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Soil GHGs in LULUCF: status and options for improvement

Non-CO_2 GHGs from soils reported in LULUCF

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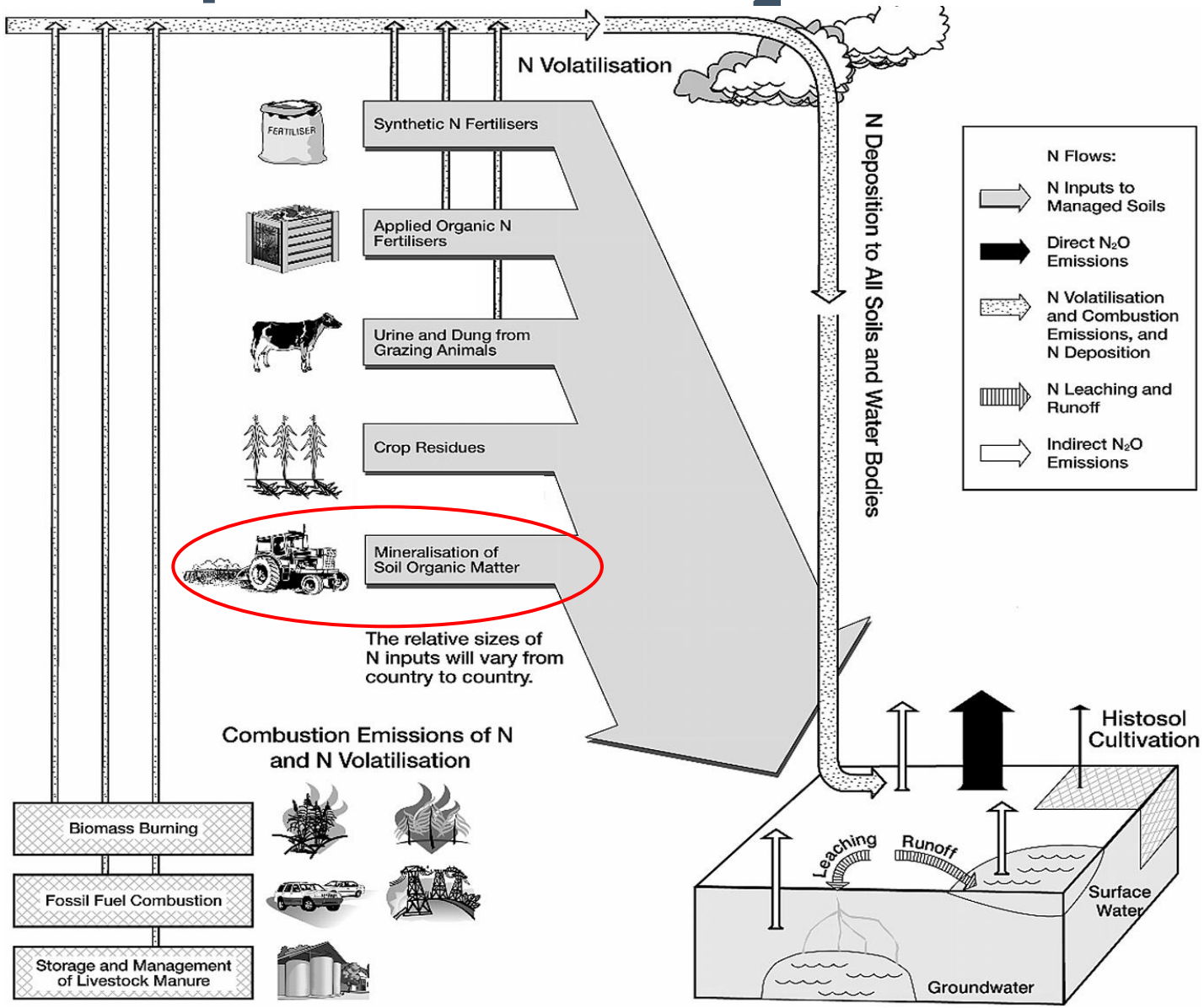
Importance of N_2O soil emissions



IPCC 2006

- We evaluated how EU Member States report non-CO_2 emissions from organic and mineral soils under the LULUCF sector**, based on 2024 GHG inventory submissions**.

- This work summarises current methodologies for non-CO_2 emissions from soils and highlights **key areas for improvement in national reporting approaches**.

Reporting N_2O soil emissions – Mineral soils

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Tier 1 - IPCC 2006, Chapter 11

N_2O–N emissions from N inputs

N_2O–N emissions from managed organic soils

EQUATION 11.1

DIRECT N_2O EMISSIONS FROM MANAGED SOILS (TIER 1)

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

N_2O–N emissions from urine and dung

Where:

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

Calculation based on EF

F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil
EF1 = emission factor for N_2O emissions from N inputs, kg N_2O–N (kg N input)$^{-1}$

Reporting N_2O soil emissions – Mineral soils

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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)

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

IPCC 2006, Chapter 11

F_{SOM} = the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

ΔC Mineral LU = average annual loss of soil carbon for each land-use type (LU), tonnes C

R = C:N ratio of the soil organic matter (e.g. a default value of 15 may be used land-use change from Forest Land or Grassland to Cropland, in the absence of more specific data for the area)

Reporting N_2O soil emissions – Organic soils

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Drained organic soils emit significant amounts of N_2O, whereas emissions from **wet organic soils are close to zero**. The main reason is **nitrogen mineralisation** associated with **organic matter decomposition** in drained organic soils.

IPCC 2013 wetland supplement: Equation 2.7 (applicable to Equation 11.1 presented in Chapter 11, Volume 4 of the 2006 IPCC Guidelines

EQUATION 2.7

DIRECT N_2O EMISSIONS FROM MANAGED/DRAINED ORGANIC SOILS

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

Calculation based on EF

F_{OS} = Annual area of managed/drained organic soils

EF2 = emission factor for N_2O emissions from drained/managed organic soils, kg N_2O–N ha^{-1} yr^{-1}

Data collection

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N_2O emissions are reported for **mineral soils in CRT Table 4(III)** and in **Table 4(II) for organic soils**

Table in a digital format (e.g. Excel) containing **all the Parameters collected from MS**:

- Tier level
- Brief methodology description
- **R** = C:N ratio of the soil organic matter → needed to calculate F_{SOM}
- **EF1 =** emission factor for N_2O emissions from N inputs, kg N_2O–N (kg N input)$^{-1}$
- **EF2 =** emission factor for N_2O emissions from drained/managed organic soils, kg N_2O–N ha^{-1} yr^{-1}
- Source of EF

GREENHOUSE GAS SOURCE AND SINK CATEGORIES
Land-use category(2)
Total for all land use categories
A. Forest land(5)
1. Forest land remaining forest land
1. Inorganic N fertilizers(6)
2. Organic N fertilizers(7)
2. Land converted to forest land
1. Inorganic N fertilizers(6)
2. Organic N fertilizers(7)
D. Wetlands(5)
1. Wetlands remaining wetlands
1. Inorganic N fertilizers(6)
2. Organic N fertilizers(7)
2. Land converted to wetlands
1. Inorganic N fertilizers(6)
2. Organic N fertilizers(7)
E. Settlements(5)
1. Settlements remaining settlements
1. Inorganic N fertilizers(6)
2. Organic N fertilizers(7)
2. Land converted to settlements
1. Inorganic N fertilizers(6)
2. Organic N fertilizers(7)
H. Other (please specify)(5) (8)

Summary of findings and gaps – Mineral soils 1/2

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Emission factor

- **All countries** use the default IPCC 2006 emission factor of **0.01 kg N_2O–N per kg N** released from soil organic matter.

Link to soil carbon estimation

- N_2O emissions are **strongly correlated** with methods used to estimate **soil carbon stock changes**.
- The C:N ratio is a key parameter for linking carbon and nitrogen dynamics.

Issues with C:N ratio reporting

- **Transparency is often lacking**: some countries mention C:N ratios but do not provide numeric values in their inventories.
- Some countries provide only one aggregated national value, even if regional variations exist.

Summary of findings and gaps – Mineral soils 2/2

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Use of country-specific C:N ratios

Some countries **use national C:N ratios** and **claim a Tier 2** approach, but:

- The C:N ratio alone **does not qualify** the method **as Tier 2**.
- **Only** the use of a country-specific **emission factor (EF1)** determines a Tier 2 classification.
- Therefore, most countries effectively report under Tier 1, even if they use national C:N data.

- **Only two countries** stratified the C:N ratios for the different country areas.
- Many countries use the same C:N ratio for the different land uses.
- Only one country use C:N ratios via Tier 3 modelling for some land uses, but then data are not showed.
- Most of the countries use default IPCC values for both EF and C:N ratio.

Summary of findings and gaps – Organic soils

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- **11 countries** report direct N_2O emissions from managed/drained organic soils.
- **4 of these countries** also report emissions from peat extraction areas.
- **4 countries** use a Tier 2 approach with country-specific emission factors (EF2).
- The **remaining countries** apply the **Tier 1** approach using default IPCC values.

Image: RSPB

Recommendations for Improvement/lessons learned

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Emission Factors

- All national inventories still use the IPCC Tier 1 emission factor (0.01 kg N–N_2O/kg N), which does not account for national soil, climate, or management differences.
- **Scientific studies show large variability in N_2O emission factors**, ranging roughly from 0.0001 to 0.085, depending on land use, soil type, and climate (Hergoualc'h et al. 2021, Räbiger et al. 2023, Thorman et al. 2020) .
- Using **country- or region-specific data** could **improve the accuracy** of N_2O emission estimates and help countries move toward **Tier 2 reporting**.

C:N ratio

- Refining **C:N ratios at national or regional level** could further **enhance reporting quality**; LUCAS soil data (2009–2022) are a key source for this.
- European datasets and studies (e.g. Matschullat et al. 2018, Paltineanu et al. 2024) already provide valuable soil C, N, and C:N ratio data that could replace default IPCC factors.

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Thank you!

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