Nitrous oxide (N_2O) emissions from decomposing crop residues in soils

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The recycling of crop residues into the soil

Crop residues : all the materials left above and below ground after harvesting or cover destruction (e.g., “catch crop”, “green manure”)

Apart from exogenous organic matters (e.g., manure, compost), crop residues are the only C input to soils

Soils sequester C preventing CO_2 from escaping into our atmosphere

Senescent wheat residue after harvest

A cover crop at green stage being destroyed

4 PER 1000 SOILS FOR FOOD SECURITY AND CLIMATE

https://www.4p1000.org/

The recycling of crop residues into the soil

Other benefits …

Crop residues : contribute main elements (e.g., nitrogen (N), phosphorous, sulfur) to the soil, supporting the crop nutrition, the soil microorganisms and soil fauna biodiversity

sustain soil organic matters (SOM) providing soil structure, nutrient retention, habitats for soil life, protection from erosion and flooding

Clover cover

But crop residues contribute to the greenhouse gas (GHG) balance of cropping systems in two ways

- Soil carbon storage in soils
- Nitrous oxide (N_2O) emissions

Agroecology : a diversity of crop residues management

↗ diversification of crops and use of inter-crop in crop rotations

Rape seed
Brassicaceae

Wheat
Poaceae

Pea
Fabaceae

Sugar beet
Amaranthaceae

Alfalfa
Fabaceae

Potatoe
Solanaceae

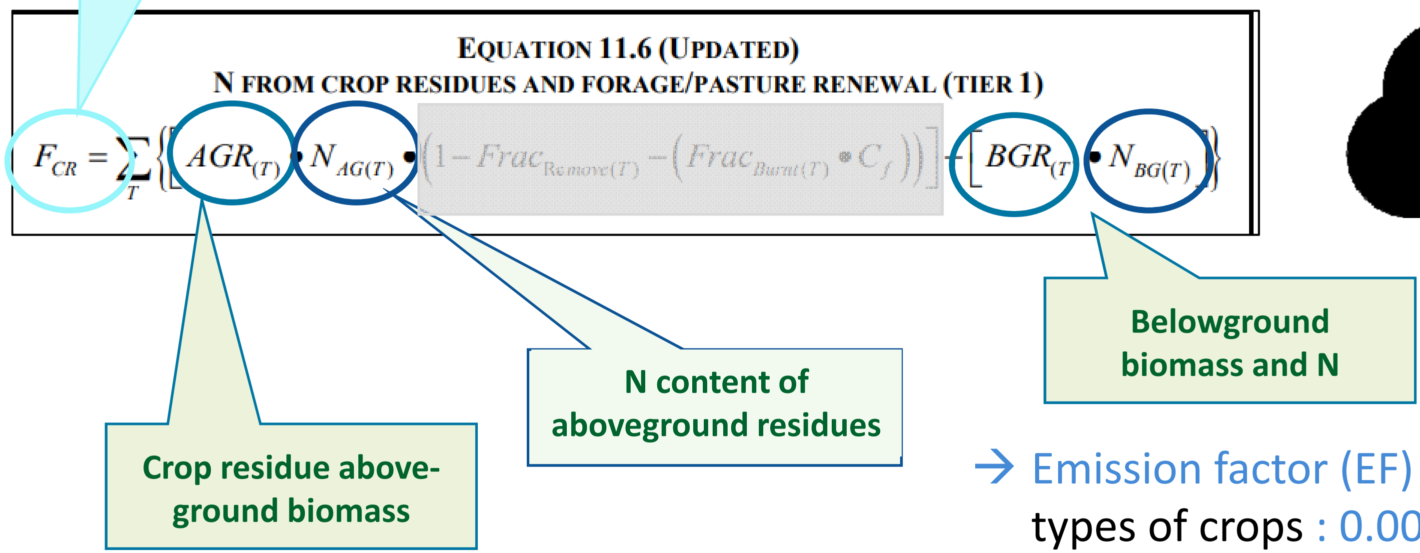
↘ Soil tillage

Direct seeding of corn in rye

→ Crop residues:
- from plant with different species, botanical families, physiological stages (maturity)
- in different recycling situations (on the soil surface, buried...)

How N_2O emission are estimated from crop residues?

In the Intergovernmental Panel on Climate Change (IPCC) Tier 1 methodology, the nature of the plant residues is taken into account by the quantity of biomass (*AGR* & *BGR*) returned and its nitrogen (N) content

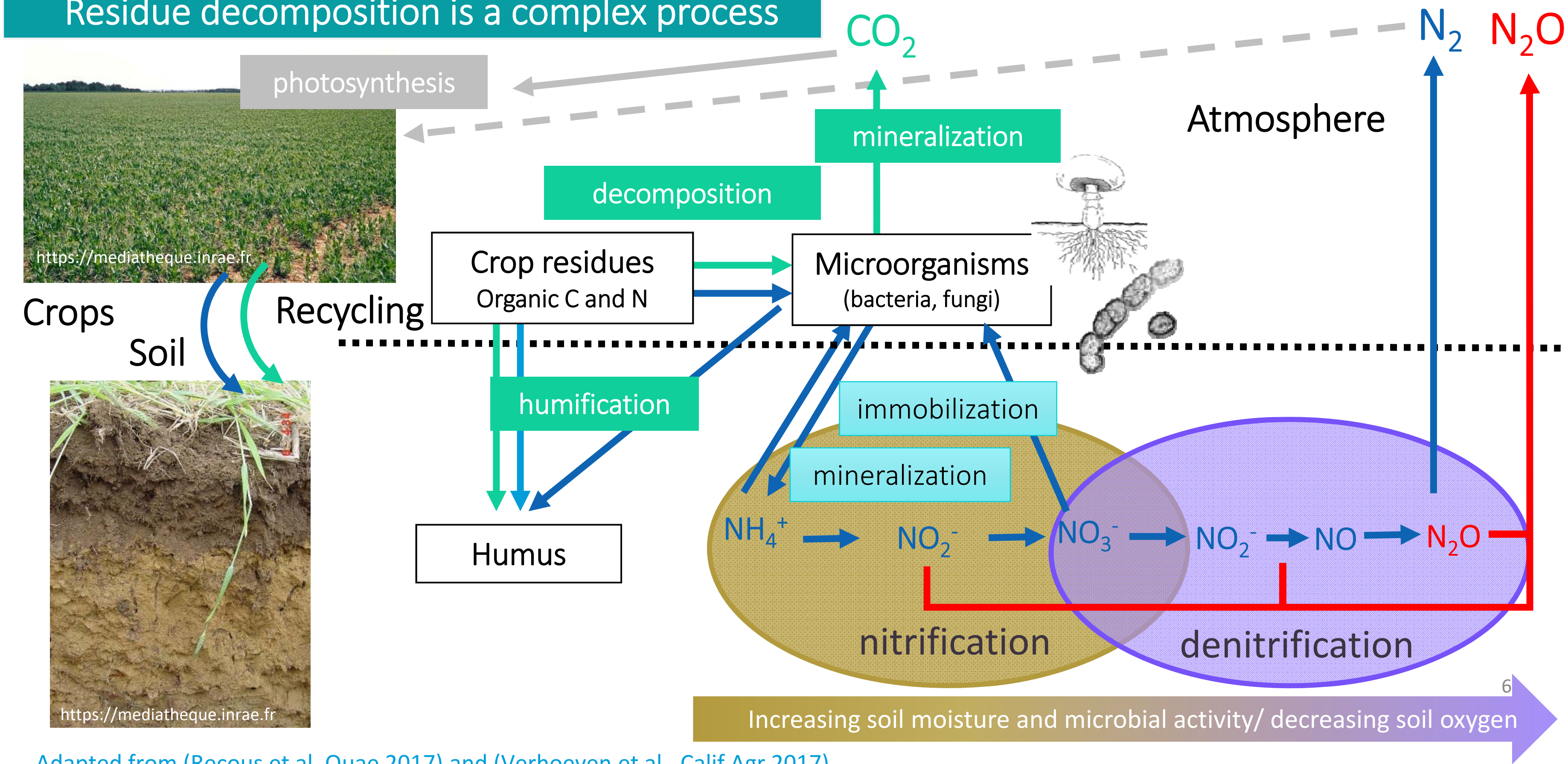


→ Emission factor (EF) standard for all types of crops : 0.005 to 0.006 kg N_2O-N kg^{-1} N returned

2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories

Is it that simple?

Residue decomposition is a complex process

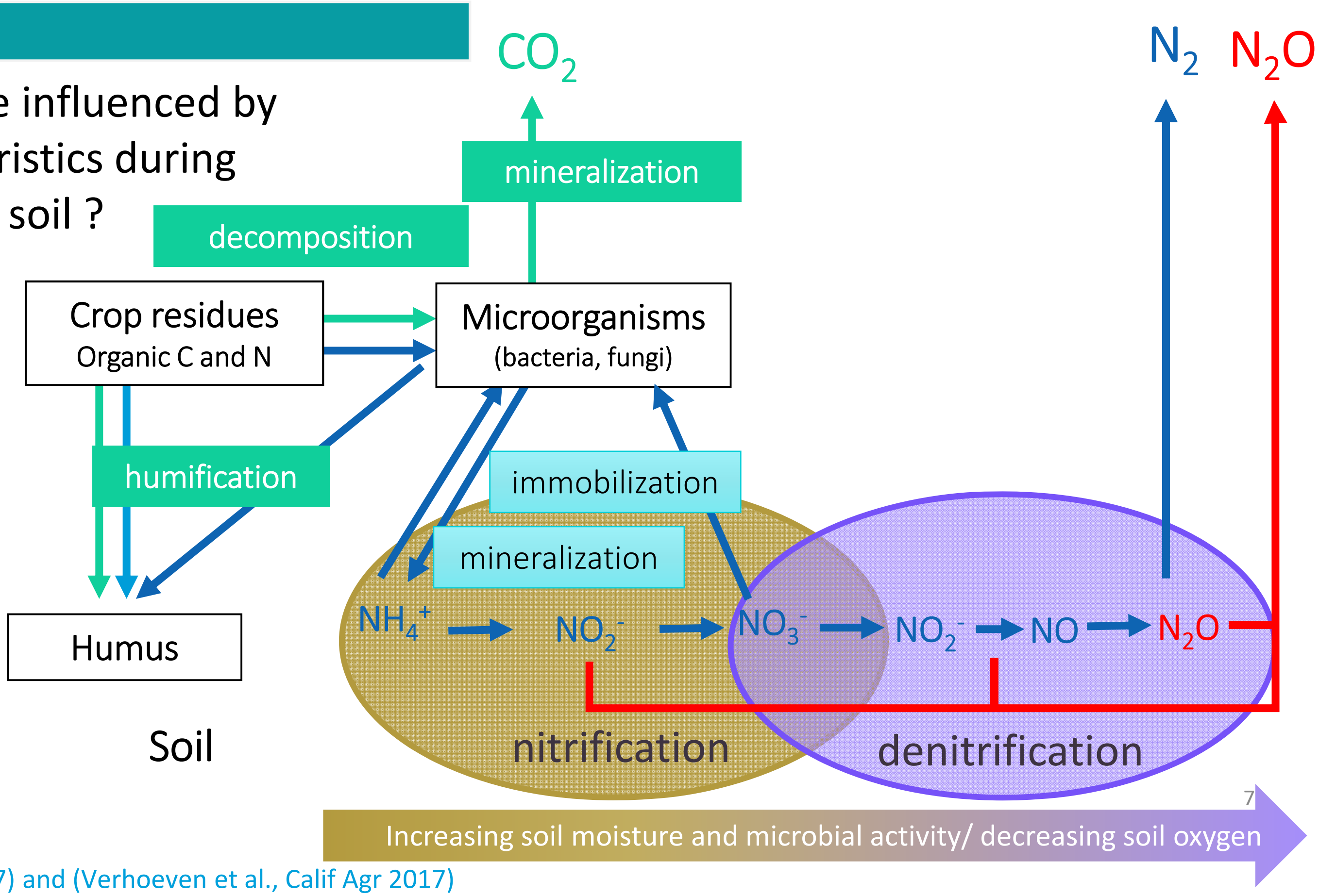


Adapted from (Recous et al. Quae 2017) and (Verhoeven et al., Calif Agr 2017)

Objectives of the study

How N_2O emissions are influenced by crop residues characteristics during their decomposition in soil ?

Experiment with 9 different crop species residues and two soils under controlled conditions



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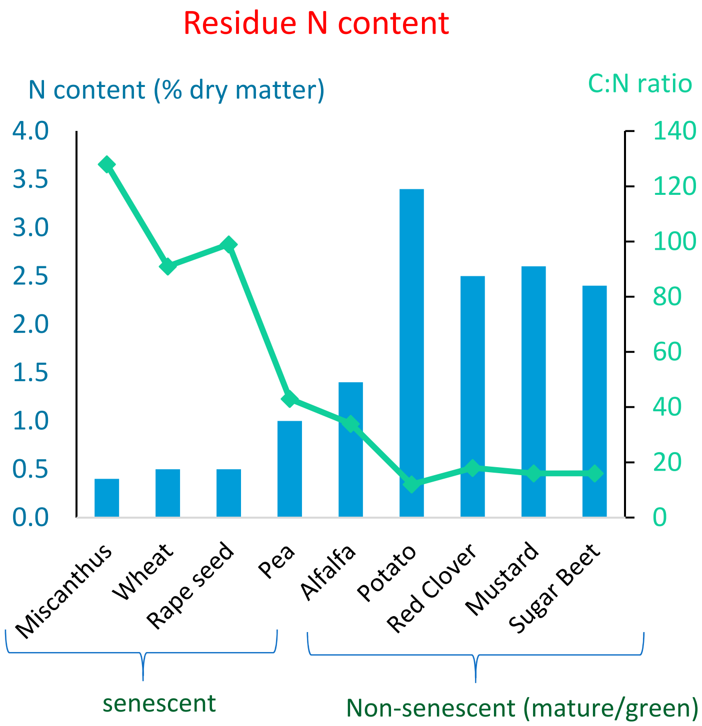
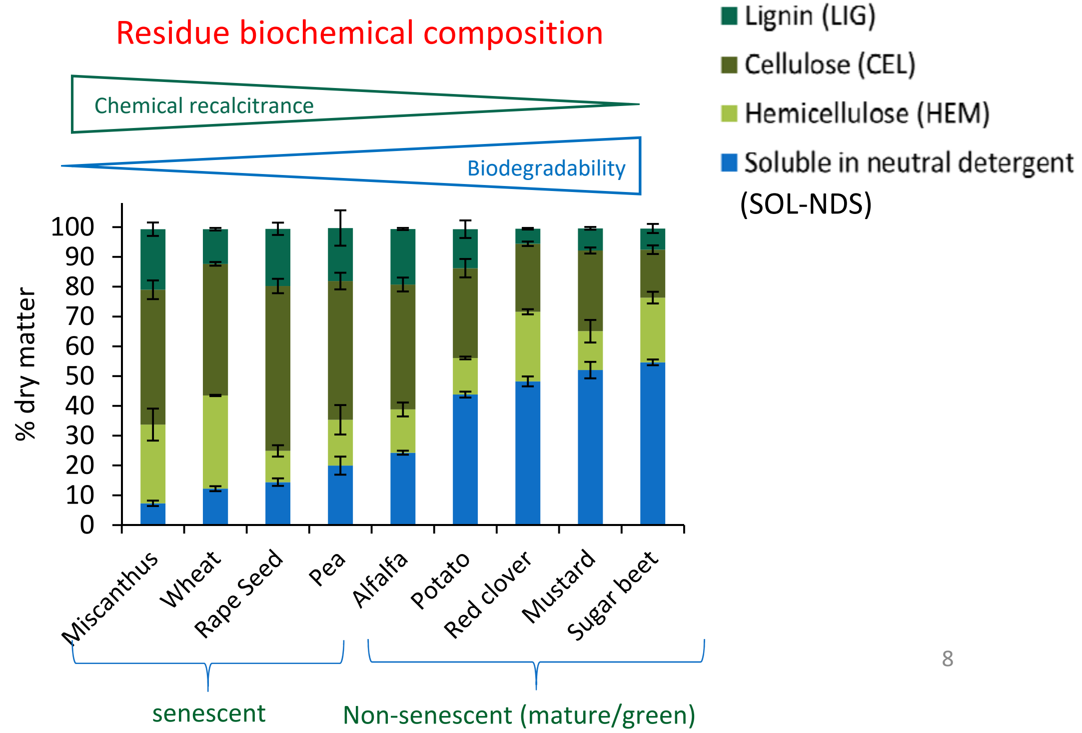
Materials and Methods

A range of crop residue “quality”

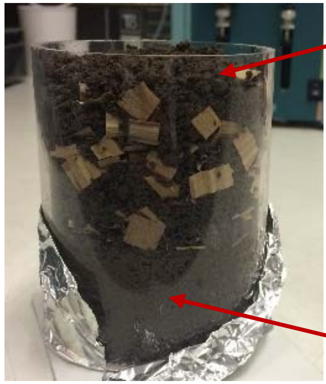
The residue chemical quality is both the N content and the biochemical composition plant tissues -> depends on crop species, plant part, and crop maturity





Materials and Methods

Soil+residue in cylinders



Crop residues mixed in the top 0-4 cm layer

No residue in the bottom 0-4 cm layer

- Controlled density of 1.25 g cm^{-3}
- 4 t residue-DM ha^{-1}
- 15°C
- 60% WFSP

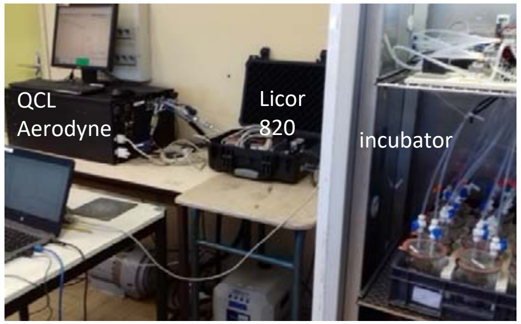
Calcareous silty clay loam (GRI) pH 8.3
Sandy loam (SLU) pH 6.2

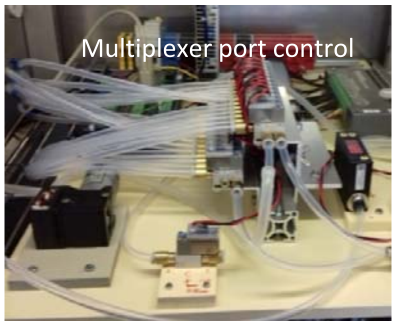
Initial residue moisture adjusted to 20% wet weight (wheat, pea, potato, rapeseed) and 80% (others)

- NO_3^- and NH_4^+ contents in the 2 layers at days 0, 4, 7, 14, 28, 60
- CO_2 trapped in NaOH

(Alavoine et al., Pedobiologia, 2008)

N_2O emissions measured by infrared spectrometry





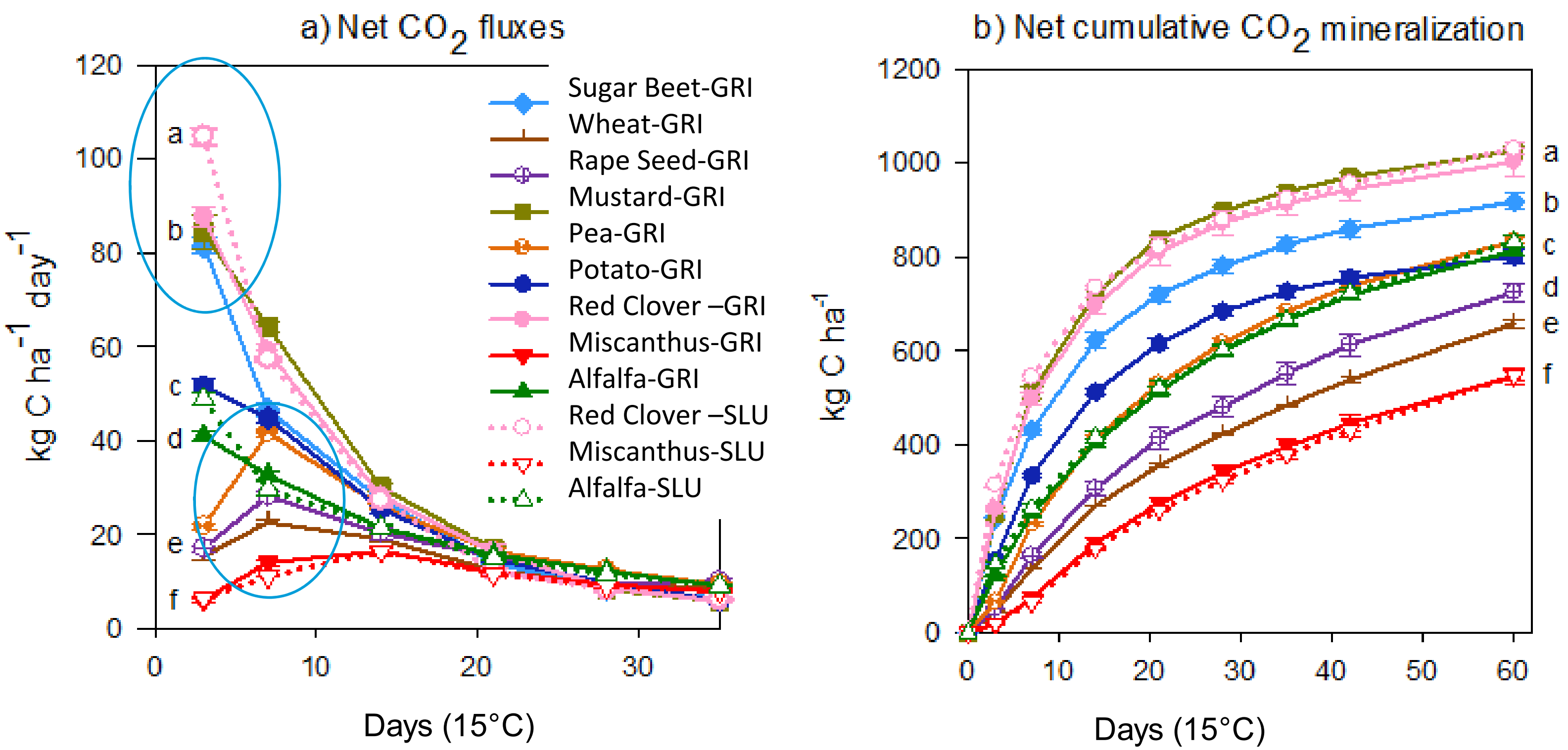
- Flux assessments by two methods : in open circuit and with accumulation in closed circuit
- Every day during 3 weeks

(Laville et al., IEEE International Workshop on Metrology for Agriculture and Forestry, 2019)

Results

Daily and cumulative CO_2 emitted

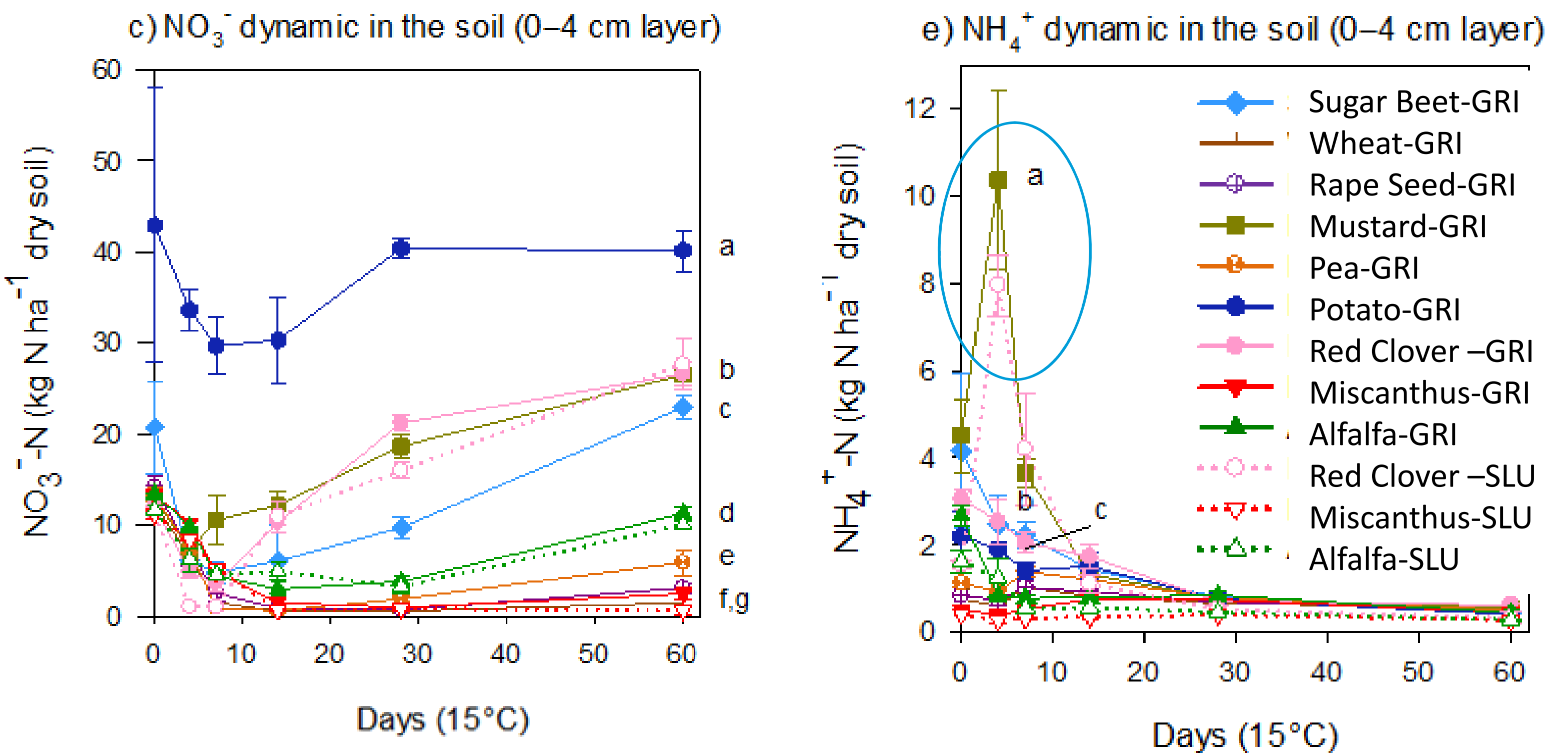
The initial CO_2 peak reflected microbial hotspots where the local available oxygen was fully consumed



(Lashermes et al. STOTEN, n°150883, 2021, https://doi.org/10.1016/j.scitotenv.2021.150883)

Results

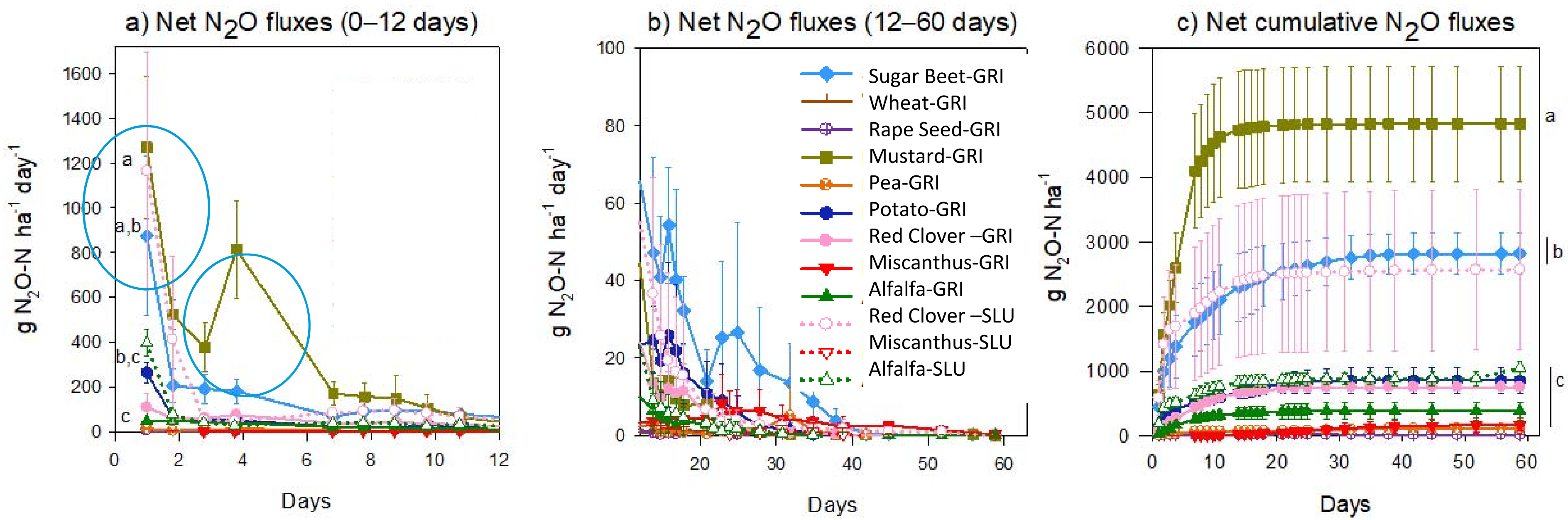
Soil mineral N dynamics: NO_3^- and NH_4^+



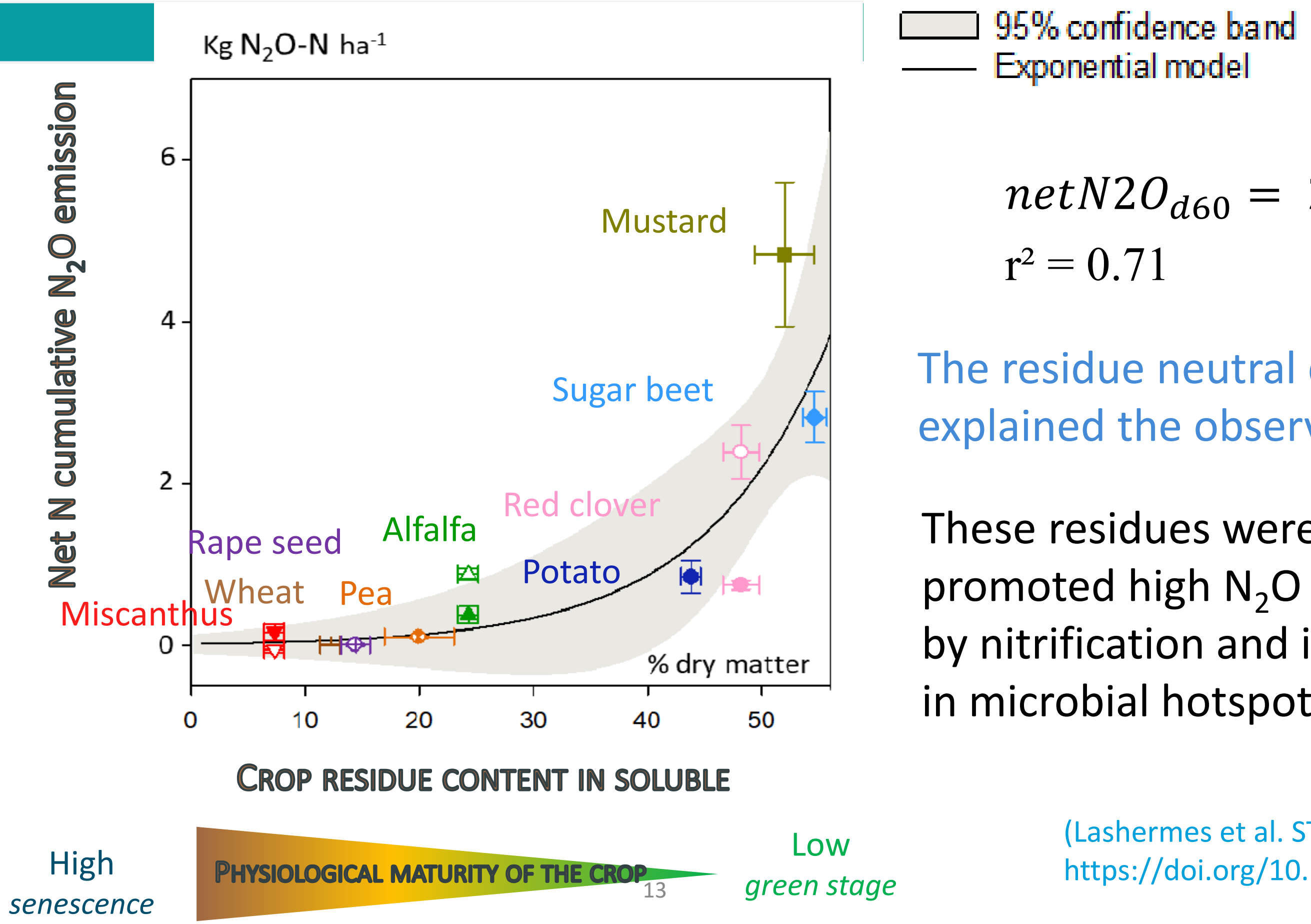
These higher soil NH_4^+ contents were related to CO_2 and N_2O emitting situations

Results

Daily and cumulative N_2O emitted



Results



$$netN2O_{d60} = 23.497 \cdot e^{0.093 \cdot SOL-NDS}$$

$r^2 = 0.71$

The residue neutral detergent soluble content explained the observed N_2O emissions

These residues were also non-senescent and promoted high N_2O emissions, likely directly by nitrification and indirectly by denitrification in microbial hotspots.

(Lashermes et al. STOTEN, n°150883, 2021, https://doi.org/10.1016/j.scitotenv.2021.150883)

Conclusions

N_2O emissions :

- occurred mainly in the very first days of decomposition
- were related to the consumption of soluble compounds
- Were further limited by microbial assimilation of mineral N (i.e., N immobilization)

Residues with a high soluble content (non-senescent) promoted N_2O emissions representing 1–5% of applied N >> 0.6 % the current recommended values for residue *EF-N_2O* in national inventories (IPCC, 2019).

Differentiated emission factors are strongly needed!

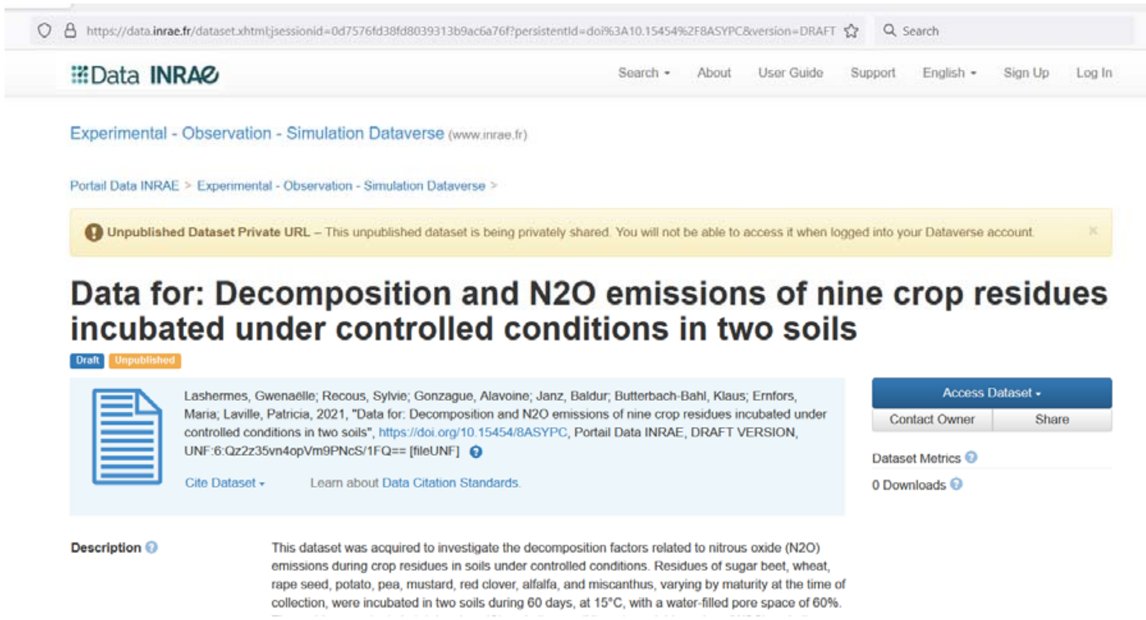
Destruction of cover crop

More studies are needed to objectively weigh the other benefits these non-senescent residues could bestow upon C storage, NO_3^- retention, and erosion limitation by soil cover.

Conclusions

The data are available on the Data INRAE repository
https://doi.org/10.15454/8ASYPC

More information about the projet :
https://projects.au.dk/residuegas/



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