GRAZING LAND AND LIVESTOCK MANAGEMENT GREENHOUSE GAS MITIGATION METHODOLOGY

MODULE NAME:

ACCOUNTING MODULE FOR EMISSIONS FROM FERTILIZER

MODULE CODE:

A-FERTILIZER

Output Parameter(s)
Parameter Name: E_FERT
Parameter Description: Net fertilizer emissions (t CO_2e)

Key Input Data:

- Atmospheric factors
- Daily meteorology
- Edaphic factors
- Cropping factors
- Tillage factors
- Fertilizer application factors
- Irrigation factors

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Purpose
To estimate emissions and net emission reductions from fertilizer use as direct and indirect parts of grazing land and livestock management greenhouse gas mitigation activities.
The module is for accounting large scale emissions from fertilizer use.
The module estimates both emissions in the baseline case and with project implementation.

Applicability Conditions
The module is applicable to all uses of fertilizer in projects accounted under this methodology. Where with-project emissions are significantly elevated (see T-XANTE) the module shall be used, in all other cases it is optional.

1.0 Calculation Procedure

In this methodology emissions resulting from fertilizer application shall be calculated using a qualifying process model[1].

The baseline shall be dynamic. *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 climatic conditions and other variable factors specific to the project and time period.

1.1 Models

Emissions resulting from fertilizer application shall be estimated using a process model. To be applicable the model shall have been accepted in scientific publications and shall have the potential to model direct and indirect emissions from fertilizer application with consideration of:

- Atmospheric factors (e.g. atmospheric background concentrations of NH_3 and CO_2; N concentration in rainfall)
- Daily meteorology
- Edaphic factors (e.g. clay content; bulk density; soil pH; SOC at surface soil[2]; soil texture; slope; depth of water retention layer; field capacity; wilting point)
- Cropping factors (e.g. crop type; planting date; harvest date; C/N ratio of the grain, leaf + stem tissue and root tissue; fraction of leaves and stem left in field after harvest; maximum yield)
- Tillage factors (e.g. number of tillage events; date and depth of tillage events)
- Fertilizer application factors (e.g. number of fertilizer applications; date of each fertilizer application; application method; type of fertilizer; fertilizer application rate; number of organic applications per year; date, type, C/N ratio and rate of organic amendment application)
- Irrigation factors (e.g. number of irrigation events; date, type and rate of irrigation event)

[1] Note that different models may be used under A-BIOTIC and A-FERTILIZER
[2] Depth as required by the process model

Examples of applicable models include DNDC[3] and Daycent[4]. DNDC is the process model prescribed in the ACR approved methodology for N_2O Emissions Reductions through Changes in Fertilizer Management (http://americancarbonregistry.org/carbon-accounting/carbon-accounting/emissions-reductions-through-changes-in-fertilizer-management); the detailed methods in the approved methodology may be directly applied here.

For application of the selected model to the project area the following criteria must be met:

There must be a study or studies (for example: scientific journals, university theses, local research studies or work carried out by the project proponent) that demonstrate that the use of the selected model is appropriate for: a) the IPCC climatic regions of 2006 IPCC AFOLU Guidelines or b) agroecological zone (AEZ) in which the project is situated using one of the options presented below[5]:

Option 1: The studies used in support of the project should meet the guidance on model applicability as outlined in IPCC AFOLU 2006 guidelines in order to show that the model is applicable for the relevant IPCC climatic region. The guidance notes that an appropriate model should be capable of representing the relevant management practices and that the model inputs (i.e., driving variables) are validated from country or region-specific locations that are representative of the variability of climate, soil and management systems in the country.

Option 2: Where available, the use of national, regional or global level agroecological zone (AEZ) classification is appropriate to show that the model has been validated for similar AEZs. It is recognized that national level AEZ classifications are not readily available; therefore this methodology allows the use of the global and regional classification.

Where a project area consists of multiple sites, it is recognized that studies demonstrating model validity using either Option 1 or Option 2 may not be available for each of the sites in the project area. In such cases the study used should be capable of demonstrating that the following two conditions are met:

i) The model is validated for at least 50% of the total project area relevant to fertilizer emissions where the project area covers up to 50,000 ha; or at least 75% of the total project area where project area relevant to biotic sequestration covers greater than 50,000 ha; and

ii) The area for which the model is validated generates at least two-thirds of the total project emission reductions from fertilizer application.

[3] http://www.dndc.sr.unh.edu/

[4] http://www.nrel.colostate.edu/projects/daycent/

[5] IPCC. 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry, and Other Land Use. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds).
Published: IGES, Japan. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

1.2 Quantification

1.2.1 Running the Model and Model Outputs

The output shall be the fertilizer-derived emission (kg N_2O-N.ha^{-1}; kg NO_3^-N.ha^{-1}; kg NH_3-N.ha^{-1} + NO_X-N.ha^{-1} volatilized) at a specific point in time. This shall vary by stratum (*i*) where variation exists in historical use and management, current management and edaphoclimatic factors.

The model shall be calibrated to the project location. Where project and site specific data can be input into the model, defaults supplied by the model shall not be used without justification.

The following parameters shall be used for data output from the model:

$NL_{DIRECT,i}$	Direct annual N_2O emissions in stratum *i*; kg N_2O-N.ha^{-1}
$NL_{LEACH,i}$	Annual nitrate leaching loss in stratum *i*; kg NO_3^-N.ha^{-1}
$NL_{VOLAT,i}$	Annual ammonia volatilization and nitric oxide emissions in stratum *i*; kg NH_3-N.ha^{-1} + NO_X-N.ha^{-1} volatilized

Calculate total average N_2O emissions in metric tons (t) CO_2-e.ha^{-1} in stratum *i* as follows:

$$GHG_{BSL\_N_2O,E,i} = \left(NL_{DIRECT,i} + \left(NL_{VOLAT,i} * EF_4\right) + \left(NL_{LEACH,i} * EF_5\right)\right) * \frac{44}{28} * GWP_{N_2O} \quad \textbf{(1)}$$

$$GHG_{P\_N_2O,E,i} = \left(NL_{DIRECT,i} + \left(NL_{VOLAT,i} * EF_4\right) + \left(NL_{LEACH,i} * EF_5\right)\right) * \frac{44}{28} * GWP_{N_2O} \quad \textbf{(2)}$$

$$GHG_{BSL\_N_2O,E} = \sum_{t=1}^{t^*}\left(\sum_{i=1}^{M}\left(GHG_{BSL,N_2O,E,i} * A_i\right)\right) \quad \textbf{(3)}$$

$$GHG_{P\_N_2O,E} = \sum_{t=1}^{t^*}\left(\sum_{i=1}^{M}\left(GHG_{P,N_2O,E,i} * A_i\right)\right) \quad \textbf{(4)}$$

Where:

$GHG_{BSL\_N2O,E,i}$	N_2O emissions as a result of fertilizer management activities in stratum *i* within the project boundary in the baseline; t CO_2-e.ha^{-1}
$GHG_{P\_N2O,E,i}$	N_2O emissions as a result of fertilizer management activities in stratum *i* within the project boundary for the project scenario; t CO_2-e.ha^{-1}
$GHG_{BSL\_N2O,E,i}$	N_2O emissions as a result of fertilizer application within the project boundary in the baseline scenario in stratum *i*; t CO_2-e.ha^{-1}

$GHG_{P\_N2O,E,i}$	N_2O emissions as a result of fertilizer application within the project boundary in the project scenario in stratum *i*; t CO_2-e.ha^{-1}
$GHG_{BSL\_N2O,E}$	N_2O emissions as a result of fertilizer management activities within the project boundary in the baseline; t CO_2-e
$GHG_{P\_N2O,E,i}$	N_2O emissions from stratum *i* as a result of fertilizer application within the project boundary in the with-project scenario; t CO_2-e.ha^{-1}
$NL_{DIRECT,i}$	Direct annual N_2O emissions in stratum *i*; kg N_2O-N.ha^{-1}
$NL_{LEACH,i}$	Annual nitrate leaching loss in stratum *i*; kg NO_3^-N.ha^{-1}
$NL_{VOLAT,i}$	Annual ammonia volatilization and nitric oxide emissions in stratum *i*; kg NH_3-N.ha^{-1} + NO_X-N.ha^{-1} volatilized
EF_4	Emission factor for N_2O emission from atmospheric deposition of N on soils and water surfaces and subsequent volatilization (default = 0.01; IPCC AFOLU Guidelines 2006 Vol.4 Ch.11 Table 11.3); kg N_2O-N (kg NH_3-N + NO_X-N volatilized)$^{-1}$
EF_5	Emission factor for N_2O emission from N leaching and runoff (default = 0.0075; IPCC AFOLU Guidelines 2006 Vol.4 Ch.11 Table 11.3); kg N_2O-N (kg N leaching/runoff)$^{-1}$
44/28	Ratio of molecular weights of N_2O and N; mol mol^{-1}
GWP_{N2O}	Global warming potential for N_2O (default = 310 for SAR-100 value in IPCC Fourth Assessment Report); t CO_2-e (t N_2O)$^{-1}$
A_i	Area of stratum *i;* ha *
i	1, 2, 3 …*M* strata
t	*1, 2, 3 …t** years elapsed since the start of the GLLM project activity

* Where stratum area is in acres convert to hectares by multiplying by 0.4047

1.2 Fertilizer production emissions

The CO_2 emissions from the production of fertilizer applied per cropland land area are calculated as follows[6]:

$$GHG_{BSL,F,E} = \sum_{t=1}^{t}\left(\sum_{i=1}^{M}(A_i * AR_{i,f} * EF_{CO_2 f})\right) \quad \textbf{(5)}$$

[6] Methods derived directly from CDM methodology: "Offsetting of synthetic nitrogen fertilizers by inoculants application in legumes-grass rotations on acidic soils on existing cropland". Available at: http://cdm.unfccc.int/UserManagement/FileStorage/BZG8LM2WO95IDQJCF634VUYTPNEKRX

$$GHG_{P,F,E} = \sum_{t=1}^{t}\left(\sum_{i=1}^{M}(A_i * AR_{i,f} * EF_{CO_2 f}) \right) \quad \textbf{(6)}$$

Where:

$GHG_{BSL\ F,E}$	Baseline GHG emissions as a result of production of fertilizer used; t CO_2-e
$GHG_{P\_F,E}$	Project GHG emissions as a result of production of fertilizer used; t CO_2-e
$EF_{CO2,f}$	Emission factor for the production of synthetic nitrogen fertilizer; t CO_2 per ton synthetic nitrogen fertilizer
A_i	Area of land where fertilizer is applied for stratum *i*; ha *
$AR_{i,f}$	Average application rate of fertilizer *f* for stratum *i; t.ha*$^{-1}$ #

* Where stratum area is in acres convert to hectares by multiplying by 0.4047
# Where application rate is in pounds per acres convert to tons per hectare by multiplying by 0.0014

$EF_{CO2,f}$ is calculated following IPCC and CDM guidelines as follows:

If the fertilizer used is urea, the $EF_{CO2,f}$ = 1.54 t CO_2e per ton urea based on IPCC default values shall be used which takes into account the fact that the total GHG emissions from urea would be GHG emissions during ammonia production – intermediate CO_2 storage in urea + CO_2 release due to urea application (see 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use; Chapter 3.2 Ammonia Production).

In case of other synthetic nitrogen fertilizers in the absence of reliable project specific data, conservative values may be calculated (as long as the mass ratio of N in the fertilizer is known) using the following formula:

$$EF_{CO_2,f} = Ncont_f * 0.82 * 2.014 \quad \textbf{(7)}$$

Where:

$EF_{CO2,f}$	The emission factor for the production of fertilizer *f*; t CO_2 per ton fertilizer *f*
$Ncont_f$	The N content of fertilizer *f* on a mass ratio basis (see parameter table for examples for common synthetic N fertilizer types); %
0.82	The mass ratio between N and NH_3
2.014	A conservative emission factor for ammonia production; t CO_2 per ton NH_3

1.3 Baseline

The baseline GHG emissions will be determined as the emissions of N_2O resulting from application of fertilizers.

$$E\_FERT_{BSL} = GHG_{BSL\_N_2O,E} + GHG_{BSL,F,E} \quad \textbf{(8)}$$

Where:

E_FERT_{BSL}	Fertilizer emissions in the baseline; t CO_2-e
$GHG_{BSL\_N2O,E}$	N_2O emissions as a result of fertilizer management activities within the project boundary in the baseline; t CO_2-e
$GHG_{BSL\_F,E}$	GHG emissions as a result of production of fertilizer used in the baseline; t CO_2-e

1.4 With-project

The with-project GHG emissions shall be estimated using the equations in this section. When applying these equations for the *ex ante* calculation of project emissions, Project Proponents shall provide estimates of the values of those parameters that are not available before the start of monitoring activities. Project Proponents must retain a conservative approach in making these estimates.

$$E\_FERT_{P} = GHG_{P\_N_2O,E} + GHG_{P,F,E} \quad \textbf{(9)}$$

Where:

E_FERT_{P}	Fertilizer emissions in the project case; t CO_2-e
$GHG_{P\_N2O,E}$	N_2O emissions as a result of fertilization within the project boundaries in the with-project scenario; t CO_2-e
$GHG_{P\ F,E}$	Project GHG emissions as a result of production of fertilizer used; t CO_2-e

1.5 Summation

Total net fossil fuel emissions will be equal to baseline minus the project:

$$E\_FERT_{prelim} = E\_FERT_{BSL} - E\_FERT_{P} \quad \textbf{(10)}$$

Where:

E_FERT_{prelim}	Net fertilizer emissions prior to uncertainty deductions; t CO_2-e
E_FERT_{BSL}	Fertilizer emissions in the baseline; t CO_2-e

E_FERT_P	Fertilizer emissions in the project case; t CO_2-e

1.6 Uncertainty

Estimated GHG emissions from GLLM activities have uncertainties associated with the measures/estimates of area or other activity data, model inputs and coefficients. It is assumed that the uncertainties associated with the estimates of the various input data are available, either as default values or estimates based on sound statistical sampling. Uncertainties arising from the measurement and monitoring shall always be quantified.

1.6.1 The use of planning to diminish uncertainty

Under the modelling approach, the Project Proponent has the option of replacing standard default input values with project-specific measurements. Project-specific measurements will decrease the model uncertainty, thereby decreasing the uncertainty and required deductions in credited ERTs.

When project-specific measurements are included, a measurement plan should be constructed that minimizes uncertainty. By developing a measurement plan that includes proper stratification and sufficient measurement plots, the Proponent can minimize uncertainty and maximize the potential for full crediting.

It is good practice to consider uncertainty at an early stage to identify the data sources with the highest uncertainty. The timely consideration of uncertainty provides the opportunity to conduct further work to diminish uncertainty.

1.6.2 Estimation of uncertainty for modelled emissions

Uncertainty shall be quantified by means of a Monte Carlo statistical analysis. Process models can include Monte Carlo analysis procedures. If present these shall be used for modelling values across the 90% confidence interval values of the input data.

The output result shall be E_FERT_{ERROR} (the total uncertainty for fertilizer emissions in %). Steps and guidance in the approved ACR methodology for N_2O Emissions Reductions through Changes in Fertilizer Management (http://americancarbonregistry.org/carbon-accounting/carbon-accounting/emissions-reductions-through-changes-in-fertilizer-management) may be used.

Uncertainty shall be further quantified across categories and between baseline and project scenarios using Monte Carlo analyses. The output (E_FERT_{ERROR}) shall be the half width of the ultimate calculated 90% confidence interval divided by estimated net fertilizer emissions.

1.6.3 Uncertainty Deduction

If $E\_FERT_{ERROR} \leq 10\%$ of E_FERT_{prelim} then no deduction for uncertainty is required ($E\_FERT_{prelim} = E\_FERT$).
If $E\_FERT_{ERROR} > 10\%$ of E_FERT_{prelim} then the modified value for E_FERT to account for uncertainty shall be:

$$E\_FERT = E\_FERT_{prelim} - \left(E\_FERT_{prelim} * \left(E\_FERT_{ERROR} - 10\%\right)\right) \quad \textbf{(11)}$$

Where:

E_FERT	Net fertilizer emissions; t CO_2-e
E_FERTprelim	Net fertilizer emissions prior to uncertainty deductions; t CO_2-e
E_FERT_{ERROR}	Total uncertainty for fertilizer emissions; %

Where E_FERT is negative (decrease in fertilizer use by the project) and:

$$E\_FERT = E\_FERT_{prelim} + \left(E\_FERT_{prelim} * \left(E\_FERT_{ERROR} - 10\%\right)\right) \quad \textbf{(12)}$$

Where:

E_FERT	Net fertilizer emissions; t CO_2-e
E_FERTprelim	Net fertilizer emissions prior to uncertainty deductions; t CO_2-e
E_FERT_{ERROR}	Total uncertainty for fertilizer emissions; %

Where E_FERT is positive (increase in fertilizer use by the project).

2.0 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 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	**Selected model inputs**
Units	**Multiple**
Description	Inputs to the selected soil organic carbon and living biomass estimation model
Relevant Section	**1.1 / 1.2**
Relevant Equation(s)	**-**
Source of Data	**Multiple**
Data Requirements	**To be specified in the PDD**

Collection Procedure	To be specified in the PDD
Revision Frequency	Project case prior to each verification; baseline prior to baseline renewal
Comments	

Parameter	$Ncont_f$
Units	N content (% of mass)
Description	The N content of fertilizer f on a mass ratio basis
Relevant Section	
Relevant Equation(s)	11,18
Source of Data	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use
Data Requirements	
Collection Procedure	
Revision Frequency	
Comments	

Synthetic nitrogen fertilizer types	N content (% of mass)
Single nutrient products N-fertilizer	
Anhydrous Ammonia (NH_3) "Ammonia"	82
Ammonium Sulfate [$(NH_4)2SO_4$]	21
Monoammonium Phosphate (MAP)	11
Diammonium Phosphate (DAP)	18
Ammonium Nitrate (NH_4NO_3)	33.5
Calcium Ammonium Nitrate (CAN)	26
Any other synthetic nitrogen fertilizer (e.g., multi nutrient fertilizers (N-P-K))	**Project proponent to calculate**