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The American Carbon Registry® Methodology for N₂O Emission Reductions through Changes in Fertilizer Management

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This methodology was developed by Timothy Pearson of Winrock International and William Salas of Applied Geosolutions LLC, and submitted to the American Carbon Registry for approval through the public consultation and scientific peer review process.

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ACRONYM LIST

See latest version of *ACR Standard* for a full list of acronyms. The following additional acronyms are used in this methodology.

AFOLU Guidelines	Agriculture, Forestry and Other Land Uses section of IPCC Guidelines for National Greenhouse Gas Inventories 2006
ALM	Agricultural Land Management
ALM ACR project activity	Agricultural Land Management activity implemented per ACR requirements
DNDC	DeNitrification-DeComposition, a simulation model of carbon and nitrogen biogeochemistry in agro-ecosystems
GPG LULUCF	IPCC Good Practice Guidance for Land-Use Land Use Change and Forestry
N	Nitrogen
N ₂	Dinitrogen
N ₂ O	Nitrous oxide
NCV	Net Calorific Value
NH ₃	Ammonia
NO	Nitric oxide
NO ₃ ⁻	Nitrate
NRCS	Natural Resources Conservation Service of the U.S. Department of Agriculture
PDF	Probability Distribution Function
PRA	Participatory Rural Appraisal
SOC	Soil organic carbon
SSURGO	Soil Survey Geographic Database of the NRCS National Cartography and Geospatial Center
UAN	Urea Ammonium Nitrate
WFPS	Water Filled Pore Space

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Finally, ACR wishes to thank the participants in the Coalition on Agricultural Greenhouse Gases (C-AGG), Technical working group on Agricultural Greenhouse Gases (T-AGG), and Market Mechanisms for Agricultural Greenhouse Gases (M-AGG) initiatives, who provided valuable support and feedback while this methodology remained in development.

INTRODUCTION

The American Carbon Registry® (ACR) is a voluntary, online greenhouse gas (GHG) registration and emissions tracking system used by members to transparently register verified, project-based emissions reductions and removals as serialized offsets; record the purchase, sale, banking and retirement of verified offsets, branded as Emission Reduction Tons (“ERTs”); and optionally report, in a separate account, verified GHG inventories.

ACR was founded in 1996 by the Environmental Defense Fund and Environmental Resources Trust, and joined Winrock International in 2007. As the first private voluntary GHG registry in the United States, ACR has set the bar for transparency and integrity that is the market standard today.

Winrock International, a non-profit public benefit corporation founded in 1984, works with people in the U.S. and around the world to empower the disadvantaged, increase economic opportunity, and sustain natural resources. Central to Winrock’s mission since its founding has been agricultural and livestock improvement, linking farmers to new markets, and enhancing food security – complemented in recent years by an objective to address potential impacts of climate change on agriculture and reduce the GHG intensity of agricultural production. Since the 1990s, Winrock has been a leader in developing science-based GHG measurement and monitoring protocols.

Purpose

This methodology is applicable to Agricultural Land Management (ALM) ACR project activities that involve a change in fertilizer management. This may include changes in fertilizer rate (quantity), type (specific synthetic or organic fertilizers), placement, timing, use of timed-release fertilizers, use of nitrification inhibitors and other factors. Activities must meet all applicability conditions in Section I to apply this methodology.

The methodology uses DNDC – a peer-reviewed, tested and highly parameterized model – to estimate, for baseline and project scenarios, direct N₂O emissions from fertilizer use and indirect emissions from leaching and ammonia volatilization.

Projects using this methodology must comply with all requirements of the *ACR Standard*, submit a GHG Project Plan for certification by ACR, and secure independent validation and verification by an ACR-approved third-party verifier of the GHG Project Plan and GHG assertions.



All ACR methodologies, whether proposed by a Proponent or developed by Winrock International, are approved through a rigorous public consultation and scientific peer review process.

Project Proponents and other interested parties should refer to www.americancarbonregistry.org for the latest version of this methodology, the *ACR Standard*, ACR sector standards, and other relevant methodologies, tools, and templates.

I. SOURCES, DEFINITIONS AND APPLICABILITY

1. Sources

This methodology is based on elements from the following methodologies:

- Approved CDM methodology AR-ACM0001 “Afforestation and reforestation of degraded land”
- The “Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities”

2. Selected Baseline Approach

Existing or historical emissions, as applicable.

3. Definitions

Definitions in the latest version of the *ACR Standard* apply.

4. Applicability

This methodology is applicable to Agricultural Land Management (ALM) ACR project activities that involve a change in fertilizer management. This may include changes in fertilizer rate (quantity), type, placement, timing, use of timed-release fertilizers, use of nitrification inhibitors and other factors.

The conditions under which the methodology is applicable are:

- Management in both baseline and project cases involves use of fertilizer for enhancing crop growth and survival on agricultural lands;
- Farms must have records of yields and fertilizer application amounts from at least 5 previous years;
- Projects must not lead to a significant decrease in yields as a result of project implementation;
- Project must incorporate a minimum of 10 individual fields¹;
- Fertilizer use must not be increased on all crops on owned or managed lands that are not part of the project;
- On organic soils² project activities may not lead to an increase in tillage relative to baseline practices.

¹ Fields may be adjacent but must be justifiable as individual fields at the time of verification.

² Soils are organic if they satisfy the requirements 1 and 2, or 1 and 3 below:

- The project does not involve the drainage or flooding of wetlands.

Emission reductions from changes in fertilizer management are permanent and cannot be reversed. This methodology therefore requires no buffer or other risk mitigation mechanism.

-
1. Thickness of 10 cm or more. A horizon less than 20 cm thick must have 12 percent or more organic carbon when mixed to a depth of 20 cm;
 2. If the soil is never saturated with water for more than a few days, and contains more than 20 percent (by weight) organic carbon (about 35 percent organic matter);
 3. If the soil is subject to water saturation episodes and has either:
 - (i) At least 12 percent (by weight) organic carbon (about 20 percent organic matter) if it has no clay; or
 - (ii) At least 18 percent (by weight) organic carbon (about 30 percent organic matter) if it has 60 percent or more clay; or
 - (iii) An intermediate, proportional amount of organic carbon for intermediate amounts of clay.
-

II. BASELINE METHODOLOGY PROCEDURE

1. Project Boundary and Eligibility of Land

ACR defines the GHG offset project boundary to include a project’s geographical implementation area, the types of GHG sources and sinks considered, and project duration.

1.1 Physical boundary

The physical boundary geographically delineates the ALM project activity under the control of the project participants. The ALM ACR project activity may contain more than one discrete area of land. At the time the GHG Project Plan is submitted, the following shall be defined:

- Each discrete area of land shall have a unique geographic identification;
- Aggregation of agricultural properties with multiple landowners is permitted under the methodology, with aggregated areas treated as a single project area;
- The project participants shall describe legal title to the land, rights of access to the avoided GHG emissions, current land tenure, and fertilizer management for each discrete area of land;
- The project participants shall justify that, during the project lifetime, each discrete area of land is expected to be subject to a change in fertilizer management through activities under the control of the project participants.

1.2 GHG assessment boundary

Carbon pools are not monitored as part of the methodology, as changes in stocks as a result of fertilizer management under this methodology are considered to be positive (and therefore conservative to omit) or *de minimis*.

The emission sources included in or excluded from the project boundary area shown in Table 1.

Table 1: Emissions sources included in the project boundary

Sources	Gas	Included / Excluded	Justification / Explanation of choice
Direct and Indirect Nitrous Oxide Emissions Resulting from	CO ₂	Excluded	Not applicable
	CH ₄	Excluded	Not applicable

Fertilizer Application	N ₂ O	Included	GHG emitted from fertilizer application
Emissions resulting from Fossil Fuel Combustion	CO ₂	Included	GHG emitted from fossil fuel combustion
	CH ₄	Included	GHG emitted from fossil fuel combustion
	N ₂ O	Included	GHG emitted from fossil fuel combustion

1.3 Project duration

Change in fertilizer management project activities may be implemented for one year or longer. Crediting Period is as specified in the *ACR Standard* or relevant ACR sector standard. Project Proponents shall apply this methodology to model the baseline and project scenarios for each reporting year since the previous verification, using the DNDC-required inputs for that reporting year. Per the *ACR Standard*, the frequency of verification depends on desired frequency of ERT issuance; all emission reductions attributable to the project activity must be verified prior to issuance.

2. Identification of the Baseline Scenario and Additionality

STEP 0. Preliminary screening based on the Start Date of the ALM project activity

As indicated in the *ACR Standard*, agriculture, forestry and other land use (AFOLU) projects with a Start Date of 1 November 1997 or later are eligible for registration.

If the Project Proponent claims the Start Date of the ALM ACR project activity is before the date of submission of a GHG Project Plan, then the Proponent shall:

- Provide evidence that the Start Date of the ALM ACR project activity was after 1 November 1997, and
- Provide evidence that the incentive from the planned sale of ERTs was seriously considered in the decision to proceed with the project activity. This evidence shall be based on (preferably official, legal and/or other corporate) documentation that was available to third parties at, or prior to, the Start Date of the project activity.

ACR may accept AFOLU projects with a Start Date earlier than 1 November 1997 on a case-by-case basis, provided the Project Proponent can verifiably demonstrate that GHG mitigation was an objective from project inception.

STEP 1. Determination of Baseline Scenario

Project Proponent shall identify realistic and credible scenarios that would have occurred on the land within the proposed project boundary in the absence of the ALM ACR project activity. The scenario should be feasible for the project participants or project developers, taking into account relevant national and/or sectoral policies³ and circumstances, such as historical practices and economic trends. The identified management scenario shall be limited to agricultural land uses. This process should clearly identify barriers and benefits of all potential scenarios.

The possible land-use scenarios to be evaluated shall include:

- Continuation of the pre-project fertilizer management (historical baseline);
- Fertilizer management as modeled under the project but in the absence of registration as an ALM ACR project activity;
- Adoption of precision agriculture;
- Change in crop to crops with lower fertilizer use.

For identifying realistic and credible management scenarios, field surveys, data and feedback from stakeholders, and information from other appropriate sources including Participatory Rural Appraisal (PRA)⁴ may be used as appropriate. PRA techniques are not mandatory, provided the Project Proponent identifies realistic and credible management scenarios. All current fertilizer management within the boundary of the proposed ALM ACR project activity may be deemed realistic and credible.

Each of the identified land use scenarios shall be evaluated relative to the following tests:

- Investment analysis to determine that the proposed project activity is either: 1) not the most economically or financially attractive, or 2) not economically or financially feasible;
- Barriers analysis; and
- Common practice analysis.

Each of the land use scenarios that do not meet at least one of the a) common practice analysis, b) the barriers analysis and c) the investment analysis shall be excluded.

³ The Annex 3 to the report of the CDM Executive Board at its twenty-second meeting and the Annex 19 to the report of the EB at its twenty-third meeting clarify how the relevant national and/or sectoral policies shall be taken into account during identification of a baseline scenario. See: <http://cdm.unfccc.int/Reference/Guidclarif>.

⁴ Participatory rural appraisal (PRA) is an approach to the analysis of local problems and the formulation of tentative solutions with local stakeholders. It makes use of a wide range of visualisation methods for group-based analysis to deal with spatial and temporal aspects of social and environmental problems. This methodology is, for example, described in Chambers R (1992): *Rural Appraisal: Rapid, Relaxed, and Participatory*. Discussion Paper 311, Institute of Development Studies, Sussex; and Theis J, Grady H (1991): *Participatory rapid appraisal for community development*. Save the Children Fund, London.

If fertilizer management as modeled under the project but in the absence of registration as an ALM ACR project activity is not excluded, then the project is not additional.

Outcome of Step 1: List of plausible alternative fertilizer management scenarios to the ALM ACR project activity.

STEP 2. Additionality Test

The Project Proponent shall test the additionality of the project using the three-pronged ACR additionality test.⁵ The project scenario as described *ex ante* using this methodology and monitored using this methodology shall be evaluated alongside the baseline scenarios identified in Step 1. If a financial analysis or a demonstration of barriers does not lead to the preclusion of the project scenario then the project shall be considered non-additional. The application of an additionality tool is recommended.⁶

Outcome of Step 2: A project scenario with proven additionality or identification of a non-additional project.

3. Stratification

If the project activity area is not homogeneous, stratification must be carried out to improve the accuracy and precision of GHG emission estimates. Different stratifications may be required for the baseline and project scenarios in order to achieve optimal accuracy and precision of the estimates of net GHG emissions reductions.

For estimation of baseline emissions, strata must be defined on the basis of parameters that are key variables in any method used to estimate changes in agricultural emissions, for example:

- Management regime
- Soil type
- Planting history
- Drainage

The project area must be stratified *ex ante*. Further stratification beyond the parameters given above is not usually warranted.

Note: In the equations used in this methodology, the letter *i* is used to represent a stratum and the letter *M* for the total number of strata.

⁵ As described in the *ACR Standard*.

⁶ Such as the CDM Tool for the Demonstration and Assessment of Additionality at: <http://cdm.unfccc.int/methodologies/PAMethodologies/tools/am-tool-01-v5.2.pdf>.

4. Modeling Approach to Direct and Indirect Emissions from Fertilizer Management

4.1 Modeling of emissions from fertilizer application

The model used for calculation of emissions resulting from fertilization must be the DeNitrification-DeComposition (DNDC) model developed by the University of New Hampshire. DNDC is a computer simulation model of carbon and nitrogen biogeochemistry in agro-ecosystems. The model can be used for predicting crop growth, soil temperature and moisture regimes, soil carbon dynamics, nitrogen leaching, and emissions of trace gases including nitrous oxide (N₂O), nitric oxide (NO), dinitrogen (N₂), ammonia (NH₃), methane (CH₄) and carbon dioxide (CO₂). DNDC is available at <http://www.dndc.sr.unh.edu/>. The latest version shall always be used.⁷

The model must be:

- Parameterized for the specific conditions of the project;
- May not be used where cultivation is occurring on histosols (organic soils).

The output of the model must be the direct N₂O emissions ($NL_{DIRECT,j,i,t}$) in kg N₂O-N, the nitrate leaching loss ($NL_{LEACH,j,i,t}$) in kg NO₃⁻-N and the nitric oxide emissions and ammonia volatilization ($NL_{VOLAT,j,i,t}$) in kg NH₃-N, by strata, in both the baseline and project scenarios through the duration of the project.

4.2 Input data to DNDC

DNDC model simulations require inputs on the location of crop fields, crops grown, local climate, soils and agricultural management practices. These input data are required for each baseline and project stratum.

The full list of inputs, units and data source is given in Table 2. More detail is found in the parameter tables.

⁷ Downloadable from <http://www.dndc.sr.unh.edu/Models.html>. Project Proponents shall use the latest version available.



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Table 2. List of DNDC inputs with units and data source. Where two data sources are indicated, the choice rests with the Project Proponent.

Input Category	Code	Input	Units	Mandatory / Optional	Data Source			
					Project records	Measured	Look-up	Default
Location	L1	GPS location of stratum	decimal ⁰	M		X		
Climate	C1	Atmospheric background NH ₃ concentration	µg N/m ³	M				X
	C2	Atmospheric background CO ₂ concentration	ppm	M				X
	C3	N concentration in rainfall	mg N/l or ppm	M				
Soils**	C4	Daily meteorology	multiple	M		X	X	
	S1	Land-use type	type	M	X			
	S2	Clay content	0-1	M		X	X	
	S3	Bulk density	g/cm ³	M		X	X	
	S4	Soil pH	value	M		X	X	
	S5	SOC at surface soil	kg C/kg	M		X	X	
	S6	Soil texture	type	M		X	X	
	S7	Slope	%	M		X	X	
	S8	Depth of water retention layer	cm	M		X	X	
	S9	High groundwater table	cm	M		X	X	
	S10	Field capacity	0-1	M		X		X
S11	Wilting point	0-1	M		X		X	
Cropping system	CR1	Crop type	type	M	X			
	CR2	Planting date	date	M	X			
	CR3	Harvest date	date	M	X			
	CR4	C/N ratio of the grain	ratio	M		X	X	
	CR5	C/N ratio of the leaf + stem tissue	ratio	M		X	X	
	CR6	C/N ratio of the root tissue	ratio	M		X	X	
	CR7	Fraction of leaves and stem left in field after harvest	0-1	M		X		
	CR8	Maximum yield	kg dry matter.ha ⁻¹	M	X			
Tillage system	T1	Number of tillage events	number	M	X			
	T2	Date of tillage events	date	M	X			
	T3	Depth of tillage events	6 depths†	M	X			
N Fertilizer	F1	Number of fertilizer applications	number	M	X			
	F2	Date of each fertilizer application	date	M	X			
	F3	Application method	surface / injection	M	X			
	F4	Type of fertilizer	type*	M	X			
	F5	Fertilizer application rate	kg N.ha ⁻¹	M	X			
	F6	Time-release fertilizer	# days for full release	M	X			
	F7	Nitrification inhibitors		M	X			
Organic Fertilizer	O1	Number of organic applications per year	number	M	X			
	O2	Date of application	date	M	X			
	O3	Type of organic amendment	type	M	X			
	O4	Application rate	kg C.ha ⁻¹	M	X			
	O5	Amendment C/N ratio	ratio	M				X
Irrigation System	I1	Number of irrigation events	number	M	X			



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12	Date of irrigation	date	M	X
13	Irrigation type	3 types‡	M	X
14	Irrigation application rate	mm	M	X

†0, 5, 10, 20, 30, 50 cm

*DND C accepts seven types of fertilizers: Urea, Anhydrous Ammonia, Ammonium Nitrate, Nitrate, Ammonium Bicarbonate, Ammonium Sulfate and Ammonium Phosphate.

‡Flood, sprinkler or surface drip tape

**Soil parameters for DND C are for the properties of the top layer of the soil profile.

4.3 Running the DNDC model

The DNDC model is written in Visual C++ 6.0 and must be run on a Microsoft Windows operating system⁸.

STEP 1: Calibrating DNDC crop model

Proper parameterization of soil physical conditions (which drive soil moisture dynamics) and crop simulation plays a crucial role in modeling C and N biogeochemistry and N₂O emissions. Through transpiration and N uptake as well as depositing litter into soil, plant growth regulates soil water, C and N regimes, which in turn determine a series of biogeochemical reactions impacting N₂O emissions. Users shall calibrate the DNDC crop model for cropping systems to be included in the project. Figure 1 outlines the steps for crop calibration. In DNDC, crops are defined by the following parameters:

- **Maximum biomass (kg C per ha):** The maximum biomass productions for grain, leaves+stems (non-harvest above ground biomass), and roots under optimum growing conditions (namely, maximum biomass assuming no N, water or growing degree day limitations). The unit is kg C.ha⁻¹ (1 kg dry matter contains 0.4 kg C). If local data are not available, then literature values can be used. Maximum yield values will be used for step 2 in figure 1 below.
- **Biomass fraction:** The grain, leaves+stem, and root fractions of total biomass at maturity.
- **Biomass C/N ratio:** Ratio of C/N for grain, leaves+stems, and roots at maturity.
- **Total N demand (kg N per ha):** Amount of the total N demanded by the crop to reach the maximum production.
- **Thermal degree days (°C):** Cumulative air temperature from seeding till maturity of the crop.
- **Water demand (g water/g dry matter):** Amount of water needed for the crop to produce a unit of dry matter of biomass.
- **N fixation index:** The default number is 1 for non-legume crops. For legume crops, the N fixation index is equal to the ratio (total N content in the plant)/(plant N taken from soil).

⁸ Download an installation package from the following site: <http://www.dnnc.sr.unh.edu>. After uncompressing the installation file package, double click "Install" in the package folder, and all of the directories and files of DNDC will be automatically created in a folder named DNDC in the C drive of your computer. The folder DNDC on your C drive contains the latest version of DNDC (e.g., DNDC9.4) and supporting data sets. Go to C:\DNDC, and click DNDC94.exe to start the model.



Default values for these parameters are provided with DNDC and can be found in the C:\DNDC\Library\Lib_crop directory. There is a crop.lst file that provides the look up table for crop numbers for each crop. All crops to be included in the ALM project shall be calibrated in DNDC using at least 5 years of observed yields.

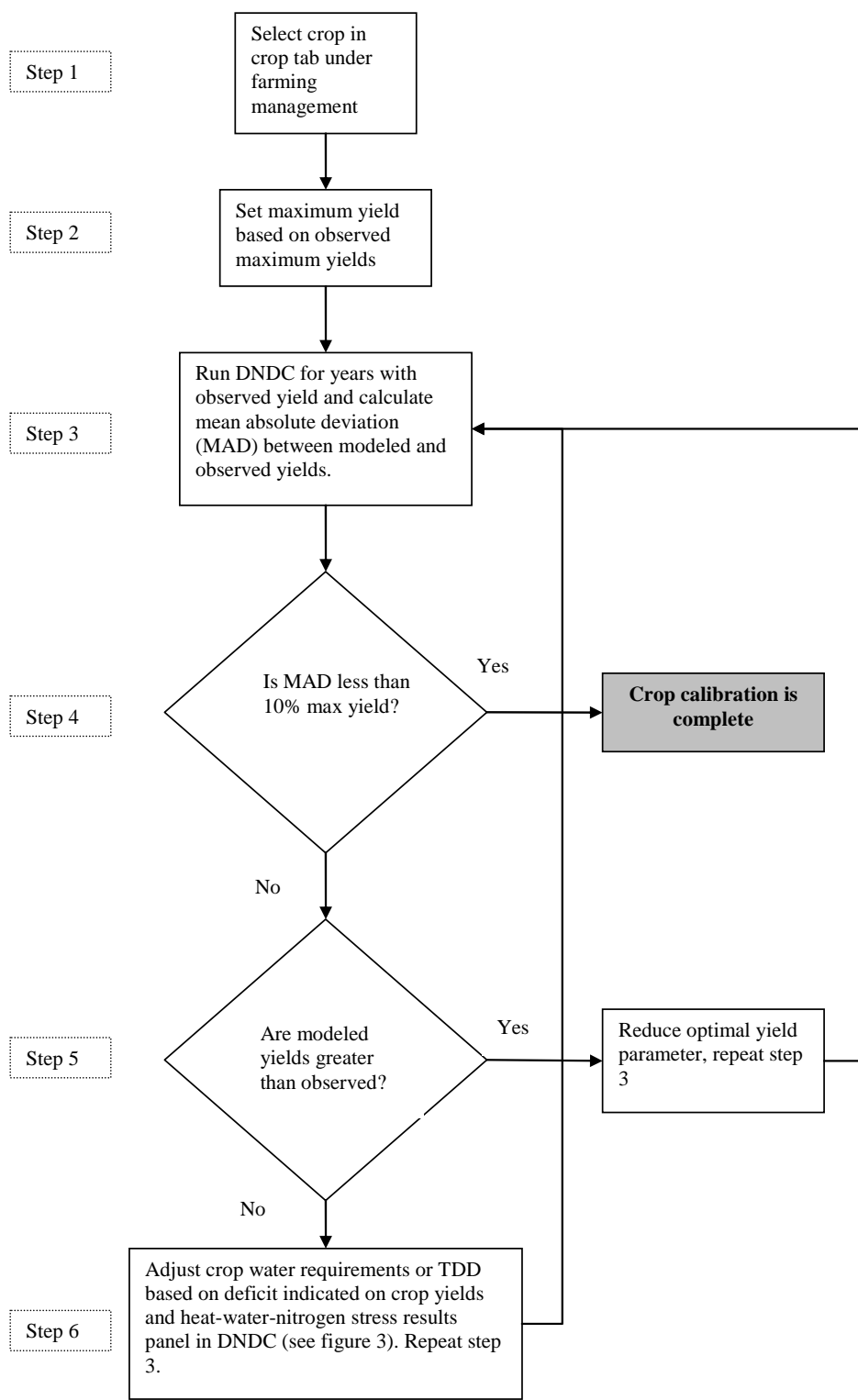


Figure 1: Crop calibration procedures. Where local data are not available literature may be used.

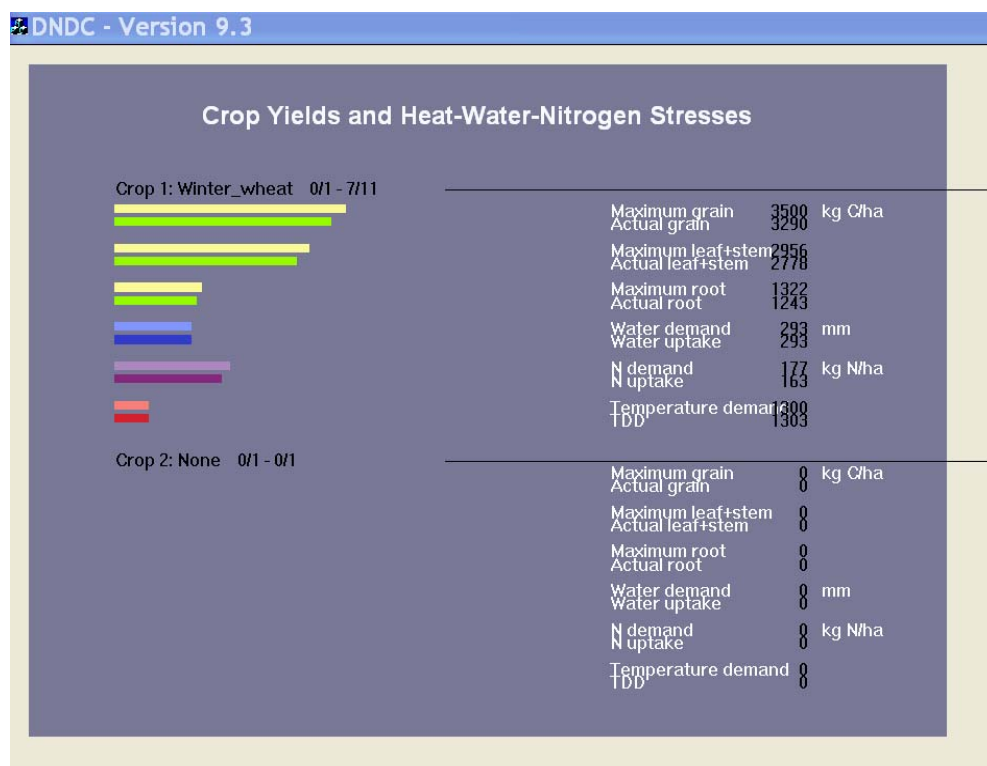


Figure 2: Example DNDC Crop Yield and Heat-Water-Nitrogen Stress panel.

Note: If the mean absolute deviation does not decrease below 10% (Step 4 in Figure 1) as crop parameters (optimal yield, TDD and crop water requirements) are refined, then choose the parameters set that provides the minimum mean absolute deviation and record the value of the minimum absolute deviation. Parameters shall be chosen using the literature and expert knowledge.

STEP 2: Define uncertainty ranges for input parameters

Soil physical and chemical properties have a significant impact on N₂O production, consumption and emissions. Project Proponents have the choice of estimating soil conditions based on field samples or soil surveys. If field measurements are used, then the target precision level for each soil parameter shall be +/-10% of the mean at a 90% confidence level. The distribution of the field values shall be assumed to be normally distributed.

If NRCS SSURGO soil survey data⁹ are used for setting soil parameters, then default uncertainty estimates shall be set based on uncertainty estimates and probability distribution functions (PDF) listed

⁹ See <http://soils.usda.gov/survey/geography/ssurgo/>.

in Table 3. For each stratum, the mean value shall be calculated as the area-weighted sum of the representative values for all compartments with the SSURGO MUKEY¹⁰.

Table 3. Source selected from <http://www.abdn.ac.uk/modelling/cost627/Questionnaire.htm>

Parameter	PDF	Uncertainty
Bulk density	Log-normal	0.1 g.cm ⁻³
Clay content	Log-normal	+/- 10%
SOC	Log-normal	+/- 20%
pH	Normal	+/- 1 pH unit

A selection of 4,096 soil parameter (SOC, pH, clay fraction and bulk density) combinations shall be compiled for the Monte Carlo DNDC model runs (STEPS 3 and 4). The selection soil parameter combination will be random selection for each parameter based on the PDF and uncertainty estimates (derived from field measurements).

STEP 3: Run DNDC in Monte Carlo mode for Baseline and Project N₂O Emissions

The baseline ($GHG_{BSL_N2O,E,i,j}$) and project ($GHG_{P_N2O,E,i,j}$) GHG emissions in stratum i for each Monte Carlo run j will be determined as the sum of direct and indirect emissions of N₂O resulting from application of fertilizers. Based on the uncertainty of input soil parameters quantified in STEP 2, DNDC will be run in Monte Carlo mode. The duration of the Monte Carlo runs should be the same as the duration of the project (e.g. two-year projects should perform a two-year Monte Carlo run). Previous cropping history has an impact on N₂O emissions. Thus, N₂O emissions for a given baseline year will be modeled by running DNDC for two years to include the year preceding the baseline year.

Once the Monte Carlo run is complete, results are recorded in a CSV file in the C:\DNDC\Result\Record\MonteCarlo folder. The name of the file is the site name as entered into DNDC. From the CSV file extract the direct N₂O emissions, nitrate leaching, NH₃ and NO emissions for Monte Carlo run j in each stratum i as follows:

$NL_{DIRECT,j,i}$ Direct annual N₂O emissions in stratum i from Monte Carlo run j ; kg N₂O-N.ha⁻¹

$NL_{LEACH,j,i}$ Annual nitrate leaching loss in stratum i from Monte Carlo run j ; kg NO₃⁻-N.ha⁻¹

¹⁰ Polygon GIS layers are linked to attribute tables via an attribute called MUKEY.

$NL_{VOLAT,j,i}$ Annual ammonia volatilization and nitric oxide emissions in stratum i from Monte Carlo run j ; kg NH₃-N.ha⁻¹ + NO_x-N.ha⁻¹ volatilized

Calculate total average N₂O emissions in metric tons (t) CO₂-e.ha⁻¹ in stratum i for all Monte Carlo runs as follows:

$$GHG_{BSL_N_2O,E,j,i} = \left(NL_{DIRECT,j,i} + \left(NL_{VOLAT,j,i} * EF_4 \right) + \left(NL_{LEACH,j,i} * EF_5 \right) \right) * \frac{44}{28} * GWP_{N_2O} \quad (1)$$

$$GHG_{P_N_2O,E,j,i} = \left(NL_{DIRECT,j,i} + \left(NL_{VOLAT,j,i} * EF_4 \right) + \left(NL_{LEACH,j,i} * EF_5 \right) \right) * \frac{44}{28} * GWP_{N_2O} \quad (2)$$

$$GHG_{BSL_N_2O,E,i} = \frac{\sum_{j=1}^N \left(GHG_{BSL,N_2O,E,j,i} \right)}{n} \quad (3)$$

$$GHG_{P_N_2O,E,i} = \frac{\sum_{j=1}^N \left(GHG_{P,N_2O,E,j,i} \right)}{n} \quad (4)$$

Where

$GHG_{BSL_N_2O,E,j,i}$ N₂O emissions as a result of fertilizer management activities for Monte Carlo run j in stratum i within the project boundary in the baseline; t CO₂-e.ha⁻¹

$GHG_{P_N_2O,E,j,i}$ N₂O emissions as a result of fertilizer management activities for Monte Carlo run j in stratum i within the project boundary for the project scenario; t CO₂-e.ha⁻¹

$GHG_{BSL_N_2O,E,j,i}$ N₂O emissions as a result of fertilizer application within the project boundary in the baseline scenario for Monte Carlo run j in stratum i ; t CO₂-e.ha⁻¹

$GHG_{P_N_2O,E,j,i}$ N₂O emissions as a result of fertilizer application within the project boundary in the project scenario for Monte Carlo run j in stratum i ; t CO₂-e.ha⁻¹

$NL_{DIRECT,j,i}$ Direct annual N₂O emissions in stratum i from Monte Carlo run j ; kg N₂O-N.ha⁻¹

$NL_{LEACH,j,i}$ Annual nitrate leaching loss in stratum i from Monte Carlo run j ; kg NO₃-N.ha⁻¹

$NL_{VOLAT,j,i}$ Annual ammonia volatilization and nitric oxide emissions in stratum i from Monte

	Carlo run j ; kg NH ₃ -N.ha ⁻¹ + NO _x -N.ha ⁻¹ volatilized
EF_4	Emission factor for N ₂ O 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 ₂ O-N (kg NH ₃ -N + NO _x -N volatilized) ⁻¹
EF_5	Emission factor for N ₂ O emission from N leaching and runoff (default = 0.0075; IPCC AFOLU Guidelines 2006 Vol.4 Ch.11 Table 11.3); kg N ₂ O-N (kg N leaching/runoff) ⁻¹
44/28	Ratio of molecular weights of N ₂ O and N; mol mol ⁻¹
GWP_{N_2O}	Global warming potential for N ₂ O (default = 310 for SAR-100 value in IPCC Fourth Assessment Report); t CO ₂ -e (t N ₂ O) ⁻¹
j	1, 2, 3 ... N Monte Carlo runs
i	1, 2, 3 ... M strata

5. Baseline Net GHG Emissions

The baseline GHG emissions will be determined as the emissions of N₂O resulting from application of fertilizers. Changes in carbon stocks will not be significant and are not tracked.

$$BE = GHG_{BSL_N_2O,E} + GHG_{BSL_FF,E} + GHG_{BSL,F,E} \quad (5)$$

Where

BE	Baseline greenhouse gas emissions; t CO ₂ -e
$GHG_{BSL_N_2O,E}$	N ₂ O emissions as a result of fertilizer management activities within the project boundary in the baseline; t CO ₂ -e
$GHG_{BSL_FF,E}$	GHG emissions as a result of fossil fuel combustion 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

5.1 Accounting baseline emissions from fertilizer application

The GHG emissions in the baseline within the project boundary can be estimated as the sum of GHG emissions for all strata as follows:

$$GHG_{BSL_N_2O,E} = \sum_{t=1}^{t^*} \left(\sum_{i=1}^M (GHG_{BSL,N_2O,E,i} * A_i) \right) \quad (6)$$

Where

$GHG_{BSL_N_2O,E}$	N ₂ O emissions as a result of fertilizer management activities within the project boundary in the baseline; t CO ₂ -e
$GHG_{BSL_N_2O,E,i}$	N ₂ O emissions from stratum i as a result of fertilizer application within the project boundary in the baseline; t CO ₂ -e.ha ⁻¹
A_i	Area of stratum i
i	1, 2, 3 ... M strata
t	1, 2, 3 ... t^* years elapsed since the start of the ALM ACR project activity

5.2 Accounting baseline emissions from fossil fuel combustion

Emissions resulting from fossil fuel combustion during agricultural land management shall be calculated as follows:

$$GHG_{BSL_FF,E} = \sum_a (Fuel_{a,t} \times EF_a) \quad (7)$$

Where

$GHG_{BSL_FF,E}$	Net CO ₂ -e emissions from fossil fuel consumption in the baseline scenario; tCO ₂ -e
$Fuel_{a,t}$	Amount of fuel of type a consumed in year t ; terrajoule (TJ)
EF_a	Emission Factor of Fuel type a ; tCO ₂ -e.TJ ⁻¹
a	Fuel type a (e.g. diesel, gasoline, etc.)

Where fuel data are collected in liters, the amount of fuel of a particular kind combusted in year t ($Fuel_{a,t}$) can be estimated as:

$$Fuel_{a,t} = \frac{(Liters_{Fuel_{a,t}} \times Density_{Fuel_a} \times NCV_{Fuel})}{10^6} \quad (8)$$

Where

- $Fuel_{a,t}$ Amount of fuel type *a* consumed in year *t*, TJ
- $Liters_{Fuel_{a,t}}$ Quantity of fuel of type *a* consumed in year *t*, ltr
- $Density_{Fuel_a}$ Density of fuel type *a*; kg.ltr⁻¹
- NCV_{Fuel_a} Net Calorific Value of Fuel type *a*; TJ.Gg⁻¹
- a* Fuel type *a* (e.g. diesel, gasoline, etc.)

In the parameter tables default values are provided for all parameters not monitored.

Where fuel data are collected in US gallons, the amount of fuel of a particular kind combusted in year *t* ($Fuel_{a,t}$) can be estimated as:

$$Fuel_{a,t} = \frac{(Gallons_{Fuel_{a,t}} \times Density_{Fuel_a} \times NCV_{Fuel})}{10^6} \quad (9)$$

Where

- $Fuel_{a,t}$ Amount of fuel type *a* consumed in year *t*, TJ
- $Gallons_{Fuel_{a,t}}$ Quantity of fuel of type *a* consumed in year *t*, gal
- $Density_{Fuel_a}$ Density of fuel type *a*; kg.gal⁻¹
- NCV_{Fuel_a} Net Calorific Value of Fuel type *a*; TJ.Gg⁻¹
- a* Fuel type *a* (e.g. diesel, gasoline, etc.)

In the parameter tables default values are provided for all parameters not monitored.

5.3 Accounting baseline emissions from fertilizer production

The CO₂ baseline emissions from the production of fertilizer applied on per cropland land area *j* are calculated as follows¹¹:

$$GHG_{BSL,F,E} = \sum_{t=1}^t \left(\sum_{i=1}^M (A_i * AR_{i,f} * EF_{CO_2,f}) \right) \quad (10)$$

Where

$GHG_{BSL,F,E}$ Baseline GHG emissions as a result of production of fertilizer used; t CO₂-e

$EF_{CO_2,f}$ Emission factor for the production of synthetic nitrogen fertilizer; t CO₂ per ton synthetic nitrogen fertilizer

A_i Area of land where fertilizer is applied for stratum *i*

$AR_{i,f}$ Average application rate of fertilizer *f* for stratum *i*; t.ha⁻¹

$EF_{CO_2,f}$ is calculated following IPCC and CDM guidelines as follows:

If the fertilizer used is urea, the $EF_{CO_2,f} = 1.54$ t CO₂e 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 CO₂ storage in urea + CO₂ 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:

$$EF_{CO_2,f} = Ncont_f * 0.82 * 2.014 \quad (11)$$

Where

$EF_{CO_2,f}$ The emission factor for the production of fertilizer *f*; t CO₂ per ton fertilizer *f*

¹¹ 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>

<i>Ncont_f</i>	The N content of fertilizer <i>f</i> 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

6. Actual Net GHG Project Emissions

The actual net GHG project emissions shall be estimated using the equations in this section. When applying these equations for the *ex ante* calculation of net GHG 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.

$$PE = GHG_{P_N_2O,E} + GHG_{P_FF,E} + GHG_{P,F,E} \quad (12)$$

Where

<i>PE</i>	Actual net project emissions; t CO ₂ -e
<i>GHG_{P_N2O,E}</i>	N ₂ O emissions as a result of fertilization within the project boundaries in the with-project scenario; t CO ₂ -e
<i>GHG_{P_FF,E}</i>	GHG emissions as a result of fossil fuel combustion within the project boundaries in the with-project scenario; t CO ₂ -e
<i>GHG_{P_F,E}</i>	Project GHG emissions as a result of production of fertilizer used; t CO ₂ -e

6.1 Estimation of GHG emissions within the project boundary from fertilizer application

The GHG emissions from fertilization within the project boundary can be estimated as the sum of GHG emissions from all strata as follows:

$$GHG_{P_N_2O,E} = \sum_{t=1}^{t^*} \left(\sum_{i=1}^M (GHG_{P,N_2O,E,i} * A_i) \right) \quad (13)$$

Where

$GHG_{P_N2O,E}$	N ₂ O emissions as a result of fertilization within the project boundaries in the with-project scenario; t CO ₂ -e
$GHG_{P_N2O,E,i}$	N ₂ O 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
A_i	Area of stratum i
i	1, 2, 3 ... M strata
t	1, 2, 3 ... t^* years elapsed since the start of the ALM ACR project activity

6.2 Estimation of GHG emissions within the project boundary from fossil fuel combustion

Emissions resulting from fossil fuel combustion during agricultural land management shall be calculated as follows:

$$GHG_{P_FF,E} = \sum_a (Fuel_{a,t} \times EF_a) \quad (14)$$

Where

$GHG_{P_FF,E}$	Net CO ₂ -e emissions of fossil fuel consumption in the with-project scenario; tCO ₂ -e
$Fuel_{a,t}$	Amount of fuel of type a consumed in year t ; terrajoule (TJ)
EF_a	Emission Factor of fuel type a ; tCO ₂ -e.TJ ⁻¹
a	Fuel type a (e.g. diesel, gasoline, etc.)

Where fuel data are collected in liters, the amount of fuel of a particular kind combusted in year t ($Fuel_{a,t}$) can be estimated as:

$$Fuel_{a,t} = \frac{(Liters_{Fuel_{a,t}} \times Density_{Fuel_a} \times NCV_{Fuel})}{10^6} \quad (15)$$

Where

$Fuel_{a,t}$	Amount of fuel type a consumed in year t ; TJ
$Liters_{Fuel_{a,t}}$	Quantity of fuel of type a consumed in year t ; ltr
$Density_{Fuel_a}$	Density of fuel type a ; kg.ltr ⁻¹

$NCV_{Fuel\ a}$ Net Calorific Value of Fuel type a ; TJ.Gg⁻¹

a Fuel type a (e.g. diesel, gasoline, etc.)

In the parameter tables default values are provided for all parameters not monitored.

Where fuel data are collected in US gallons, the amount of fuel of a particular kind combusted in year t ($Fuel_{a,t}$) can be estimated as:

$$Fuel_{a,t} = \frac{(Gallons_{Fuel\ a,t} \times Density_{Fuel\ a} \times NCV_{Fuel})}{10^6} \quad (16)$$

Where

$Fuel_{a,t}$ Amount of fuel type a consumed in year t ; TJ

$Gallons_{Fuel\ a,t}$ Quantity of fuel of type a consumed in year t ; gal

$Density_{Fuel\ a}$ Density of fuel type a ; kg.gal⁻¹

$NCV_{Fuel\ a}$ Net Calorific Value of Fuel type a ; TJ.Gg⁻¹

a Fuel type a (e.g. diesel, gasoline, etc.)

In the parameter tables default values are provided for all parameters not monitored.

6.3 Accounting project emissions from fertilizer production

The CO₂ project emissions from the production of fertilizer applied on per cropland land area j are calculated as follows¹²:

$$GHG_{P,F,E} = \sum_{t=1}^t \left(\sum_{i=1}^M (A_i * AR_{i,f} * EF_{CO_2f}) \right) \quad (17)$$

Where

$GHG_{P,F,E}$ Project GHG emissions as a result of production of fertilizer used; t CO₂-e

¹² 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>

$EF_{CO_2,f}$	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
$AR_{i,f}$	Average application rate of fertilizer f for stratum i ; t.ha ⁻¹

$EF_{CO_2,f}$ is calculated following IPCC and CDM guidelines as follows:

If the fertilizer used is urea, the $EF_{CO_2,f} = 1.54$ tCO₂e per ton urea based on IPCC may be used which takes into account the fact that the total GHG emissions from urea would be GHG emissions during ammonia production – intermediate CO₂ storage in urea + CO₂ 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:

$$EF_{CO_2,f} = Ncont_f * 0.82 * 2.014 \quad (18)$$

Where

$EF_{CO_2,f}$	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	Conservative emission factor for ammonia production; t CO ₂ per ton NH ₃

7. Leakage

Under the applicability conditions of this methodology, yields may not be decreased as a result of project implementation. As a result there can be no shifting of activities nor any market impacts of the project. Specifically, fertilizer use may not be decreased in one location and increased in another location outside the project boundary. There shall be no limitation on the management of fields outside the project boundaries, but Project Proponents shall demonstrate that fertilizer use has not been shifted.

Leakage under this methodology is therefore equal to zero. This shall be demonstrated through a comparison of the yield estimations by DNDC across the project for the baseline case against the with-project case. Total yield shall not be decreased in the with-project scenario relative to the baseline scenario by more than 5% in any given year.

It is possible that yields will increase in the project scenario relative to the baseline potentially leading to *positive leakage*. This increases the benefit of the project and the conservativeness of estimates, but the GHG benefits of positive leakage are not quantified or credited.

8. Net GHG Emissions

The net GHG emission reduction is the actual net project GHG emissions minus the baseline GHG emissions. The following general formula can be used to calculate the net GHG removals by emission reductions of an ALM ACR project activity ($C_{ALM-ACR}$) in t CO₂-e.

$$ER_{ALM-ACR} = PE - BE \quad (19)$$

Where

$ER_{ALM-ACR}$ Net greenhouse gas emission reduction; t CO₂-e

PE Actual net project emissions; t CO₂-e

BE Baseline emissions; t CO₂-e

Estimated GHG emissions from ALM activities have uncertainties associated with the measures/estimates of area or other activity data, DNDC inputs and coefficients. It is assumed that the uncertainties associated with the estimates of the various input data are available (see Section 4, Step 2), either as default values or estimates based on sound statistical sampling. Uncertainties arising from the measurement and monitoring shall always be quantified.

Uncertainty at all times is defined as the 90% confidence interval as a percentage of the mean.

8.1 The use of planning to diminish uncertainty

Under the DNDC modeling 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.

8.2 Estimation of uncertainty for modeled emissions

Model uncertainty shall be derived from the set of 4,096 Monte Carlo runs for both the baseline and project simulations separately. Model uncertainty at 90% confidence level shall be calculated on a per stratum basis as follows:

$$UNCERTAINTY_{BSL,i} = \frac{\left(\frac{S_{BSL,i}}{\sqrt{4096}}\right) * 1.645}{GHG_{BSL_N2O,E,i}} \quad (20)$$

$$UNCERTAINTY_{P,i} = \frac{\left(\frac{S_{P,i}}{\sqrt{4096}}\right) * 1.645}{GHG_{P_N2O,E,i}} \quad (21)$$

$$S_{BSL,i} = \sqrt{\frac{\sum_{j=1}^n \left(GHG_{BSL_N2O,E,j,i} - GHG_{BSL_N2O,E,i}\right)^2}{(4096 - 1)}} \quad (22)$$

$$S_{P,i} = \sqrt{\frac{\sum_{j=1}^n \left(GHG_{P_N2O,e,j,i} - GHG_{P_N2O,E,i}\right)^2}{(4096 - 1)}} \quad (23)$$

Where

UNCERTAINTY_{BSL,i} Total uncertainty in stratum i in baseline scenario; %

UNCERTAINTY_{P,i} Total uncertainty in stratum i in the with-project scenario; %

S_{BSL,i} Standard deviation of the modeled baseline GHG emissions in stratum i derived from the Monte Carlo runs.

$S_{P,i}$	Standard deviation of project GHG emissions in stratum i derived from the Monte Carlo runs.
$GHG_{BSL_N2O,E,i}$	N ₂ O emissions as a result of fertilizer application within the project boundary in the baseline scenario for stratum i; t CO ₂ -e.ha ⁻¹
$GHG_{P_N2O,E,i}$	N ₂ O emissions as a result of fertilizer application within the project boundary in the project scenario for stratum i; t CO ₂ -e.ha ⁻¹
$GHG_{BSL_N2O,E,j,i}$	N ₂ O emissions as a result of fertilizer application within the project boundary in the baseline scenario for Monte Carlo run j in stratum i; t CO ₂ -e.ha ⁻¹
$GHG_{P_N2O,E,j,i}$	N ₂ O emissions as a result of fertilizer application within the project boundary in the project scenario for Monte Carlo run j in stratum i; t CO ₂ -e.ha ⁻¹
j	1, 2, 3 ... N Monte Carlo runs
i	1, 2, 3 ...M strata

8.3 Total uncertainty of ACR-ALM project

The total project uncertainty is calculated at the time of reporting through propagating the errors across strata and then between the error in baseline emissions and the error in the project emissions:

$$UNCERTAINTY_{BSL} = \sqrt{UNCERTAINTY_{BSL,i1}^2 + UNCERTAINTY_{BSL,i1}^2 + \dots + UNCERTAINTY_{BSL,iM}^2} \quad (24)$$

$$UNCERTAINTY_P = \sqrt{UNCERTAINTY_{P,i1}^2 + UNCERTAINTY_{P,i1}^2 + \dots + UNCERTAINTY_{P,iM}^2} \quad (25)$$

$$ER_{ALM-ACR_ERROR} = \sqrt{UNCERTAINTY_{BSL}^2 + UNCERTAINTY_P^2} \quad (26)$$

Where

$ER_{ALM-ACR_ERROR}$ Total uncertainty for ALM-ACR Project; %

$Uncertainty_{BSL}$ Total uncertainty in baseline scenario; %

Uncertainty _P	Total uncertainty in the with-project scenario; %
Uncertainty _{B_{SL},i}	Total uncertainty in stratum i in baseline scenario; %
Uncertainty _{P,i}	Total uncertainty in stratum i in the with-project scenario; %
i	1, 2, 3 ...M strata

8.4 Uncertainty Deduction

If $ER_{ALM-ACR_ERROR} \leq 10\%$ of $ER_{ALM-ACR}$ then no deduction for uncertainty is required.

If $ER_{ALM-ACR_ERROR} > 10\%$ of $ER_{ALM-ACR}$ then the modified value for $C_{ALM-ACR}$ to account for uncertainty shall be:

$$= ER_{ALM-ACR} - \left(ER_{ALM-ACR} * \left(ER_{ALM-ACR_ERROR} - 10\% \right) \right) \quad (27)$$

Where

$ER_{ALM-ACR}$ Net GHG emission reduction; t CO₂-e

$ER_{ALM-ACR_ERROR}$ Total uncertainty for ALM-ACR Project; %

8.5 Calculation of ERTs

To estimate the amount of ERTs that can be issued at time $t=t_2$ (the date of verification) for monitoring period $T=t_2-t_1$, this methodology uses the following equation:

$$ERTs = ER_{ALM-ACR,t2} - ER_{ALM-ACR,t1} \quad (28)$$

Where

ERTs Emission Reduction Tons

$ER_{ALM-ACR,t2}$ Net GHG emission reduction, as estimated for $t^*=t_2$; t CO₂-e

$ER_{ALM-ACR,t1}$ Net GHG emission reduction, as estimated for $t^*=t_1$; t CO₂-e

Emission reductions from changes in fertilizer management are permanent and cannot be reversed. The calculation of ERTs therefore requires no buffer deduction or other risk mitigation mechanism.

9. Data and parameters not Monitored (Default or Possibly Measured One Time)

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

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 under-estimation of net GHG emissions must be selected.

9.1 DNDC Inputs

Soil Input Parameters

Data / parameter:	S1: Land use
Data unit:	N/A
Used in equations:	Used by DNDC
Description:	Description of land use
Source of data:	Users shall select one of the four options in DNDC: upland crop field, rice paddy field, moist grassland/pasture or dry grassland/pasture.
Measurement procedures (if any):	N/A
Any comment:	

Data / parameter:	S2: Soil Clay Content
Data unit:	% clay
Used in equations:	Used by DNDC
Description:	% clay particles of the top 10cm of soil.
Source of data:	Field measurement or use of NRCS Soil Survey Geographic (SSURGO) Database defaults
Measurement procedures (if any):	If field measurements are used, then the soil suspension by hydrometer method shall be used to quantify % clay. Discussion of this method can be found in Sheldrick and Wang (1993).
Any comment:	Sheldrick, B. H. and Wang, C. 1993. Particle-size Distribution. pp. 499-511. In: Carter, M. R. (ed), Soil Sampling and Methods of Analysis, Canadian Society of Soil Science, Lewis Publishers, Ann Arbor, MI.

Data / parameter:	S3: Soil Bulk Density
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Data unit:	g/cm ³
Used in equations:	Used by DNDC
Description:	Soil bulk density of the top 10cm of soil. Bulk density is the ratio of the mass of dry solids to the bulk volume of the soil
Source of data:	Field measurement or use of NRCS Soil Survey Geographic (SSURGO) Database defaults.
Measurement procedures (if any):	If field measurements are used, then quantify soil bulk density by direct by measurement of soil volume (core measurement) and mass (drying and weighing soil sample).
Any comment:	See Blake, G. R. and Hartge, K. H. 1986. Bulk density. p. 363-375. <i>In:</i> A. Klute et al. (ed.) Methods of soil analysis: Part 1: Physical and Mineralogical Methods. Monograph Number 9 (Second Edition). ASA, Madison, WI.

Data / parameter:	S4: Soil pH
Data unit:	pH units
Used in equations:	Used by DNDC
Description:	Soil pH of the top 10cm of soil is the negative logarithm of the hydrogen ion concentration of soils.
Source of data:	Field measurement or use of NRCS Soil Survey Geographic (SSURGO) Database defaults.
Measurement procedures (if any):	If field measurements are used, then quantify soil pH using the saturated paste and pH meter.
Any comment:	See U.S. Salinity Laboratory Staff. 1954. pH reading of saturated soil paste. p. 102. <i>In:</i> L. A. Richards (ed.) Diagnosis and improvement of saline and alkali soils. USDA Agricultural Handbook 60. U.S. Government Printing Office, Washington, D.C. for a description of the saturated paste and pH meter approach.

Data / parameter:	S5: Soil carbon concentration
Data unit:	%
Used in equations:	Used by DNDC
Description:	Concentration of soil carbon in the top 5cm of soil in each stratum
Source of data:	Field measurement or use of NRCS Soil Survey Geographic (SSURGO) Database defaults
Measurement procedures (if any):	If field measurements are used, then the following measurement procedures shall be followed: Step 1. Collect soil samples of the top 0-5cm of soils. See guidance in Pearson et al. 2005 and 2007 Step 2. Measure % soil organic matter. Measurement methods are: (1) loss-on-ignition, (2) hydrogen peroxide digestion or (3) Walkley-Black Method. Step 3: Convert % soil organic matter to % soil organic carbon. A conversion factor of

	1.724 has been used to convert organic matter to organic carbon based on the assumption that organic matter contains 58% organic C (i.e., g organic matter/l .724 = g organic C) (Nelson and Sommers, 1996).
Any comment:	<p>Nelson, D.W. and L.E. Sommers. 1996. Total carbon, organic carbon, and organic matter. In: Methods of Soil Analysis, Part 2, 2nd ed., A.L. Page et al., Ed. Agronomy. 9:961-1010. Am. Soc. of Agron., Inc. Madison, WI.</p> <p>Pearson, T., S. Walker and S. Brown (2005) Sourcebook for BioCarbon Fund Projects. Prepared for BioCarbon Fund of World Bank.</p> <p>Pearson, TRH, S.L. Brown and R.A. Birdsey. 2007. Measurement guidelines for the sequestration of forest carbon. Gen. Tech. Rep. NRS-18. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 42 p.</p>

Data / parameter:	S6: Soil Texture Class
Data unit:	N/A
Used in equations:	Used by DNDC
Description:	NRCS Soil Texture class
Source of data:	Field measurement or use of NRCS Soil Survey Geographic (SSURGO) Database defaults.
Measurement procedures (if any):	<p>Use NRCS Soil texture lookup table. Users shall select the soil texture class based on their soil's clay, silt and sand content following the NRCS soil texture class definition:</p>

Any comment:	
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Data / parameter:	S7: Field Slope
Data unit:	% slope
Used in equations:	Used by DNDC
Description:	Slope of the field
Source of data:	Field measurement.
Measurement procedures (if any):	
Any comment:	The slope for level soil is 0

Data / parameter:	S8: Depth of water-retention layer
Data unit:	cm
Used in equations:	Used by DNDC
Description:	Water retention layer is layer in the soil that restricts water movement down through the soil. Depth to the water retention layer is distance from the soil surface down to the retention layer.
Source of data:	Measurement.
Measurement procedures (if any):	Users shall measure the depth to the plow pan.
Any comment:	<p>This field is required only for sites with periodic ponding or the soil drainage class is defined as somewhat poorly drained, poorly drained or very poorly drained in the NRCS SSURGO database.</p> <p>Applicable water-retention layers exist only within the top 100cm of the soil profile. Water retention layers can be formed by soil compaction (common for intensively grazed pasture or a plow pan).</p>

Data / parameter:	S9: Ground water table
Data unit:	cm
Used in equations:	Used by DNDC
Description:	Daily estimate of depth to water table.
Source of data:	Measurement.
Measurement procedures (if any):	If fields are tile drained, then one can assume that the water table is at the depth of the tile drains. Local well measurements can be used to estimate daily water table depth.
Any comment:	These data are required only if the water table is either seasonally above 50cm or the soil drainage class is defined as somewhat poorly drained, poorly drained or very poorly

	drained in the NRCS SSURGO database.
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Data / parameter:	S10: Field Capacity
Data unit:	0 - 1
Used in equations:	Used by DNDC
Description:	WFPS (Water Filled Pore Space) at soil field capacity. Field capacity is the point at which the excess water has drained from the soil (soil moisture at 1/10 bar tension).
Source of data:	Field measurement or use DNDC defaults, which are based on soil texture.
Measurement procedures (if any):	Field capacity WFPS is calculated as the ratio of volumetric water content (θ) and total soil porosity (P_t) at soil moisture content of 1/10 bars tension: $\%WFPS = (\theta/P_t) \cdot 100$
Any comment:	

Data / parameter:	S11: Wilting Point
Data unit:	0 - 1
Used in equations:	Used by DNDC
Description:	WFPS (Water Filled Pore Space) at wilting point. Wilting point is the minimal soil moisture content where crop will not wilt (soil moisture at 15 bars tension)
Source of data:	Field measurement or use DNDC defaults, which are based on soil texture.
Measurement procedures (if any):	Wilting Point WFPS is calculated as the ratio of volumetric water content (θ) and total soil porosity (P_t) at soil moisture content of 15 bars tension: $\%WFPS = (\theta/P_t) \cdot 100$
Any comment:	

Cropping System Input Parameters

Data / parameter:	CR9: Maximum Crop Yield
Data unit:	Kg dry matter.ha ⁻¹
Used in equations:	Used by DNDC
Description:	This is the maximum achievable crop yield for the region.
Source of data:	Farmer's records.
Measurement procedures (if any):	
Any comment:	This is the highest historical yield from at least the past 5 years. This will be used for crop parameterization (Step 1 in section 4.1.1.2)

9.2 Other inputs

Fossil Fuel Combustion

Data / parameter:	EF_a																
Data unit:	tCO ₂ -e.TJ ⁻¹																
Used in equations:	7, 14																
Description:	Emission factor																
Source of data:	Table 1.4 Chapter 1 Volume 2 of IPCC, 2006.																
Measurement procedures (if any):	<p>Default emission factors are presented in the table below.</p> <p>Table: Road transport default CO₂ emission factors.^a</p> <table border="1"> <thead> <tr> <th>Fuel Type</th> <th>Default effective CO₂ emission factor (tCO₂.TJ⁻¹)</th> </tr> </thead> <tbody> <tr> <td>Motor gasoline</td> <td>69.3</td> </tr> <tr> <td>Gas/Diesel Oil</td> <td>74.1</td> </tr> <tr> <td>Liquefied Petroleum Gases</td> <td>63.1</td> </tr> <tr> <td>Kerosene</td> <td>71.9</td> </tr> <tr> <td>Lubricants</td> <td>73.3</td> </tr> <tr> <td>Compressed Natural Gas</td> <td>56.1</td> </tr> <tr> <td>Liquefied Natural Gas</td> <td>56.1</td> </tr> </tbody> </table> <p>^a Values represent 100% oxidation of fuel carbon content.</p> <p>The emission factors assume that 100% of the carbon content of the fuel is oxidized during or immediately following the combustion process (for all fuel types in all vehicles) irrespective of whether the CO₂ has been emitted as CO₂, CH₄, CO or NMVOC or as particulate matter.</p>	Fuel Type	Default effective CO ₂ emission factor (tCO ₂ .TJ ⁻¹)	Motor gasoline	69.3	Gas/Diesel Oil	74.1	Liquefied Petroleum Gases	63.1	Kerosene	71.9	Lubricants	73.3	Compressed Natural Gas	56.1	Liquefied Natural Gas	56.1
Fuel Type	Default effective CO ₂ emission factor (tCO ₂ .TJ ⁻¹)																
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Lubricants	73.3																
Compressed Natural Gas	56.1																
Liquefied Natural Gas	56.1																
Any comment:																	

Data / parameter:	$Density_{Fuel\ a}$										
Data unit:	kg/ltr of kg/gal (US gallons)										
Used in equations:	8 / 9, 15 / 16										
Description:	Density of Fuel type										
Source of data:	Table A3.8 Page 181 of the Energy Statistics Manual of OECD/IEA, 2005.										
Measurement procedures (if any):	<p>Densities for relevant petroleum products as presented in table A3.8</p> <p>Typical Density Values for Selected Petroleum Products</p> <table border="1"> <thead> <tr> <th>Fuel Type</th> <th>Density (kg.ltr⁻¹)</th> <th>Liters per ton</th> <th>Density (kg.gal⁻¹)</th> <th>Gallons per ton</th> </tr> </thead> <tbody> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>	Fuel Type	Density (kg.ltr ⁻¹)	Liters per ton	Density (kg.gal ⁻¹)	Gallons per ton					
Fuel Type	Density (kg.ltr ⁻¹)	Liters per ton	Density (kg.gal ⁻¹)	Gallons per ton							

	Motor gasoline	0.7407	1350	2.800	357
	Gas/Diesel Oil	0.8439	1185	3.190	313
	Naphtha	0.6906	1448	2.610	383
	Aviation gasoline	0.7168	1350	2.710	357
	Aviation Turbine fuel	0.8026	1246	3.034	330
	Other kerosene	0.8026	1246	3.034	330
Any comment:					

Data / parameter:	NCV _a																																									
Data unit:	GJ/tonne																																									
Used in equations:	8 / 9, 15 / 16																																									
Description:	Net Caloric Value per Fuel Type																																									
Source of data:	Table A3.8, page 181, IEA Statistics Manual, OECD/IEA, 2005; and, Table 1.2, Chapter 1, Volume 2, IPCC 2006 Inventory Guidelines																																									
Measurement procedures (if any):	<p>Default NCVs are presented in tables below.</p> <table border="1" data-bbox="446 987 1177 1302"> <thead> <tr> <th>Fuel Type</th> <th>Density (kg.ltr⁻¹)</th> <th>NCV (GJ.t⁻¹)^a</th> </tr> </thead> <tbody> <tr> <td>Motor gasoline</td> <td>0.7407</td> <td>44.75</td> </tr> <tr> <td>Gas/Diesel Oil</td> <td>0.8439</td> <td>43.38</td> </tr> <tr> <td>Naphtha</td> <td>0.6906</td> <td>45.34</td> </tr> <tr> <td>Aviation gasoline</td> <td>0.7168</td> <td>45.03</td> </tr> <tr> <td>Aviation Turbine fuel</td> <td>0.8026</td> <td>43.92</td> </tr> <tr> <td>Other kerosene</td> <td>0.8026</td> <td>43.92</td> </tr> </tbody> </table> <p>^a 1000 GJ = 1 TJ</p> <p>Table: Default NCVs (excerpt from table 1.2, Chapter 1, Volume 2, IPCC, 2006 Inventory Guidelines)</p> <table border="1" data-bbox="479 1417 1096 1858"> <thead> <tr> <th>Fuel type (English description)</th> <th>Default Net Caloric Value (NCV) (TJ.Gg⁻¹)^b</th> </tr> </thead> <tbody> <tr> <td>Crude Oil</td> <td>42.3</td> </tr> <tr> <td>Orimulsion</td> <td>27.5</td> </tr> <tr> <td>Natural Gas Liquids</td> <td>44.2</td> </tr> <tr> <td>Motor Gasoline</td> <td>44.3</td> </tr> <tr> <td>Aviation Gasoline</td> <td>44.3</td> </tr> <tr> <td>Jet Gasoline</td> <td>44.3</td> </tr> <tr> <td>Jet Kerosene</td> <td>44.1</td> </tr> <tr> <td>Other Kerosene</td> <td>43.8</td> </tr> <tr> <td>Gas/Diesel Oil</td> <td>43.0</td> </tr> </tbody> </table>	Fuel Type	Density (kg.ltr ⁻¹)	NCV (GJ.t ⁻¹) ^a	Motor gasoline	0.7407	44.75	Gas/Diesel Oil	0.8439	43.38	Naphtha	0.6906	45.34	Aviation gasoline	0.7168	45.03	Aviation Turbine fuel	0.8026	43.92	Other kerosene	0.8026	43.92	Fuel type (English description)	Default Net Caloric Value (NCV) (TJ.Gg ⁻¹) ^b	Crude Oil	42.3	Orimulsion	27.5	Natural Gas Liquids	44.2	Motor Gasoline	44.3	Aviation Gasoline	44.3	Jet Gasoline	44.3	Jet Kerosene	44.1	Other Kerosene	43.8	Gas/Diesel Oil	43.0
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	bio-gasoline/bio-diesel	27.0
	other liquid biofuels	27.4
	^b T.J.Gg ⁻¹ = GJ.t ⁻¹	
Any comment:	For more NCVs for other fuels, see the original data sources.	

Fertilizer Production

Data / parameter:	N_{cont_f}																		
Data unit:	N content (% of mass)																		
Used in equations:	11,18																		
Description:	The N content of fertilizer f on a mass ratio basis																		
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use																		
Measurement procedures (if any):	<table border="1"> <thead> <tr> <th>Synthetic nitrogen fertilizer types</th> <th>N content (% of mass)</th> </tr> </thead> <tbody> <tr> <td colspan="2">Single nutrient products N-fertilizer</td> </tr> <tr> <td>Anhydrous Ammonia (NH₃) "Ammonia"</td> <td>82</td> </tr> <tr> <td>Ammonium Sulfate [(NH₄)₂SO₄]</td> <td>21</td> </tr> <tr> <td>Monoammonium Phosphate (MAP)</td> <td>11</td> </tr> <tr> <td>Diammonium Phosphate (DAP)</td> <td>18</td> </tr> <tr> <td>Ammonium Nitrate (NH₄NO₃)</td> <td>33.5</td> </tr> <tr> <td>Calcium Ammonium Nitrate (CAN)</td> <td>26</td> </tr> <tr> <td>Any other synthetic nitrogen fertilizer (e.g., multi nutrient fertilizers (N-P-K))</td> <td>Project proponent to calculate</td> </tr> </tbody> </table>	Synthetic nitrogen fertilizer types	N content (% of mass)	Single nutrient products N-fertilizer		Anhydrous Ammonia (NH ₃) "Ammonia"	82	Ammonium Sulfate [(NH ₄) ₂ SO ₄]	21	Monoammonium Phosphate (MAP)	11	Diammonium Phosphate (DAP)	18	Ammonium Nitrate (NH ₄ NO 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
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Any comment:																			

III. MONITORING METHODOLOGY

All data collected as part of monitoring must be archived electronically and retained for at least two years after the end of the project. 100% of the data must be monitored if not indicated otherwise in tables below. All measurements must be conducted according to relevant standards.

1. Monitoring of Project Implementation

Information shall be provided, and recorded in the GHG Project Plan, to establish that:

- i. The geographic position of the project boundary is recorded for all areas of land;
 - The geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded and archived. This can be achieved by field survey (e.g., using GPS), or by using georeferenced spatial data (e.g., maps, GIS datasets, orthorectified aerial photography, or georeferenced remote sensing images).
- ii. Commonly accepted principles of agricultural land management are implemented;
 - Standard operating procedures (SOPs) and quality control / quality assurance (QA/QC) procedures for field data collection and data management shall be applied. Use or adaptation of SOPs already applied in national monitoring, or available from published handbooks, or from the *IPCC AFOLU Guidelines 2006*, is recommended;
 - The fertilizer management plan, together with a record of the plan as actually implemented during the project shall be available for verification, as appropriate.

2. Data and Parameters Monitored

The following parameters must be monitored during the project activity. When applying all relevant equations provided in this methodology for the *ex ante* calculation of net GHG emissions, Project Proponents shall provide transparent estimations for the parameters that are monitored during the crediting period. These estimates shall be based on measured or existing published data where possible. 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 over-estimation of net GHG emissions must be selected.

Location Input Parameter:

Data / parameter:	A _i
Data unit:	ha

Used in equations:	6, 10, 13, 17 and implicitly used in Section 4 (<i>Location Parameter L1</i>)
Description:	Area of stratum <i>i</i>
Source of data:	GPS coordinates and / or legal parcel records and farm records
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	It shall be assumed ex-ante that field boundaries and strata areas shall not change through time

Climate Input Parameters:

Data / parameter:	C1: Background NH₃ Concentration
Data unit:	µg N.m⁻³
Used in equations:	Used by DNDC
Description:	Average background concentration of atmospheric NH ₃ .
Source of data:	Default value is 0.06 µg N.m ⁻³
Measurement procedures (if any):	N/A
Any comment:	If the users decide to modify the default values, then rationale for the changes must be recorded

Data / parameter:	C2: Background CO₂ Concentration
Data unit:	ppm
Used in equations:	Used by DNDC
Description:	Average background concentration of atmospheric CO ₂ .
Source of data:	Default value is 350 ppm
Measurement procedures (if any):	N/A
Any comment:	If the users decide to modify the default values, then rationale for the changes must be recorded.

Data / parameter:	C3: Atmospheric N Deposition
Data unit:	mg N.l⁻¹ or ppm
Used in equations:	Used by DNDC
Description:	Average annual N (dissolved nitrate and ammonium) concentration in rainfall

Source of data:	These data are available from National Atmospheric Deposition Program National Trends Network (http://nadp.sws.uiuc.edu/Default.aspx).
Measurement procedures (if any):	N/A
Any comment:	

Data / parameter:	C4: Daily Meteorology
Data unit:	Temperature in degrees Celsius, Precipitation in cm, wind speed in m/sec, solar radiation in MJ/m²/day
Used in equations:	Used by DNDC
Description:	Daily weather data from local weather station
Source of data:	These data shall either be collected from the nearest weather station.
Measurement procedures (if any):	N/A
Any comment:	<p>Meteorology Format 1:</p> <p>The first line is a file name. The first column contains dates in Julian day, the second column maximum daily air temperatures in °C, the third column minimum daily air temperatures in °C, and the fourth column daily precipitation in cm. The following is an example of Format 1:</p> <pre> Example1 1 -0.5 -4.5 0.0 2 0.0 -1.2 1.2 3 3.5 0.8 0.5 4 5.7 2.0 0.0 . . 365 5.6 -0.2 0.0 </pre> <p>Meteorology Format 2:</p> <p>The first line is a file name, which must be a string. The first column contains dates in Julian day, the second column maximum daily air temperatures in °C, the third column minimum daily air temperatures in °C, the fourth column daily precipitation in cm, and the fifth column solar radiation in million J/m²/day. The following is an example of Format 2:</p> <pre> Example2 1 -0.5 -4.5 0.0 1.23 2 0.0 -1.2 1.2 1.59 3 3.5 0.8 0.5 3.20 4 5.7 2.0 0.0 2.25 . . 365 5.6 -0.2 0.0 1.11 </pre> <p>Meteorology Format 3:</p>

The first line is a file name, which must be a string. The first column contains dates in Julian day, the second column maximum daily air temperatures in °C, the third column minimum daily air temperatures in °C, the fourth column daily precipitation in cm, and the fifth column daily average wind speed in m/second. The following is an example of Format 3:

```

Example3
1      -0.5   -4.5   0.0   0.25
2       0.0   -1.2   1.2   1.10
3       3.5    0.8   0.5   0.80
4       5.7    2.0   0.0   0.02
.
.
365    5.6   -0.2   0.0   0.00
    
```

Meteorology Format 4:

The first line is a file name, which must be a string. The first column contains dates in Julian day, the second column maximum daily air temperatures in °C, the third column minimum daily air temperatures in °C, the fourth column daily precipitation in cm, the fifth column daily average wind speed in m/second, and the sixth column solar radiation in MJ/m²/day. The following is an example of Format 4:

```

Example4
1      -0.5   -4.5   0.0   0.25   19.169
2       0.0   -1.2   1.2   1.10   16.321
3       3.5    0.8   0.5   0.80   17.418
4       5.7    2.0   0.0   0.02   21.009
.
.
365    5.6   -0.2   0.0   0.00   17.239
    
```

Cropping System Input Parameters

Data / parameter:	CR1: Crop Type
Data unit:	N/A
Used in equations:	Used by DNDC
Description:	This is the crop or crops that were grown on the site.
Source of data:	Farmer records.
Measurement procedures (if any):	
Any comment:	Use of cover crops in the rotation shall be identified as such

Data / parameter:	CR2: Planting Date
Data unit:	Month, day and year.

Used in equations:	Used by DNDC
Description:	Date of planting.
Source of data:	Farmer records.
Measurement procedures (if any):	
Any comment:	

Data / parameter:	CR3: Harvest Date
Data unit:	Month, day and year.
Used in equations:	Used by DNDC
Description:	This is the date of the crop harvest.
Source of data:	Farmer records.
Measurement procedures (if any):	
Any comment:	

Data / parameter:	CR4: C/N ratio of the grain
Data unit:	(unitless)
Used in equations:	Used by DNDC
Description:	This is the ratio of the carbon and nitrogen content of the harvest portion of the crop.
Source of data:	Tissue sampling measurement
Measurement procedures (if any):	Standard lab techniques.
Any comment:	

Data / parameter:	CR5: C/N ratio of leaf+stem tissue
Data unit:	(unitless)
Used in equations:	Used by DNDC
Description:	This is the ratio of carbon and nitrogen content of the leaf and stem tissues combined.
Source of data:	Tissue sampling measurement.
Measurement procedures (if any):	Standard lab techniques.
Any comment:	

Data / parameter:	CR6: <i>C/N ratio of root tissue</i>
Data unit:	(unitless)
Used in equations:	Used by DNDC
Description:	This is the ratio of carbon and nitrogen content of the root tissues.
Source of data:	Tissue sampling measurements.
Measurement procedures (if any):	Standard lab techniques.
Any comment:	

Data / parameter:	CR7: <i>Fraction of leaves and stems left in field after harvest</i>
Data unit:	%
Used in equations:	Used by DNDC
Description:	This is the fraction of leaves and stems left in the field after harvest.
Source of data:	Farmer records.
Measurement procedures (if any):	
Any comment:	

Tillage System Input Parameters

Data / parameter:	T1: <i>Number of tillage events</i>
Data unit:	N/A
Used in equations:	Used by DNDC
Description:	This is the number of days when the field is tilled.
Source of data:	Farmer records.
Measurement procedures (if any):	
Any comment:	A tillage event is defined as day in which the fields are tilled. Multiple pass on the same day are considered a single event.

Data / parameter:	T2: <i>Date of each tillage event</i>
Data unit:	Month, day and year.
Used in equations:	Used by DNDC
Description:	Date of each tillage event.
Source of data:	Farmer records.
Measurement	

procedures (if any):	
Any comment:	

Data / parameter:	T3: Depth of each tillage event
Data unit:	Cm
Used in equations:	Used by DNDC
Description:	This is the depth of the tillage for each event.
Source of data:	Farmer records.
Measurement procedures (if any):	
Any comment:	DNDC allows for 6 depths: 0cm (mulch crop residue), 5cm, 10cm, 20cm, 30cm and 50cm.

Nitrogen Fertilizer Input Parameters

Data / parameter:	F1: Number of fertilizer applications
Data unit:	N/A
Used in equations:	Used by DNDC
Description:	This is the number of days with nitrogen fertilizer application in a given year
Source of data:	Farmer records.
Measurement procedures (if any):	
Any comment:	

Data / parameter:	F2: Date of each fertilizer event
Data unit:	Month, day and year.
Used in equations:	Used by DNDC
Description:	Date of each nitrogen fertilizer application event.
Source of data:	Farmer records.
Measurement procedures (if any):	
Any comment:	

Data / parameter:	F3: Fertilizer application method
Data unit:	N/A

Used in equations:	Used by DNDC
Description:	This is a description of how the nitrogen fertilizer was applied for each event. There are two options: surface or injection. If injection was used, then user's must specify the depth in cm.
Source of data:	Farmer records.
Measurement procedures (if any):	
Any comment:	

Data / parameter:	F4: Fertilizer Type
Data unit:	N/A
Used in equations:	Used by DNDC
Description:	Type of fertilizer used for each fertilizer event. DNDC accepts seven types of fertilizers: Urea, Anhydrous Ammonia, Ammonium Nitrate, Nitrate, Ammonium Bicarbonate, Ammonium Sulfate and Ammonium Phosphate
Source of data:	Farmer records.
Measurement procedures (if any):	
Any comment:	If the fertilizer used is a combination of types (e.g. UAN which is a combination of urea and ammonium nitrate), then separate the application into several fertilizer types based on the combination ratios

Data / parameter:	F5: Fertilizer application rate
Data unit:	kg N.ha ⁻¹
Used in equations:	Used by DNDC
Description:	Application rate of nitrogen fertilizer in kg N.ha ⁻¹ for each fertilizer type
Source of data:	Farmer records.
Measurement procedures (if any):	
Any comment:	

Data / parameter:	F6: Use of time release fertilizer
Data unit:	Days
Used in equations:	Used by DNDC
Description:	If farmer's used time release fertilizer, then they must specify the release rate in days.
Source of data:	Farmer records and published release rates from fertilizer manufacturer.
Measurement	

procedures (if any):	
Any comment:	

Data / parameter:	F7: Use of Nitrification Inhibitors
Data unit:	Effectiveness (% reduction in nitrification) and duration of the nitrification inhibitor (days)
Used in equations:	Used by DNDC
Description:	If farmer uses a nitrification inhibitor, then this parameter describes its effectiveness in terms of % reduction in nitrification rates and the duration in days the inhibitor works.
Source of data:	Fertilizer manufacturer records.
Measurement procedures (if any):	
Any comment:	Efficiency is defined as the percent reduction in rates of nitrification. Values of 0.5 and 1 indicate a 50% and 100% reduction of nitrification for the effective duration are needed.

Organic Amendment Input Parameters

Data / parameter:	O1: Number of Organic Amendment Applications Per Year
Data unit:	dimensionless
Used in equations:	Used by DNDC
Description:	Number of applications in the year
Source of data:	Farmer records
Measurement procedures (if any):	
Any comment:	

Data / parameter:	O2: Date of Application
Data unit:	dimensionless
Used in equations:	Used by DNDC
Description:	The date of each application of organic amendments listed in input O1
Source of data:	Farmer records
Measurement procedures (if any):	
Any comment:	

Data / parameter:	O3: Type of Organic Amendment
--------------------------	--------------------------------------

Data unit:	dimensionless
Used in equations:	Used by DNDC
Description:	Type of manure. Five types of manure (e.g., farmyard manure, green manure, straw, liquid animal waste, and compost) are parameterized in DNDC.
Source of data:	Farmer records
Measurement procedures (if any):	
Any comment:	

Data / parameter:	O4: Application Rate
Data unit:	kg C.ha ⁻¹
Used in equations:	Used by DNDC
Description:	The application rate of the organic amendments in kg C per ha per application
Source of data:	Farmer records
Measurement procedures (if any):	
Any comment:	

Data / parameter:	O5: Amendment C/N Ratio
Data unit:	dimensionless
Used in equations:	Used by DNDC
Description:	The ratio of C/N in the organic amendment.
Source of data:	The default value is provided by DNDC but should be modified if data are available
Measurement procedures (if any):	
Any comment:	

Irrigation System Input Parameters

Data / parameter:	I1: Number of Irrigation Events
Data unit:	dimensionless
Used in equations:	Used by DNDC
Description:	Number of irrigation events each year
Source of data:	Farmer records
Measurement procedures (if any):	

Any comment:	
--------------	--

Data / parameter:	I2:Date of Irrigation Events
Data unit:	dimensionless
Used in equations:	Used by DNDC
Description:	The date of each irrigation event specified input I1
Source of data:	Farmer records
Measurement procedures (if any):	
Any comment:	

Data / parameter:	I3:Irrigation Type
Data unit:	dimensionless
Used in equations:	Used by DNDC
Description:	The type of irrigation system used
Source of data:	Farmer records
Measurement procedures (if any):	
Any comment:	DNDC has three irrigation type settings: flood, sprinkler or surface drip tape.

Data / parameter:	I4:Irrigation Application Rate
Data unit:	mm
Used in equations:	Used by DNDC
Description:	Amount of water applied during each irrigation event listed in input I1
Source of data:	Farmer records
Measurement procedures (if any):	
Any comment:	

Fossil Fuel Combustion

Data / parameter:	Liters_{Fuel,a,t} or Gallons_{Fuel,a,t}
Data unit:	liters or US gallons
Used in equations:	8 / 9, 15 / 16
Description:	Fuel consumed

Source of data:	Records of fuel consumed or distance travelled by vehicles (farmer records).
Measurement procedures (if any):	<p>In the absence of direct fuel consumption data, each major fuel type used by each road vehicle type can be estimated from data of vehicle kilometers travelled (which requires a km registration system) or from the expenditure on fuel (on the basis of receipts/fuel acquired).</p> <p>Records / monitoring shall be continuous and consumption/mileage shall be divided by equipment type / road vehicle type.</p> <p>Where estimation of fossil fuel combustion is elected as an emission source, fossil fuel use by the project both inside and outside the project boundary shall be recorded and considered as project emissions.</p>
Any comment:	For the baseline case, fossil fuel use shall be derived from farm records collected over at least the previous two years.

Fertilizer Production

Data / parameter:	$AR_{i,f}$
Data unit:	(metric) t.ha ⁻¹
Used in equations:	10,17
Description:	Average application rate of fertilizer <i>f</i> for stratum <i>i</i>
Source of data:	Farmer records
Measurement procedures (if any):	
Any comment:	

3. Conservative Approach and Uncertainties

To help reduce uncertainties in accounting of emissions and removals, this methodology uses, whenever possible, the proven methods from the GPG-LULUCF, GPG-2000, the IPCC's Revised 2006 Guidelines and the tools and methodologies of the CDM Executive Board. Tools and guidance from the CDM Executive Board on conservative estimation of emissions and removals are also used. Despite this, potential uncertainties still arise from the choice of parameters to be used. Uncertainties may result in uncertainties in the estimation of both baseline net GHG emissions and the actual net GHG emissions, especially when global default values are used.

It is recommended that Project Proponents identify key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances must then be obtained for these key parameters, whenever possible. These values must be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources¹³;
- National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or
- In the absence of the above sources of information, expert opinion may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value must be briefly noted in the GHG Project Plan. For any data provided by experts, the GHG Project Plan shall also record the expert's name, affiliation, and principal qualification as an expert (e.g., that they are a member of a country's national agricultural statistics technical advisory group), and should include in an annex a 1-page summary CV for each expert consulted.

In choosing key parameters of making important assumptions based on information that is not specific to the project circumstances, such as in use of default data, Project Proponents must select values that will lead to an accurate estimation of net GHG emissions, taking into account uncertainties. If uncertainty is significant, project participants must choose data such that it tends to over-estimate, rather than under-estimate, net GHG emissions.

¹³ Typically, citations for sources of data used should include: the report or paper title, publisher, page numbers, publication date etc (or a detailed web address). If web-based reports are cited, hardcopies should be included as Annexes in the GHG Project Plan if there is any likelihood such reports may not be permanently available.

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