analysis shall combine uncertainties across each of the categories for both baseline and project scenarios, and between baseline and project scenarios. The output (E_ENT_{ERROR}) shall be the half width of the ultimate calculated 90% confidence interval divided by estimated net enteric emissions.

2.6.1 Uncertainty Deduction

If E_ENT_{ERROR} ≤ 10% of E_ENT_{prelim} then no deduction for uncertainty is required (E_ENT_{prelim} = *E_ENT*).

If E_ENT_{ERROR} > 10% of E_ENT_{prelim} then the modified value for *E_ENT* to account for uncertainty shall be:

$$E\_ENT = E\_ENT_{prelim} * \left(1 - \left(E\_ENT_{ERROR} - 10\%\right)\right) \quad \textbf{(9)}$$

Where:

E_ENT	Net enteric emissions; t CO_2-e
E_ENT_{prelim}	Net enteric emissions prior to uncertainty deductions; t CO_2-e

E_ENT_{ERROR}	Total uncertainty for enteric emissions; %

Where E_ENT is negative (decrease in enteric emissions as a result of the project) and:

$$E\_ENT = E\_ENT_{prelim} * (1 + (E\_ENT_{ERROR} - 10\%)) \quad (10)$$

Where:

E_ENT	Net enteric emissions; t CO_2-e
E_ENT_{prelim}	Net enteric emissions prior to uncertainty deductions; t CO_2-e
E_ENT_{ERROR}	Total uncertainty for enteric emissions; %

Where E_ENT is positive (increase in enteric emissions as a result of the project).

3. Input Data Sources and Requirements

In choosing key parameters or making important assumptions based on information that is not specific to the project circumstances, such as in use of existing published data, Project Proponents must retain a conservative approach: that is, if different values for a parameter are equally plausible, a value that does not lead to overestimation of net GHG emissions reductions or net sequestration must be selected.

It is a requirement that project developers include an explanation and justification for all parameters selected and used in the module.

Parameter	BW_m
Units	Kg
Description	Mass of animal under management *m*
Relevant Section	1.2
Relevant Equation(s)	1, 2, 3
Source of Data	Direct measurement of mean animal weight
Data Requirements	
Collection Procedure	Dairy: once a year Beef: together with vaccination, or any other activity in the chute
Revision Frequency	At each verification
Comments	Where mass is recorded in pounds multiply by 0.4536 to convert to kg Baseline animal mass and ex-ante estimates of animal mass shall be justified from historical records in the livestock operation, from justifiably representative literature or justifiably representative data from neighboring operations.

Parameter	DEE_x
Units	%
Description	% ether extract for each feed *x* in diet
Relevant Section	1.2
Relevant Equation(s)	1, 2, 3
Source of Data	A sample of each feed x will be sent to a laboratory for analysis. Wet chemistry shall be used.
Data Requirements	
Collection Procedure	For grains and hays: where the ration changes run a sample. For diets >50% hay samples must be run each season. For pasture: any time that there is a possibility of change in the quality of the pasture, this could be due to management or environment
Revision Frequency	At each verification
Comments	

Parameter	GEI_x
Units	$Mcal.day^{-1}$
Description	Gross energy intake for each feed (*x*) in diet
Relevant Section	1.2
Relevant Equation(s)	1, 2, 3
Source of Data	The total gross energy will be calculated by adding the GEI from each feed. The GE from each feed will be determined with Bomb Calorimetry in a laboratory
Data Requirements	
Collection Procedure	
Revision Frequency	With each new feed or for pasture at least every two months
Comments	

Parameter	NDF_x
Units	%
Description	% of neutral detergent fiber for each feed (*x*) in diet
Relevant Section	1.2
Relevant Equation(s)	1, 2, 3
Source of Data	A sample of each feed *x* will be sent to a laboratory for analysis. Wet chemistry shall be used.
Data Requirements	
Collection	For grains: run one sample a year if the same source. For hays, run a

Procedure	sample per season if the same source. For pasture: any time that there is a possibility of change in the quality of the pasture (this could be due to management or environment) Peer-reviewed literature values may be used where direct applicability can be demonstrated
Revision Frequency	At each verification
Comments	

Parameter	$\boldsymbol{Prop_x}$
Units	%
Description	Proportion of feed *x* in diet
Relevant Section	1.2
Relevant Equation(s)	1, 2, 3
Source of Data	Producer or any consultant involved with diet formulation shall record and report the proportion of each feed *x* in diet
Data Requirements	
Collection Procedure	
Revision Frequency	At each verification
Comments	For the given reporting period $Prop_x$ should represent the proportion of total feed. Thus this will include both multiple feed types at any specific point in time as well as variation over time. Where feed is grazing proportion shall reflect any change in quality see DEE and NDF.