# VCS MODULE VMD0029

# ESTIMATION OF EMISSIONS OF NON-$CO_2$ GHGs FROM SOILS

Version 1.1

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Sectoral Scope 14

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# 1 SOURCES

CDM methodology *AR-AM0004 Reforestation or afforestation of land currently under agricultural use*.

Denitrification-decomposition process model (DNDC).

Willey Z. B. Chameides, 2007 Harnessing Farms and Forests in the Low Carbon Economy, Nicolas Institute for Environmental Policy Solutions.

# 2 SUMMARY DESCRIPTION OF THE MODULE

This module provides a suite of methods and approaches for estimating the emissions of $CH_4$ and $N_2O$ from soils resulting from nitrogen inputs and soil processes.

# 3 DEFINITIONS

**Emission Factor:** The average emission rate of a given pollutant for a given source, relative to the intensity of a specific activity.

**Significant:** A pool or source is significant if it does not meet the criteria for being deemed de minimus. Specific carbon pools and GHG sources, including carbon pools and GHG sources that cause project and leakage emissions, may be deemed de minimis and do not have to be accounted for if together the omitted decrease in carbon stocks (in carbon pools) or increase in GHG emissions (from GHG sources) amounts to less than five percent of the total GHG benefit generated by the project.

# 4 APPLICABILITY CONDITIONS

Applicable to projects where significant increases in the emissions of $N_2O$ or $CH_4$ from the soils within the project area are expected under the project scenario as compared with the baseline scenario.

# 5 PROCEDURES

**Introduction:**

Soils and decaying organic material (including litter-fall in forests, fertilizers used on croplands, and manure stored in lagoons) can emit both methane and nitrous oxides, which are significant GHGs. This module is used to estimate the amounts of these GHGs emitted from the soil within the project area.

Emissions of methane and nitrogenous compounds from soils occur as a result of complex processes governed by both organic and inorganic variables.

Currently a number of different methods exist for the estimation of releases of methane and nitrogenous compounds into the atmosphere from soils. This module uses a hierarchical approach to the estimation of these releases, with more complete approximations of the processes and emissions used where larger emissions are expected. This hierarchy of methods is shown in the table below. Note that the ranges of expected emissions overlap for each method. The more complete model should be used where possible within these overlap ranges.

**Table 1:** Selection of methods

| Expected change in emissions of N compounds and $CH_4$, measured in $CO_2$e, as a percentage of total project gross GHG benefit | Method | Typical Example |
|---|---|---|
| 0 - 5% | IPCC[1] | Dryland range restoration |
| 2 - 10% | DNDC subset[2] | Changes in tilled soil management including changes in fertilization practices |
| 5% + | DNDC[3] | Changes in wetland management (rice cultivation, re-establishment of wetlands, drainage and tiling) Intensive use of organic amendments (manures, etc.) or fertilizers |

NOTE: When emissions of $N_2O$ from soils are being calculated, project proponents must ensure that emissions calculated under the manure management section of module *VMD0028 Estimation of Emissions from Domesticated Animals* are not also calculated here, as this would result in double counting.

If emissions of non-$CO_2$ GHGs from soils is significant, this module must be used in conjunction with the module *VMD0019 Methods to Predict Future Conditions* to project soil GHG emissions under the baseline and project scenarios, and also must be used during the monitoring phase to estimate soil GHG emissions. When using this module to calculate baseline emissions, minimum baseline estimates for $N_2O$ and $CH_4$ emissions must be based on documented management records averaged over the five year period prior to the project start date. Documented management records may include fertilizer purchase records, manure production estimates and/or livestock data. For new management entities or where such records are unavailable, minimum baseline estimates must be based on a conservative estimate of common practice in the region.

Application of the methods is undertaken using the following steps:

**Step 1: Document and map the following variables**

- Amount, location, timing and conditions of applications of organic or inorganic fertilizers, and type of fertilizer applied.
- Amount, location and timing of areas subject to flooding, and duration of flooding
- Amount and location of nitrogen fixing species
- Soil conditions, temperature and moisture regimes

[1] IPCC (2000) Good practice guidance LULUCF and IPCC (1996) Revised Guidelines for National Greenhouse Gas Inventories, IPCC (2006) Guidelines for National Greenhouse Gas Inventories

[2] Willey Z. B. Chameides, 2007 Harnessing Farms and Forests in the Low Carbon Economy , Nicolas Institute for Environmental Policy Solutions

[3] Willey Z. B. Chameides, 2007 Harnessing Farms and Forests in the Low Carbon Economy , Nicolas Institute for Environmental Policy Solutions

- Management activities

Note that if application of organic fertilizers is a direct result of grazing of domestic animals resident within the project area, calculations of emissions must be made using the module *VMD0028 Estimation of Emissions from Domesticated Animals*. Summation of net GHG change for those applications of organic fertilizers must not be accounted in this methodology, to avoid double counting.

**Step 2: Determine the method to be used**

Estimate the percentage of changes in emissions resulting from emissions of $CH_4$ and nitrous oxides, as a percentage of the total project GHG fluxes. This estimation can be undertaken using a wide variety of methods, including local knowledge or research, or a rough calculation using one of the methods outlined in Step 3 below. Document the methods used to arrive at this estimation. Based on the estimation, select the methods for calculating methane and nitrous oxide emissions.

**Step 3: Calculate the emissions of Methane and Nitrous Oxides**

Based on the determination made in Step 2 above, use one of the following methods to calculate the emissions of $CH_4$ and N compounds.

**Method 1:** IPCC methods

**Methane Emissions**

Methane emissions occur principally due to the existence of anaerobic conditions in soils due to saturation and flooding. Methane emissions may also result from drainage practice changes in land use not involving flooding or saturation. However, availability of data on these changes is very limited, and changes from practice change in land use are largely expected to be small relative to total project fluxes. Thus this method calculates methane emissions only under conditions of flooding or saturation.

Methane emissions are calculated using the following equation:

$$E_{s,CH_4} = \sum_s (A_{sat,s} \cdot ((P_{icefree,sat,s} \cdot (CH_{4dif,ni} + CH_{4bub,ni})) + (P_{ice,sat,s} \cdot CH_{4dif,i}))) \cdot 21 \cdot 10^{-3} \qquad (13.1)$$

Where

| | | |
|---|---|---|
| $E_{s,CH_4}$ | = | Total emissions of $CH_4$ from the project area, t $CO_2$e $yr^{-1}$ in year t and strata s |
| *s* | = | Strata |
| $A_{sat,s}$ | = | The mean area of saturated soils in stratum s, ha |
| $P_{icefree,sat,s}$ | = | Period of during which the soil is saturated and ice free in stratum s, days |
| $CH_{4dif,ni}$ | = | The rate of emissions of $CH_4$ by diffusion during ice free days, kg $ha^{-1}$ $day^{-1}$ |
| $CH_{4bub,ni}$ | = | The rate of emissions of $CH_4$ by bubbling during ice free days, kg $ha^{-1}$ $day^{-1}$ |
| $P_{ice,sat,s}$ | = | Period during which the soil is saturated and ice covered in stratum s, days |
| $CH_{4dif,i}$ | = | The rate of emissions of $CH_4$ by diffusion during ice covered days, kg $ha^{-1}day^{-1}$ |
| 21 | = | Global warming potential for $CH_4$ |
| $10^{-3}$ | = | Conversion from kilograms to tonnes |

Rates for emissions of methane must be drawn from local research. Where such research does not exist, the following default IPCC values may be used:

**Table 2:** Default emission values for $CH_4$ **(**IPCC GPG LULUCF 2000 Table 14.3.1.1)

| **Ecosystem** | $CH_{4dif,ni}$ | $CH_{4bub,ni}$ | $CH_{4dif,i}$ |
|---|---|---|---|
| | kg/ha/day | kg/ha/day | kg/ha/day |
| Boreal | 0.11 +/-88% | 0.29 +/-160% | 0.05 +/-60% |
| Cold Temperate | 0.2 +/-55% | 0.14 +/-70% | |
| Warm Temperate, dry | 0.063 +/-50% | | |
| Warm Temperate, wet | 0.096 +/-77% | | |
| Tropical, wet | 0.64 +/-330% | 2.83 +/-45% | |
| Tropical, moist, long dry season | 0.31 +/-190% | 1.9 +/-155% | |
| Tropical, moist, short dry season | 0.44 +/-465% | 0.13 +/-135% | |
| Tropical, dry | 0.3 +/-115% | 0.3 +/-324% | |

Note that the range of variation for many of the default values is very high. Where project proponents choose to use a value other than the mean provided, they must justify the reason for the choice made, and demonstrate that it is conservative.

Where values do not exist for a given variable for the ecosystem in question, values from the most similar ecosystem must be substituted.

Definitions of the ecosystem types may be found in the Glossary of the IPCC GPG for LULUCF 2003 (IPCC 2003).

**Nitrous oxide emissions**

The following method may only be used to determine nitrous oxide emissions where it can be shown that nitrogen application rates and the absorptive capacity of the soils is such that loss of nitrogen due to leaching or run-off is unlikely. Otherwise, Method 2, DNDC subset, must be used to estimate nitrous oxide emissions.

**Step A:** Monitoring and estimating the amount of nitrogen in synthetic and organic fertilizer used within the project area.

$$N_{SN-Fert,t} = \sum_s A_s \cdot N_{SN-Fert,k,t} \cdot 0.001 \quad (13.2)$$

$$N_{ON-Fert,t} = \sum_s A_s \cdot N_{ON-Fert,k,t} \cdot 0.001 \quad (13.3)$$

Where:

| | | |
|---|---|---|
| $N_{SN-Fert,t}$ | = | Total use of synthetic fertilizer within the project area, tonnes N $yr^{-1}$ in year t |
| $N_{ON-Fert,t}$ | = | Total use of organic fertilizer within the project area, tonnes N $yr^{-1}$ in year t |
| $A_s$ | = | Area of stratum s with fertilization, ha $yr^{-1}$ |
| $N_{SN-Fert,k,t}$ | = | Use of synthetic fertilizer per unit area for stratum s, kg N $ha^{-1}$ $yr^{-1}$ in year t |
| $N_{ON-Fert,k,t}$ | = | Use of organic fertilizer per unit area for stratum s, kg N $ha^{-1}$ $yr^{-1}$ in year t |
| 0.001 | = | Conversion kg N to tonnes N |

**Step B:** Choosing the fractions of synthetic and organic nitrogen fertilizer that is emitted as $NO_X$ and $NH_3$, and emission factors.

As noted in GPG 2000 and 1996 IPCC Guidelines, the default emission factor is 1.25% of applied nitrogen, and this value must be used when country-specific factors are unavailable or project specific factors are not developed. Project proponents may develop specific emission factors that are more appropriate for their project. Specific good practice guidance on how to derive specific emission factors is given in Box 4.1 of GPG 2000. The default values for the fractions of synthetic and organic fertilizer nitrogen that are emitted as $NO_X$ and $NH_3$ are 0.1 and 0.2 respectively in 1996 IPCC Guideline[4].

**Step C:** Calculating direct nitrous oxide emissions from nitrogen fertilization[5]

$$E_{s,N_20} = \left[ (F_{SN} + F_{ON}) \cdot EF_1 \right] \cdot 44/28 \cdot 310 \qquad (13.4)$$

$$F_{SN} = N_{SN-Fert,t} \cdot (1 - Frac_{GASF}) \qquad (13.5)$$

$$F_{ON} = N_{ON-Fert,t} \cdot (1 - Frac_{GASM}) \qquad (13.6)$$

Where:

| | | |
|---|---|---|
| $E_{s,N2O}$ | = | The direct $N_2O$ emission as a result of nitrogen application within the project area during monitoring interval, tonnes $CO_2$-e $yr^{-1}$ in year t |
| $F_{SN}$ | = | Amount of synthetic fertilizer nitrogen applied adjusted for volatilization as $NH_3$ and $NO_X$, tonnes N $yr^{-1}$ |
| $F_{ON}$ | = | Annual amount of organic fertilizer nitrogen applied adjusted for volatilization as $NH_3$ and $NO_X$, tonnes N $yr^{-1}$ |
| $N_{SN-Fert}$ | = | Amount of synthetic fertilizer nitrogen applied, tonnes N $yr^{-1}$ |
| $N_{SN-Fert}$ | = | Amount of organic fertilizer nitrogen applied, tonnes N $yr^{-1}$ |
| $EF_1$ | = | Emission Factor for emissions from N inputs, tonnes $N_2O$-N (tonnes N input)$^{-1}$ |
| $Frac_{GASF}$ | = | The fraction that volatilizes as $NH_3$ and $NO_X$ for synthetic fertilizers, dimensionless |
| $Frac_{GASM}$ | = | The fraction that volatilizes as $NH_3$ and $NO_X$ for organic fertilizers, dimensionless |
| 44/28 | = | Ration of molecular weights of $N_2O$ and nitrogen, dimensionless |
| 310 | = | Global Warming Potential for $N_2O$ |

**Notes to application of the models or equations:**

- If organic fertilizers were applied, and those organic fertilizers arose from livestock and manure management practices already accounted in module *VMD0028 Estimation of Emissions from Domesticated Animals* Step 3, they must not be counted here, to avoid double counting.
- If organic fertilizers are applied on top of snow or frozen ground, it is difficult to be sure where or under what conditions the nitrogen in the fertilizer will interact with soils and plant communities. Therefore the nitrogen content of these fertilizers must conservatively be assumed to be 100% emitted as nitrous oxide.

If nitrogen fixing plants are present, nitrogen input from nitrogen fixing species will depend on the species, percent cover, and site conditions within which the plants are growing. For agronomic or other species

[4] Refers to table 4-17 and table 4-18 in 1996 IPCC Guideline

[5] Refers to Equation 3.2.18 in IPCC GPG-LULUCF, Equation 4.22 and Equation 4.23 in GPG-2000

where good data exists on the rates of nitrogen fixation, this data must be used to determine the amount of nitrogen input into the soils. For other species, where such data does not exist, data from known species must be used to determine the rate of nitrogen input. For non-woody species, for example, rates and conditions of nitrogen fixation by alfalfa may be used as a proxy for the nitrogen fixation of other species. In order to ensure conservatism, the percentage cover of the unknown species, as determined in the field, must be multiplied by 2, to a maximum of 100% cover, and the resulting cover number used to determine the expected fixation by alfalfa. Where such species with unknown rates of nitrogen fixation exist in quantities, project monitoring may include ongoing measurement of soil nitrogen, assist in the fine-tuning of future nitrogen fixation estimates for these species.

**Method 2:** DNDC subset

Willey et al (2007) derived equations from the DNDC model. These equations take into account a large number of variables driving changes in the emissions of GHGs.

Use the equations in **Table 3** to estimate changes in methane emissions resulting from changes in:

- The duration of flooding and drainage during the growing season.
- The amount of time between manure application and flooding.
- The amount of carbon added to the soils as manure.
- The carbon content of the soil.
- The acidity (pH) of the soil.

Use the equations in **Table 4** to estimate change in nitrous oxide emissions resulting from changes in:

- The application rate of the nitrogen fertilizer.
- The application rate of carbon in the manure.
- The amount of organic carbon in the topsoil.
- The crop demand for nitrogen.
- The water input from precipitation and irrigation.
- The average annual air temperature.
- The clay content of the soil.
- The acidity (pH) of the soil.
- The land use (cropland, rice paddy, or grassland.) Note that the project area must be stratified according to land use in order to use this method.

**Table 3** - Equations derived from Results of DNDC Simulations to Estimate Methane Emissions from saturated Soils in the United States

| | |
|---|---|
| Parametric equation | $E_{s,CH_4} = \prod_{i=0}^{7} A_i \bullet clay^{B_0}$ |
| Coefficient equations | $A_0 = 108.61$<br>$A_1 = (F - 2D + 2.4711) \bullet 80.464^{-1}$<br>$A_2 = 0.0106 \cdot T^{1.5021}$<br>$A_3 = 1.5127 \cdot Ln(PH) - 1.8492$<br>$A_4 = 0.185 \cdot Ln(Y) - 0.6204$<br>$A_5 = 7E\text{-}05(MD)^{-0.2605}(MA) + 0.9989$<br>$A_6 = 19.612 \cdot SOC^2 - 0.2877 \cdot SOC + 0.9834$ |

 

| | |
|---|---|
| | $A_7 = -0.5669 \bullet Ln(LEAK) + 1.8394$<br>$B_0 = -0.73$ |
| Definitions | $E_{s,CH4}$ : soil $CH_4$ flux in growing season, kg $CH_4$ – C/h<br>*clay*: soil clay fraction<br>$A_{0\text{-}7}$: coefficients, kg $CH_4$ – C/ha<br>$B_0$: coefficient for the clay component<br>*F:* flooded days during the growing season<br>*D*: drained days during the growing season<br>*T:* mean annual air temperature, ◦C<br>*PH:* soil pH<br>*MD:* days of manure amendment before start of flooding<br>*MA:* amount of manure amended, kg manure – C/ha<br>*SOC:* soil organic carbon content, kg C/kg soil<br>*LEAK*: soil water leaking rate, mm/day<br>*Y:* crop yield, kg C/ha/growing season |

**Notes:* The symbol ∏ is used to denote the product of a series in much the same way that Σ is used to denote the sum of a series. Thus $\prod_{1=0}^{3} x_i = x_0 \cdot x_1 \cdot x_2 \cdot x_3$

**Table 4** Equations Derived from Results of DNDC Simulations to Estimate Nitrous Oxide Emissions from Soils in the United States.

| | |
|---|---|
| Total annual soil $N_2O$ flux, kg $N_20$) – N/ha/yr | $E_{s,N2O} = \prod_{i=0}^{3} A_i + \prod_{j=1}^{2} B_j \frac{R_{fn}}{\prod_{k=0}^{6} K_k + R_{fn}}$ |
| Coefficient equations | $A_0$ = 1/(LU)<br>$A_1$ = 245C-1.4385<br>$A_2$ = 1E-05$(CN)^2$ – 0.0053(CN) +1.5254<br>$A_3$ = 0.9259$e^{0.0005(M)}$<br>$B_1$ =0.2207$e^{0.1858(T)}$$B_2$ =21.704*lnC + 122.51<br>$K_0$ = 300<br>$K_1$ = 0.2356$e^{0.1694(T)}$<br>$K_2$ = 1E-05$(P)^2$ – 0.004(P) + 5.5656<br>$K_3$ = 1.0339$e^{3.9509\ (clay)}$<br>$K_4$ = 0.2029$(PH)^2$ – 2.7911(PH)+ 10.568<br>$K_5$ = 0.0745$e^{0.0166(CN)}$<br>$K_6$ = -9E-05(M) + 0.9808 |

| | |
|---|---|
| Definitions | $E_{s,N2O}$: annual soil $N_20$ flux, kg N/ha/yr<br>$R_{fn}$ : fertilizer application rate, kg N/ha/yr<br>$A_{0-3}$: background $N_20$ flux coefficients, kg N/ha/yr<br>$B_{1-2}$: saturated $N_20$ flux coefficients, kg N/ha/yr<br>$K_{0-6}$: rate coefficients<br>*C*: SOC content in top soil (top 15 cm.), kg C/kg soil<br>*CN:* crop demand for N, kg N/ha<br>*M:* manure application rate, kg C/ha<br>*T:* mean annual air temperature, ◦C<br>*P:* total annual precipitation, mm<br>*clay:* soil clay fraction<br>*PH*: soil pH<br>*LU:* land-use type (cropland 1, rice paddy 2, grassland 3) |

**Notes:* The symbol ∏ is used to denote the product of a series in much the same way that Σ is used to denote the sum of a series. Thus $\prod_{1=0}^{3} x_i = x_0 \cdot x_1 \cdot x_2 \cdot x_3$

<u>**Method 3:** DNDC</u>

Estimating methane and nitrous oxide emissions relies on the denitrification-decomposition process model, or DNDC (Li, Frolking, and Frolking 1992; Li, Narayanan, and Harriss 1996; Li, Aber, Stange, Butterbach-Bahl, and Papen 2000; and Li 2001). An example of the implementation of this approach is contained in the GHG Wizard version of DNDC. It uses data provided with the model on the weather, soil types, and crop types/acreage of each county in the United States, as well as user-specified data on fertilization, tillage, and other management practices for each crop rotation and year. The model uses this information to estimate changes in soil carbon, changes in methane and nitrous oxide emissions, and the global warming equivalents of these emissions. (See the DNDC website for the model, instructions on its use, and detailed discussions of its applications.) The model is supplied with source data for the United States, but can be used for other locations where source data can be provided.

Where DNDC is used it must be calibrated for the location and circumstances of the project.

If changes in emissions of methane and nitrous oxide are expected to constitute less than 50% of the total difference in estimated atmospheric GHGs between the baseline and project scenario, the DNDC model may be calibrated using existing local or regional time series data on soil emissions of methane and nitrous oxide, if such data exists. Otherwise, project proponents must collect their own calibration data. If changes in emissions of methane and nitrous oxide are expected to constitute 50% or more of the total difference in estimated atmospheric GHGs between the baseline and project scenarios, project proponents must collect local time series data covering the full annual cycle, and use that data to calibrate DNDC. In either case the uncertainty of the calibration data must be taken into account when determining the uncertainty deduction as described by the latest version of the VCS Standard. If the available time series data provides sufficient statistically tested data on emissions under different meteorological and management conditions for local soil conditions, it may also be possible to build a site specific model or customize another model and use this model in place of DNDC.

**Step 4 : Summation of soil emissions**

The total emissions from soils for a given year t will be summed using the following equation:

$$E_s = E_{s,CH_4} + E_{s.N_2O} \qquad (13.7)$$

Where:

| | | |
|---|---|---|
| $E_s$ | = | Total emissions from non-$CO_2$ GHGs from soils for a given monitoring period, $tCO_2eyr^{-1}$ |
| $E_{s,CH4}$ | = | $CH_4$ emission from the project area for a given monitoring period, $tCO_2e\ yr^{-1}$ |
| $E_{s,N2O}$ | = | $N_2O$ emission as a result of nitrogen application within the project area for a given monitoring period, $tCO_2$-e $yr^{-1}$ |

# 6 PARAMETERS

| **Data Unit / Parameter:** | $E_{S,CH4}$ |
|---|---|
| Data unit: | t $CO_2e\ yr^{-1}$ |
| Description: | Total methane emissions from project area |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Total emissions of $CH_4$ from the project area for a given monitoring period |
| Any comment: | |

| **Data Unit / Parameter:** | *s* |
|---|---|
| Data unit: | Name |
| Description: | Strata |
| Source of data: | Assigned |
| Justification of choice of data or description of measurement methods and procedures applied: | Strata name |
| Any comment: | |

| **Data Unit / Parameter:** | $A_{sat,s}$ |
|---|---|
| Data unit: | Hectares |
| Description: | Mean area of saturated soils |
| Source of data: | Field surveys |
| Justification of choice of data or description of measurement methods and procedures applied: | The mean areas of saturated soils in stratum s |
| Any comment: | |

| **Data Unit / Parameter:** | $P_{icefree, sat, s}$ |
|---|---|
| Data unit: | # |
| Description: | Period of during which the soil is saturated and ice free |
| Source of data: | Field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Days the soil of strata s is saturated and ice free |
| Any comment: | |

| **Data Unit / Parameter:** | $CH_{4dif,ni}$ |
|---|---|
| Data unit: | kg ha$^{-1}$ day$^{-1}$ |
| Description: | Rate of emissions of $CH_4$ by diffusion during ice free days |
| Source of data: | Peer reviewed local research, IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | The rate of emissions of $CH_4$ by diffusion during ice free days |
| Any comment: | |

| **Data Unit / Parameter:** | $CH_{4bub,ni}$ |
|---|---|
| Data unit: | kg ha$^{-1}$ day$^{-1}$ |
| Description: | Rate of emissions of $CH_4$ by bubbling during ice free days |
| Source of data: | Peer reviewed local research, IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | The rate of emissions of $CH_4$ by bubbling during ice free days |
| Any comment: | |

| **Data Unit / Parameter:** | $P_{ice,sat,s}$ |
|---|---|
| Data unit: | kg ha$^{-1}$ day$^{-1}$ |
| Description: | Period during which the soil is saturated and ice covered in stratum |
| Source of data: | Field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Period during which the soil is saturated and ice covered in stratum |
| Any comment: | |

 

| **Data Unit / Parameter:** | $CH_{4dif,i}$ |
|---|---|
| Data unit: | kg ha$^{-1}$ day$^{-1}$ |
| Description: | Rate of emissions of $CH_4$ by diffusion during ice covered days |
| Source of data: | Peer reviewed local research, IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | The rate of emissions of $CH_4$ by diffusion during ice covered days |
| Any comment: | |

| **Data Unit / Parameter:** | $N_{SN\text{-}Fert,t}$ |
|---|---|
| Data unit: | tonnes N yr$^{-1}$ in year t |
| Description: | Total use of synthetic fertilizer within the project area |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Total use of synthetic fertilizer within the project area |
| Any comment: | |

| **Data Unit / Parameter:** | $N_{ON\text{-}Fert,t}$ |
|---|---|
| Data unit: | tonnes N yr$^{-1}$ in year t |
| Description: | Total use of organic fertilizer within the project area |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Total use of organic fertilizer within the project area |
| Any comment: | |

| **Data Unit / Parameter:** | $E_{s,N2O}$ |
|---|---|
| Data unit: | tonnes |
| Description: | Direct N2O emissions as result of Nitrogen application |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | The direct N2O emission as a result of nitrogen application within the project area during monitoring interval |
| Any comment: | |

| **Data Unit / Parameter:** | $A_s$ |
|---|---|
| Data unit: | ha $yr^{-1}$ |
| Description: | Area of stratum s with fertilization |
| Source of data: | Module *VMD0018 Methods to Determine Stratification* |
| Justification of choice of data or description of measurement methods and procedures applied: | |
| Any comment: | |

| **Data Unit / Parameter:** | $F_{SN}$ |
|---|---|
| Data unit: | |
| Description: | Amount of synthetic fertilizer nitrogen applied adjusted for volatilization as NH3 and NOX [1] |
| Source of data: | Calculated from field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Amount of synthetic fertilizer nitrogen applied adjusted for volatilization as NH3 and NOX, |
| Any comment: | |

| **Data Unit / Parameter:** | $F_{ON}$ |
|---|---|
| Data unit: | |
| Description: | Annual amount of organic fertilizer nitrogen applied adjusted for volatilization as NH3 and NOX |
| Source of data: | Calculated from field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Annual amount of organic fertilizer nitrogen applied adjusted for volatilization as NH3 and NOX |
| Any comment: | |

| **Data Unit / Parameter:** | $N_{SN\text{-}Fert}$ |
|---|---|
| Data unit: | tonnes N $yr^{-1}$ |
| Description: | Amount of synthetic fertilizer nitrogen applied |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Amount of synthetic fertilizer nitrogen applied |
| Any comment: | |

| **Data Unit / Parameter:** | $N_{SN\text{-}Fert}$ |
|---|---|
| Data unit: | tonnes N $yr^{-1}$ |
| Description: | Amount of organic fertilizer nitrogen applied |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Amount of organic fertilizer nitrogen applied |
| Any comment: | |

| **Data Unit / Parameter:** | $EF_1$ |
|---|---|
| Data unit: | tonnes $N_2O$-N (tonnes N input)$^{-1}$ |
| Description: | Emission factor for emissions from N inputs, tonnes $N_2O$-N |
| Source of data: | IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | Emission factor for emissions from N inputs, tonnes $N_2O$-N |
| Any comment: | |

| **Data Unit / Parameter**: | $Frac_{GASF}$ |
|---|---|
| Data unit: | Dimensionless |
| Description: | Fraction that volatilizes as $NH_3$ and $NO_X$ for synthetic fertilizers |
| Source of data: | IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | The fraction that volatilizes as NH3 and $NO_X$ for synthetic fertilizers |
| Any comment: | |

| **Data Unit / Parameter:** | $Frac_{GASM}$ |
|---|---|
| Data unit: | Dimensionless |
| Description: | Fraction that volatilizes as $NH_3$ and $NO_X$ for organic fertilizers |
| Source of data: | IPCC |
| Justification of choice of data or description of measurement methods and procedures applied: | The fraction that volatilizes as $NH_3$ and $NO_X$ for organic fertilizers |
| Any comment: | |

| **Data Unit / Parameter:** | *F* |
|---|---|
| Data unit: | # |
| Description: | Flooded days |
| Source of data: | Field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Number of days during which the site is flooded during the growing season |
| Any comment: | |

| **Data Unit / Parameter:** | *clay* |
|---|---|
| Data unit: | Dimensionless |
| Description: | Soil clay fraction |
| Source of data: | Laboratory testing of field samples |
| Justification of choice of data or description of measurement methods and procedures applied: | Fraction of the total mass of the soil which is made up of clay |
| Any comment: | |

| **Data Unit / Parameter:** | $A_{0-7}$ |
|---|---|
| Data unit: | # |
| Description: | Coefficient equation outputs |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Outputs of coefficient equations for the DNDC subset |
| Any comment: | |

| **Data Unit / Parameter:** | $B_0$ |
|---|---|
| Data unit: | Coefficient |
| Description: | Constant |
| Source of data: | Willey Z. B. Chameides, 2007 Harnessing Farms and Forests in the Low Carbon Economy , Nicolas Institute for Environmental Policy Solutions.p229 |
| Justification of choice of data or description of measurement methods and procedures applied: | Clay component constant for the DNDC subset equations |
| Any comment: | |

| **Data Unit / Parameter:** | *D* |
|---|---|
| Data unit: | # |
| Description: | Drained days during the growing season |
| Source of data: | Field data |
| Justification of choice of data or description of measurement methods and procedures applied: | |
| Any comment: | |

| **Data Unit / Parameter:** | *T* |
|---|---|
| Data unit: | ◦C |
| Description: | Mean annual temperature |
| Source of data: | Local climatological data |
| Justification of choice of data or description of measurement methods and procedures applied: | Mean annual air temperature |
| Any comment: | |

| **Data Unit / Parameter:** | *PH* |
|---|---|
| Data unit: | pH |
| Description: | Soil pH |
| Source of data: | Laboratory testing of samples |
| Justification of choice of data or description of measurement methods and procedures applied: | Soil pH |
| Any comment: | |

| **Data Unit / Parameter:** | *MD* |
|---|---|
| Data unit: | # |
| Description: | Days of manure |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Days of manure amendment before start of flooding |
| Any comment: | |

| **Data Unit / Parameter:** | *MA* |
|---|---|
| Data unit: | kg manure – C/ha |
| Description: | Amount of manure |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Amount of manure amended |
| Any comment: | |

| **Data Unit / Parameter:** | *SOC* |
|---|---|
| Data unit: | kg C/kg soil |
| Description: | Soil organic carbon Content |
| Source of data: | Laboratory testing of field samples |
| Justification of choice of data or description of measurement methods and procedures applied: | Soil organic carbon content |
| Any comment: | |

| **Data Unit / Parameter:** | *LEAK* |
|---|---|
| Data unit: | mm/day |
| Description: | Soil Water leaking rate |
| Source of data: | Local climatological data |
| Justification of choice of data or description of measurement methods and procedures applied: | Soil water leaking rate |
| Any comment: | |

| **Data Unit / Parameter:** | *Y* |
|---|---|
| Data unit: | kg C/ha/growing season |
| Description: | Crop yield |
| Source of data: | Crop data |
| Justification of choice of data or description of measurement methods and procedures applied: | Crop yield |
| Any comment: | |

| **Data Unit / Parameter:** | $R_{f\,n}$ |
|---|---|
| Data unit: | kg N/ha/yr |
| Description: | Fertilizer application rate |
| Source of data: | Inventory of fertilizer use |
| Justification of choice of data or description of measurement methods and procedures applied: | Fertilizer application rate |
| Any comment: | |

| **Data Unit / Parameter:** | $A_{0\text{-}3}$ |
|---|---|
| Data unit: | kg N/ha/yr |
| Description: | Coefficient equations for N emissions |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Background $N_2$0 flux coefficients for the $N_2$0 equations in the DNDC subset |
| Any comment: | |

| **Data Unit / Parameter:** | $B_{1\text{-}2}$ |
|---|---|
| Data unit: | kg N/ha/yr |
| Description: | Coefficient equations for N emissions |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Saturated N20 flux coefficients for the $N_2$0 equations in the DNDC subset |
| Any comment: | |

| **Data Unit / Parameter:** | $K_{0\text{-}7}$ |
|---|---|
| Data unit: | Rate coefficients |
| Description: | Coefficient equations for N emissions |
| Source of data: | Calculated |
| Justification of choice of data or description of measurement methods and procedures applied: | Calculated rate coefficients for N emissions in the DNDC subset |
| Any comment: | |

| **Data Unit / Parameter:** | *C* |
|---|---|
| Data unit: | kg C/kg soil |
| Description: | SOC content in top soil |
| Source of data: | Laboratory testing of field samples |
| Justification of choice of data or description of measurement methods and procedures applied: | SOC content in top soil (top 15 cm of the soil) |
| Any comment: | |

| **Data Unit / Parameter:** | *CN* |
|---|---|
| Data unit: | kg N/ha |
| Description: | Crop demand for N |
| Source of data: | Standard site specific agricultural N demand calculation based on laboratory results from soil samples |
| Justification of choice of data or description of measurement methods and procedures applied: | Crop demand for N |
| Any comment: | |

| **Data Unit / Parameter:** | *P* |
|---|---|
| Data unit: | mm |
| Description: | Total annual precipitation |
| Source of data: | Local climatological data |
| Justification of choice of data or description of measurement methods and procedures applied: | Total annual precipitation |
| Any comment: | |

| **Data Unit / Parameter:** | *LU* |
|---|---|
| Data unit: | # |
| Description: | Land-use type |
| Source of data: | Field data |
| Justification of choice of data or description of measurement methods and procedures applied: | Land-use type category (cropland: 1, rice paddy: 2, grassland: 3) |
| Any comment: | |

## 7 REFERENCES AND OTHER INFORMATION

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## DOCUMENT HISTORY

| Version | Date | Comment |
|---|---|---|
| v1.0 | 16 Nov 2012 | Initial version released |
| V1.1 | 14 Jan 2013 | Corrections to certain coefficient equations and definitions used in the DNDC subset method have been incorporated |