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LULUCF-TR
GHG Monitoring and Reporting System

Review_methods for estimation of **N2O emissions from managed soils**

1st workshop style training, 22-24 October 2018, Ankara
"**Technical Assistance for Developed Analytical Basis for Land Use, Land Use Change and Forestry (LULUCF) Sector**"
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AESA CONSORTIUM

Relevant LULUCF land categories:

- 4A. Forest land
- 4D. Wetlands
- 4E. Settlements

NB. N2O emissions from Cropland and Grasslands reported under Agriculture sector

Terminology:

N2O emissions = [N2O-N] *x* 28/44

N_2O-N = fraction of total N contained by source convertible to N2O emission
F = activity data

N2O Emissions from Managed Soils: **Direct N2O emissions sources from managed soils**

- **human-induced N inputs to managed soils**:
  - **synthetic N** fertilisers (F_{SN});
  - **organic N** applied as fertiliser (e.g., animal manure, compost, sewage sludge, rendering waste) (F_{ON});
  - **urine and dung N** deposited on pasture, range and paddock by grazing animals (F_{PRP});
  - **N in crop residues** (above-ground and below-ground), including from N-fixing crops and from forages during pasture renewal (F_{CR})

- **mineralisation of N in soil organic matter following drainage/management of organic soils:**
  - **drainage/management** of organic soils (i.e., Histosols) (F_{OS})

- **mineralisation of N by cultivation/land-use change on mineral soils:**
  - **N mineralisation** associated with loss of soil organic matter resulting from change of land use or management of mineral soils (F_{SOM})

N2O Emissions from Managed Soils: **Direct N2O emissions (Tier 1)**

EQUATION 11.1
DIRECT N_2O EMISSIONS FROM MANAGED SOILS (TIER 1)

$$N_2O_{Direct}\text{–}N = N_2O\text{–}N_{N\,inputs} + N_2O\text{–}N_{OS} + N_2O\text{–}N_{PRP}$$

EQUATION 11.2
DIRECT N_2O EMISSIONS FROM MANAGED SOILS (TIER 2)

$$N_2O_{Direct}\text{–}N = \sum_i \left(F_{SN} + F_{ON}\right)_i \bullet EF_{1i} + \left(F_{CR} + F_{SOM}\right) \bullet EF_1 + N_2O\text{–}N_{OS} + N_2O\text{–}N_{PRP}$$

N_2O_{Direct} –N = N2O–N emissions from managed soils, kg N2O–N yr-1

N_2O–$N_{N\,inputs}$ = N2O–N emissions from *N inputs to managed soils*, kg N2O–N yr-1

N_2O–N_{OS} = N2O–N emissions from *managed organic soils*, kg N2O–N yr-1

N_2O–N_{PRP} = N2O–N emissions from *urine and dung inputs to grazed soils*, kg N2O–N yr-1

N2O Emissions from Managed Soils: **Direct N2O emissions (Tier 1)**

N2O–N*N inputs* = **F** (amount of ...., kg N2O–N yr-1) * **EF1** (emission factor for share of N which is convertetible to N2O emissions, from N inputs)

$$N_2O\text{–}N_{N\ inputs} = \left[\begin{array}{l}\left[\left(F_{SN} + F_{ON} + F_{CR} + F_{SOM}\right) \bullet EF_1\right] + \\ \left[\left(F_{SN} + F_{ON} + F_{CR} + F_{SOM}\right)_{FR} \bullet EF_{1FR}\right]\end{array}\right]$$

SN –syntetic fertilizer, ON-organic fertilizers, CR-crop rezidues, **SOM – soil organic matter**

FR-flooded rice

N2O Emissions from Managed Soils: **Direct N2O emissions (Tier 1)**

N2O–N*os* = **F** (area of ...., kg N2O–N ha-1) * **EF2** (mission factor for N2O emissions from drained/managed organic soils)

$$N_2O\text{–}N_{OS} = \left[\begin{array}{l}\left(F_{OS,CG,Temp} \bullet EF_{2CG,Temp}\right) + \left(F_{OS,CG,Trop} \bullet EF_{2CG,Trop}\right) + \\ \left(F_{OS,F,Temp,NR} \bullet EF_{2F,Temp,NR}\right) + \left(F_{OS,F,Temp,NP} \bullet EF_{2F,Temp,NP}\right) + \\ \left(F_{OS,F,Trop} \bullet EF_{2F,Trop}\right)\end{array}\right]$$

N2O Emissions from Managed Soils: **Direct N2O emissions (Tier 1)**

N2O–N*PRP* = **F** (amount of ...., kg N2O–N ha-1) * **EF3** (emission factor for N2O from urine and dung N deposited on pasture, range and paddock by grazing animals)

$$N_2O\text{–}N_{PRP} = \left[\left(F_{PRP,CPP} \bullet EF_{3PRP,CPP}\right) + \left(F_{PRP,SO} \bullet EF_{3PRP,SO}\right)\right]$$

N2O Emissions from Managed Soils: **Direct N2O emissions (Tier 1)**

TABLE 11.1
DEFAULT EMISSION FACTORS TO ESTIMATE DIRECT N_2O EMISSIONS FROM MANAGED SOILS

Emission factor	Default value	Uncertainty range
EF_1 for N additions from mineral fertilisers, organic amendments and crop residues, and N mineralised from mineral soil as a result of loss of soil carbon [kg N_2O–N (kg N)$^{-1}$]	0.01	0.003 - 0.03
EF_{1FR} for flooded rice fields [kg N_2O–N (kg N)$^{-1}$]	0.003	0.000 - 0.006
$EF_{2\,CG,\,Temp}$ for temperate organic crop and grassland soils (kg N_2O–N ha^{-1})	8	2 - 24
$EF_{2\,CG,\,Trop}$ for tropical organic crop and grassland soils (kg N_2O–N ha^{-1})	16	5 - 48
$EF_{2F,\,Temp,\,Org,\,R}$ for temperate and boreal organic nutrient rich forest soils (kg N_2O–N ha^{-1})	0.6	0.16 - 2.4
$EF_{2F,\,Temp,\,Org,\,P}$ for temperate and boreal organic nutrient poor forest soils (kg N_2O–N ha^{-1})	0.1	0.02 - 0.3
$EF_{2F,\,Trop}$ for tropical organic forest soils (kg N_2O–N ha^{-1})	8	0 - 24
$EF_{3PRP,\,CPP}$ for cattle (dairy, non-dairy and buffalo), poultry and pigs [kg N_2O–N (kg N)$^{-1}$]	0.02	0.007 - 0.06
$EF_{3PRP,\,SO}$ for sheep and 'other animals' [kg N_2O–N (kg N)$^{-1}$]	0.01	0.003 - 0.03

Sources:

EF_1: Bouwman et al. 2002a,b; Stehfest & Bouwman, 2006; Novoa & Tejeda, 2006 in press; EF_{1FR}: Akiyama *et al.*, 2005; $EF_{2CG,\,Temp}$, $EF_{2CG,\,Trop}$, $EF_{2F,Trop}$: Klemedtsson *et al.*, 1999, IPCC Good Practice Guidance, 2000; $EF_{2F,\,Temp}$: Alm *et al.*, 1999; Laine *et al.*, 1996; Martikainen *et al.*, 1995; Minkkinen *et al.*, 2002: Regina *et al.*, 1996; Klemedtsson *et al.*, 2002; $EF_{3,\,CPP}$, $EF_{3,\,SO}$: de Klein, 2004.

N loss in soil management

EQUATION 11.8

N MINERALISED IN MINERAL SOILS AS A RESULT OF LOSS OF SOIL C THROUGH CHANGE IN LAND USE OR MANAGEMENT (TIERS 1 AND 2)

$$F_{SOM} = \sum_{LU}\left[\left(\Delta C_{Mineral,\,LU} \bullet \frac{1}{R}\right) \bullet 1000\right]$$

$\Delta C_{Mineral,\,LU}$ = average annual loss of soil carbon for each land-use type (LU), tonnes C (Note: for Tier 1, $\Delta C_{mineral,\,LU}$ will have a single value for all land-uses and management systems. Using Tier 2 the value for $\Delta C_{mineral,\,LU}$ will be disaggregated by individual land-use and/or management systems.

R = C:N ratio of the soil organic matter. A default value of 15 (uncertainty range from 10 to 30) for the C:N ratio (R) may be used for situations involving land-use change from Forest Land or Grassland to Cropland, in the absence of more specific data for the area. A default value of 10 (range from 8 to 15) may be used for situations involving management changes on *Cropland Remaining Cropland*. C:N ratio can change over time, land use, or management practice [17]. If countries can document changes in C:N ratio, then different values can be used over the time series, land use, or management practice.

N2O Emissions from Managed Soils: **in-direct N2O emissions sources**

- **Volatilisation and deposition** & **leaching and runoff** from land associated to:
  - synthetic N fertilisers (F_{SN});
  - organic N applied as fertiliser (e.g., animal manure, compost, sewage sludge, rendering waste) (F_{ON});
  - urine and dung N deposited on pasture, range and paddock by grazing animals (F_{PRP});
  - N in crop residues (above-ground and below-ground), including from N-fixing crops and from forages during pasture renewal (F_{CR});
  - N mineralisation associated with loss of soil organic matter resulting from change of land use or management of mineral soils (F_{SOM})

N2O Emissions from Managed Soils: **In-direct N2O emissions (Tier 1)**

EQUATION 11.9
N_2O FROM ATMOSPHERIC DEPOSITION OF N VOLATILISED FROM MANAGED SOILS (TIER 1)

$$N_2O_{(ATD)}\text{-}N = [(F_{SN} \bullet Frac_{GASF}) + ((F_{ON} + F_{PRP}) \bullet Frac_{GASM})] \bullet EF_4$$

Frac GASF, GASM = fraction that volatilises as NH3 and NOx
[kg N volatilised (kg of N applied or deposited)-1]

EF4 = emission factor for N2O emissions from atmospheric deposition of N on soils and water surfaces,
[kg N–N2O (kg NH3–N + NOx–N volatilised)-1]

EQUATION 11.10
N_2O FROM N LEACHING/RUNOFF FROM MANAGED SOILS IN REGIONS WHERE LEACHING/RUNOFF OCCURS (TIER 1)

$$N_2O_{(L)}\text{-}N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \bullet Frac_{LEACH\text{-}(H)} \bullet EF_5$$

Frac LEACH-(H) = fraction leaching/runoff occurs that
[kg N (kg of N additions)-1]

EF5 = emission factor for N2O emissions from N leaching and runoff
[kg N2O–N (kg N leached and runoff)-1]

N2O Emissions from Managed Soils: **In-direct N2O emissions (Tier 1)**

TABLE 11.3
DEFAULT EMISSION, VOLATILISATION AND LEACHING FACTORS FOR INDIRECT SOIL N_2O EMISSIONS

Factor	Default value	Uncertainty range
EF_4 [N volatilisation and re-deposition], kg N_2O–N (kg NH_3–N + NO_X–N volatilised)$^{-1}$ [22]	0.010	0.002 - 0.05
EF_5 [leaching/runoff], kg N_2O–N (kg N leaching/runoff) $^{-1}$ [23]	0.0075	0.0005 - 0.025
$Frac_{GASF}$ [Volatilisation from synthetic fertiliser], (kg NH_3–N + NO_X–N) (kg N applied) $^{-1}$	0.10	0.03 - 0.3
$Frac_{GASM}$ [Volatilisation from all organic N fertilisers applied , and dung and urine deposited by grazing animals], (kg NH_3–N + NO_x–N) (kg N applied or deposited) $^{-1}$	0.20	0.05 - 0.5
$Frac_{LEACH-(H)}$ [N losses by leaching/runoff for regions where Σ(rain in rainy season) - Σ (PE in same period) > soil water holding capacity, OR where irrigation (except drip irrigation) is employed], kg N (kg N additions or deposition by grazing animals)$^{-1}$	0.30	0.1 - 0.8

Note: The term $Frac_{LEACH}$ previously used has been modified so that it now only applies to regions where soil water-holding capacity is exceeded, as a result of rainfall and/or irrigation (excluding drip irrigation), and leaching/runoff occurs, and redesignated as $Frac_{LEACH-(H)}$. In the definition of $Frac_{LEACH-(H)}$ above, PE is potential evaporation, and the rainy season(s) can be taken as the period(s) when rainfall > 0.5 * Pan Evaporation. (Explanations of potential and pan evaporation are available in standard meteorological and agricultural texts). For other regions the default $Frac_{LEACH}$ is taken as zero.

CO2 EMISSIONS FROM LIMING

EQUATION 11.12
ANNUAL CO_2 EMISSIONS FROM LIME APPLICATION

$$CO_2\text{–}C\ Emission = (M_{Limestone} \bullet EF_{Limestone}) + (M_{Dolomite} \bullet EF_{Dolomite})$$

CO2–C Emission = annual C emissions from lime application, t C yr-1

M = annual amount of calcic limestone (CaCO3) or dolomite (CaMg(CO3)2), tyr-1

EF = emission factor, tonne of C (tonne of limestone or dolomite) -1. Default emission factors **EF = 0.12** for limestone and **EF=0.13** for dolomite

CO2 EMISSIONS FROM UREA FERTILIZATION

EQUATION 11.13
ANNUAL CO_2 EMISSIONS FROM UREA APPLICATION

$$CO_2\text{–}C\ Emission = M \bullet EF$$

CO2–C Emission = annual C emissions from urea ($CO(NH_2)_2$) application, tC yr-1

M = annual amount of urea fertilisation, t urea yr-1

EF = emission factor, tC (tonne of urea)-1. The default emission factor **EF = 0.20** for carbon emissions from urea applications (carbon content of urea on an atomic weight basis (20% for CO(NH2)2)).

Emissions and removals from drainage and rewetting and other management of organic and mineral soils

2006 IPCC Guidelines (Chapter 7: Wetlands)

TABLE 7.1
SECTIONS ADDRESSING MAJOR GREENHOUSE GAS EMISSIONS FROM MANAGED WETLANDS

Land-use category/GHG	Peatlands	Flooded Land
Wetlands Remaining Wetlands		
CO_2	Section 7.2.1.1	No Guidance [1]
CH_4	No Guidance [2]	Appendix 3
N_2O	Section 7.2.1.2	No Guidance [3]
Lands Converted to Wetlands		
CO_2	Section 7.2.2.1	Section 7.3.2.1 and Appendix 2
CH_4	No Guidance [2]	Appendix 3
N_2O	Section 7.2.2.2	No Guidance [3]

2013 IPCC Wetland Supplement – include EFs for CH4 and N2O

Chapter 2	Drained Inland Organic Soils
Chapter 3	Rewetted Organic Soils
Chapter 4	Coastal Wetlands
Chapter 5	Inland Wetland Mineral Soils
Chapter 6	Constructed Wetlands for Wastewater Treatment

See TABLE 1 COVERAGE OF THE WETLANDS SUPPLEMENT