

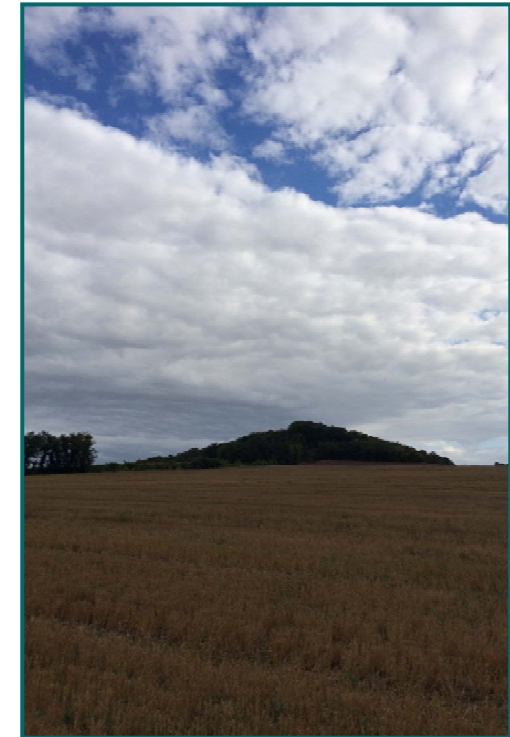


Nitrous oxide (N₂O) emissions from decomposing crop residues in soils

Gwenaëlle Lashermes, Sylvie Recous,
Gonzague Alavoine, Baldur Janz, Klaus
Butterbach-Bahl, Maria Erfors,
Patricia Laville

gwenaelle.lashermes@inrae.fr

Fractionation of AgroResources and
Environment lab, Reims, France



Reims, 12 October 2021 –
The ICOS France Science day

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**



<https://precisionagriculture.re/soil-residue-management/>
Senescent wheat residue after harvest



(Petit et al., ASD, 2018)

A cover crop at green stage being destroyed



<http://www.fao.org/soils-2015>

Soils sequester C preventing CO₂ from escaping into our atmosphere



<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



ResidueGas stakeholder webinar

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 N₂O 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

Crop residue N input

EQUATION 11.6 (UPDATED)
N FROM CROP RESIDUES AND FORAGE/PASTURE RENEWAL (TIER 1)

$$F_{CR} = \sum_T \left\{ \left[AGR_{(T)} \cdot N_{AG(T)} \cdot \left(1 - \text{Frac}_{\text{Remove}(T)} - \left(\text{Frac}_{\text{Burn}(T)} \cdot C_f \right) \right) \right] + \left[BGR_{(T)} \cdot N_{BG(T)} \right] \right\}$$



Crop residue above-ground biomass

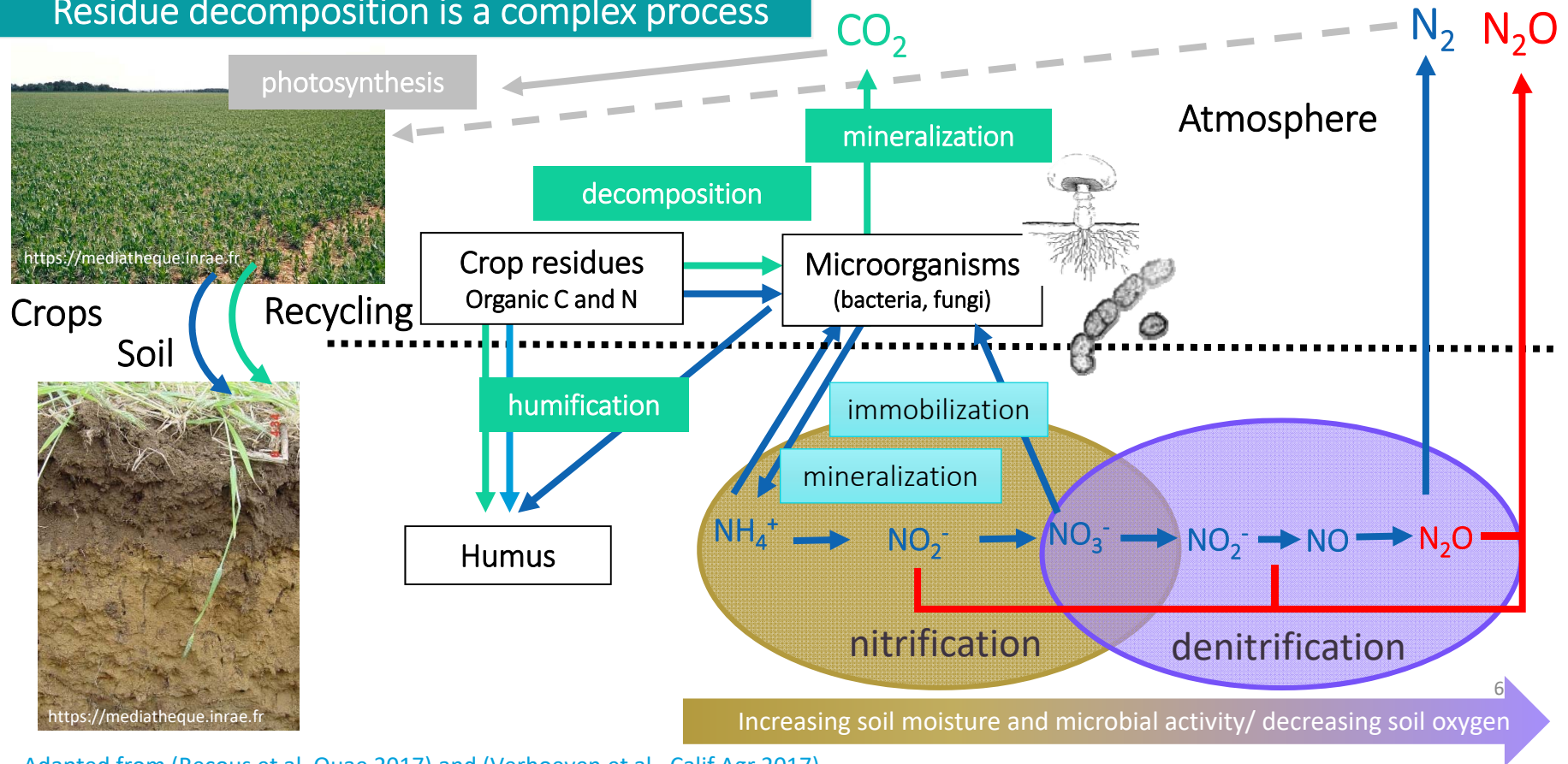
N content of aboveground residues

Belowground biomass and N

→ Emission factor (EF) standard for all types of crops : 0.005 to 0.006 kg N₂O-N kg⁻¹ N returned

Is it that simple?

Residue decomposition is a complex process

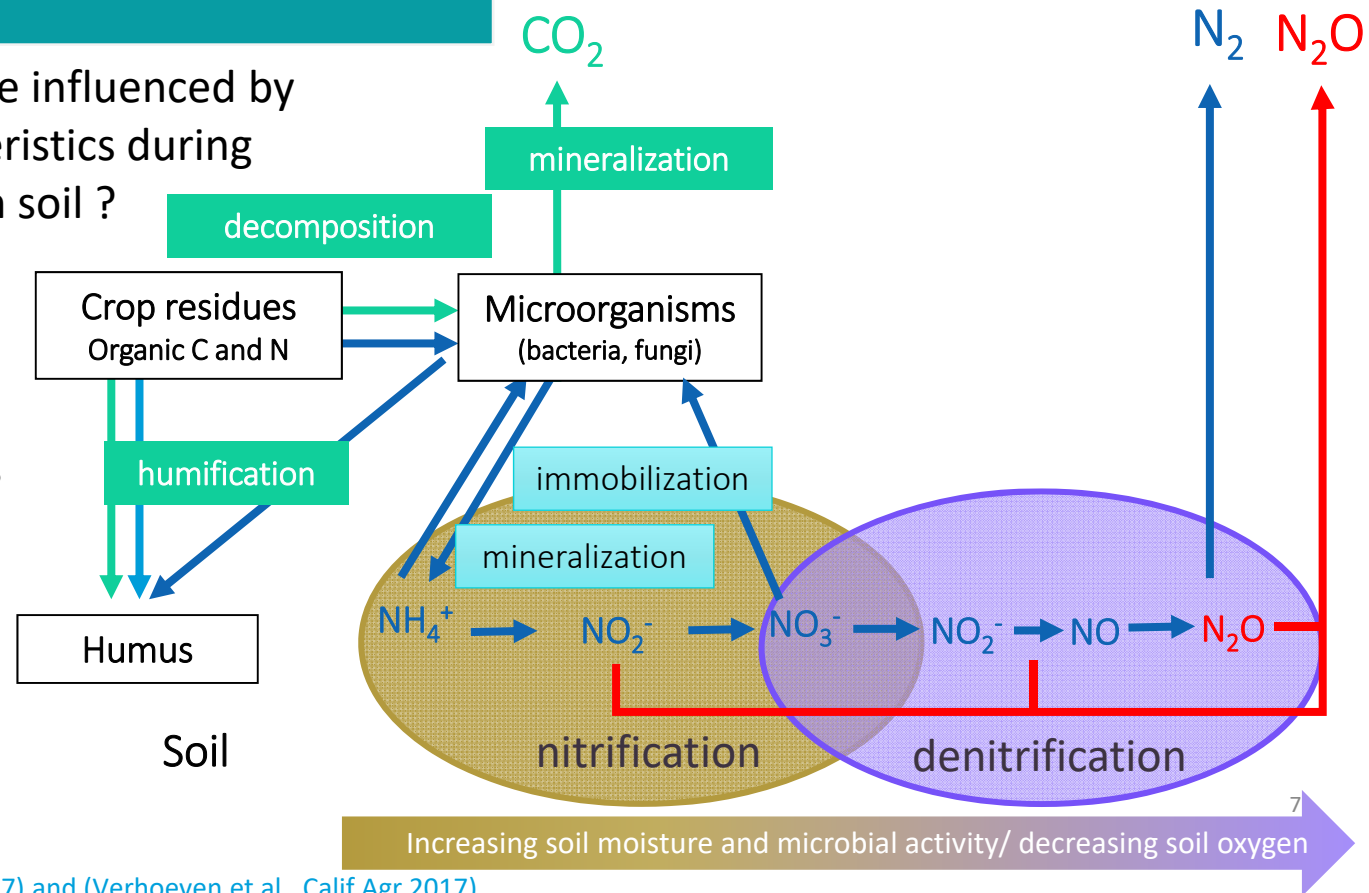


Adapted from (Recous et al. Quae 2017) and (Verhoeven et al., Calif Agr 2017)

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



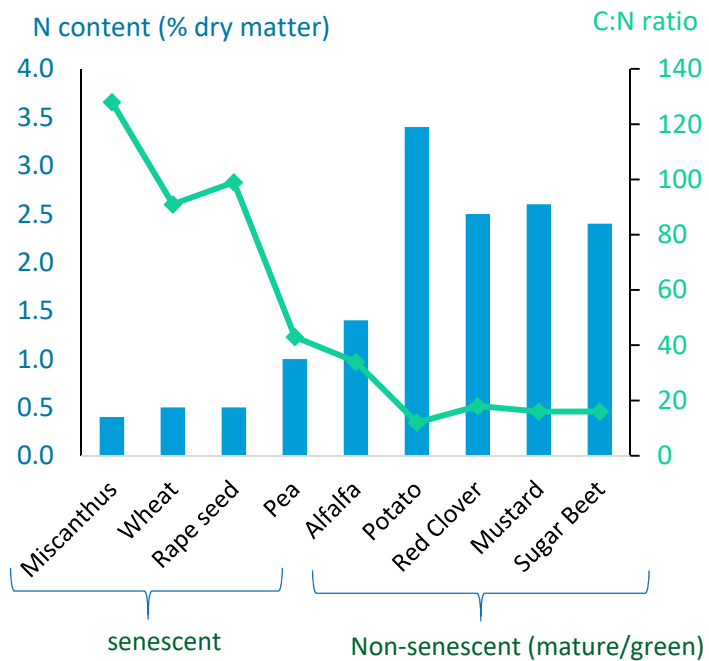
Adapted from (Recous et al. Quae 2017) and (Verhoeven et al., Calif Agr 2017)

Materials and Methods

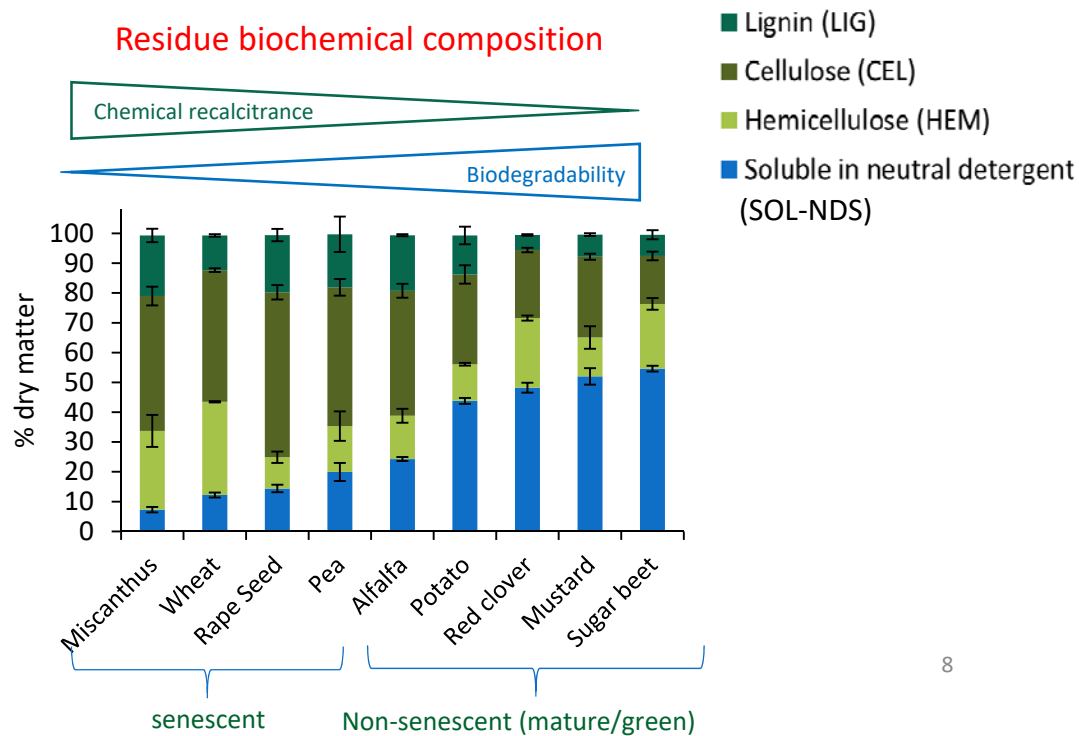
A range of crop residue "quality"

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

Residue N content

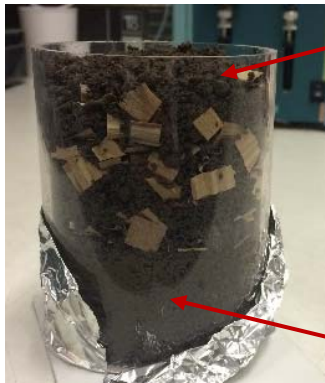


Residue biochemical composition



Materials and Methods

Soil+residue in cylinders



Crop residues mixed in the top 0-4 cm layer

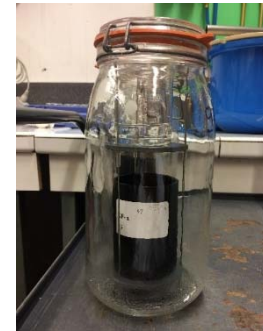
Calcareous silty clay loam (GRI) pH 8.3
Sandy loam (SLU) pH 6.2

No residue in the bottom 0-4 cm layer

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



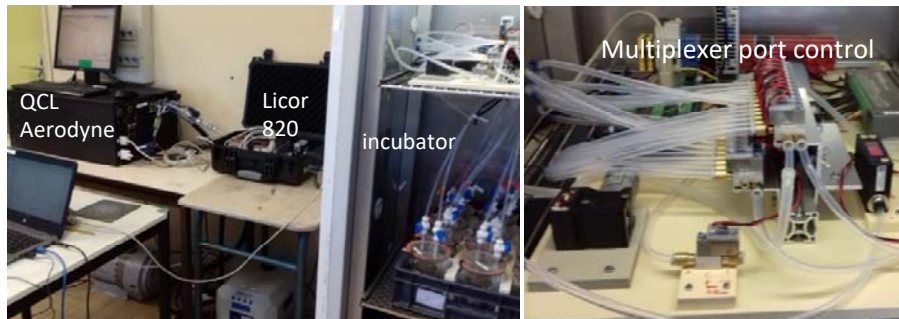
Initial residue moisture adjusted to 20% wet weight (wheat, pea, potato, rapeseed) and 80% (others)



- 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



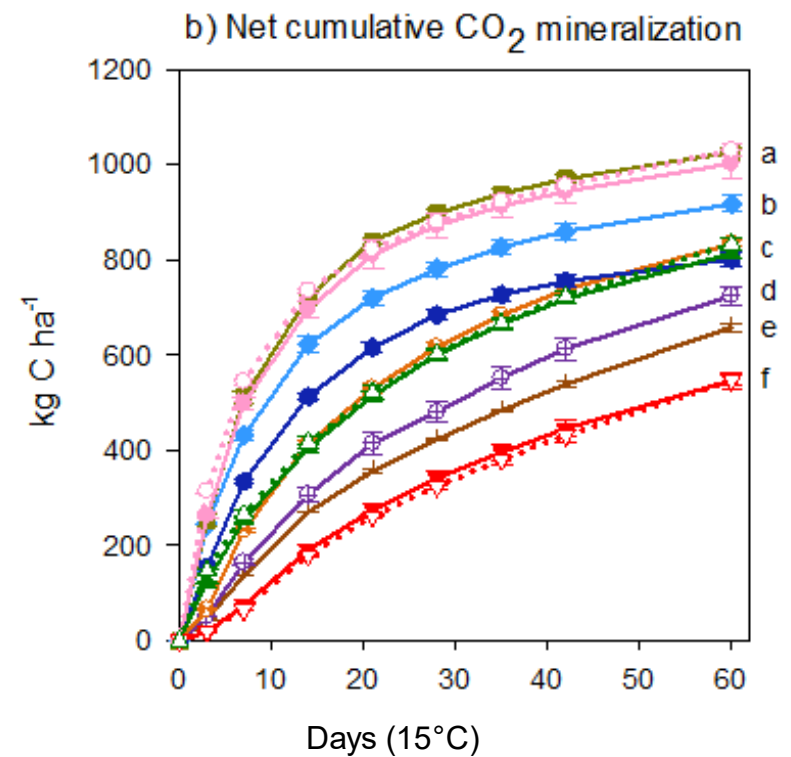
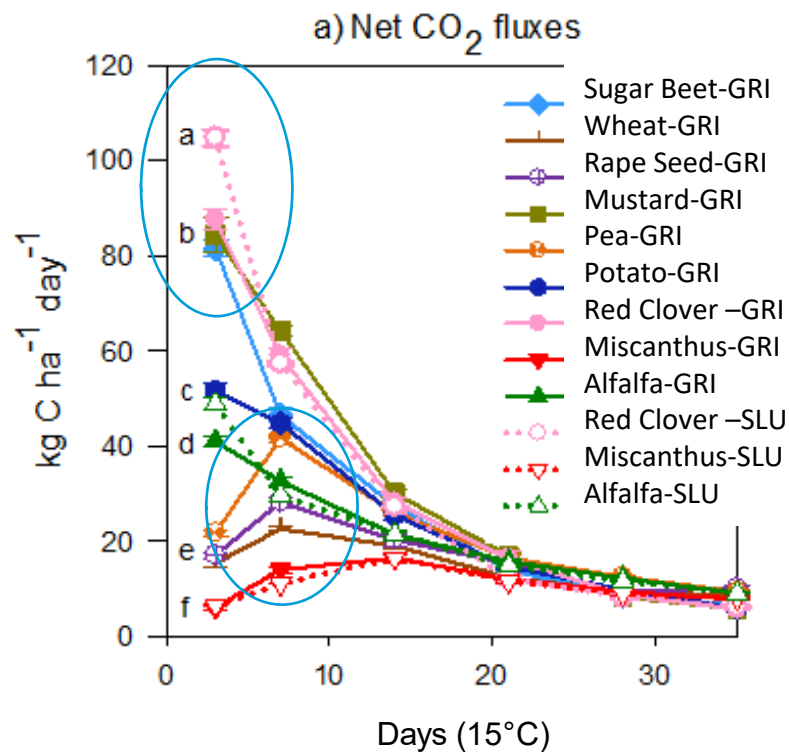
- Flux assessments by two methods : in open circuit and with accumulation in closed circuit
- Every day during 3 weeks

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

Results

Daily and cumulative CO₂ emitted

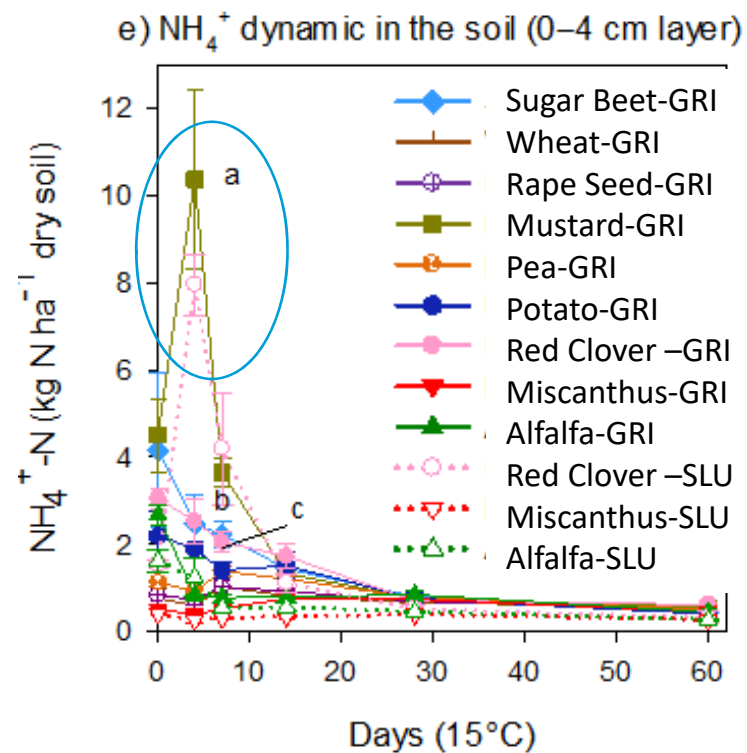
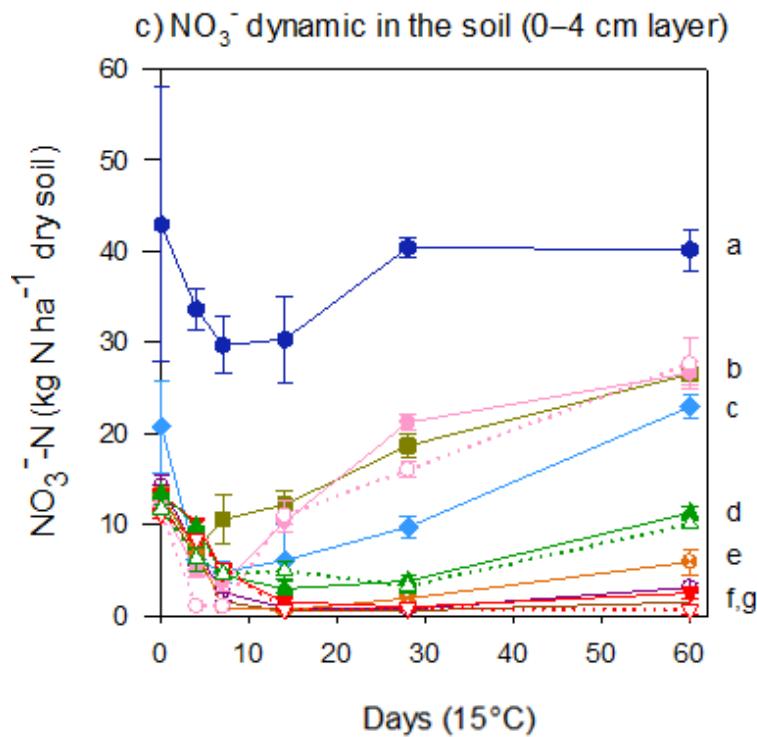
The initial CO₂ peak reflected microbial hotspots where the local available oxygen was fully consumed



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

Results

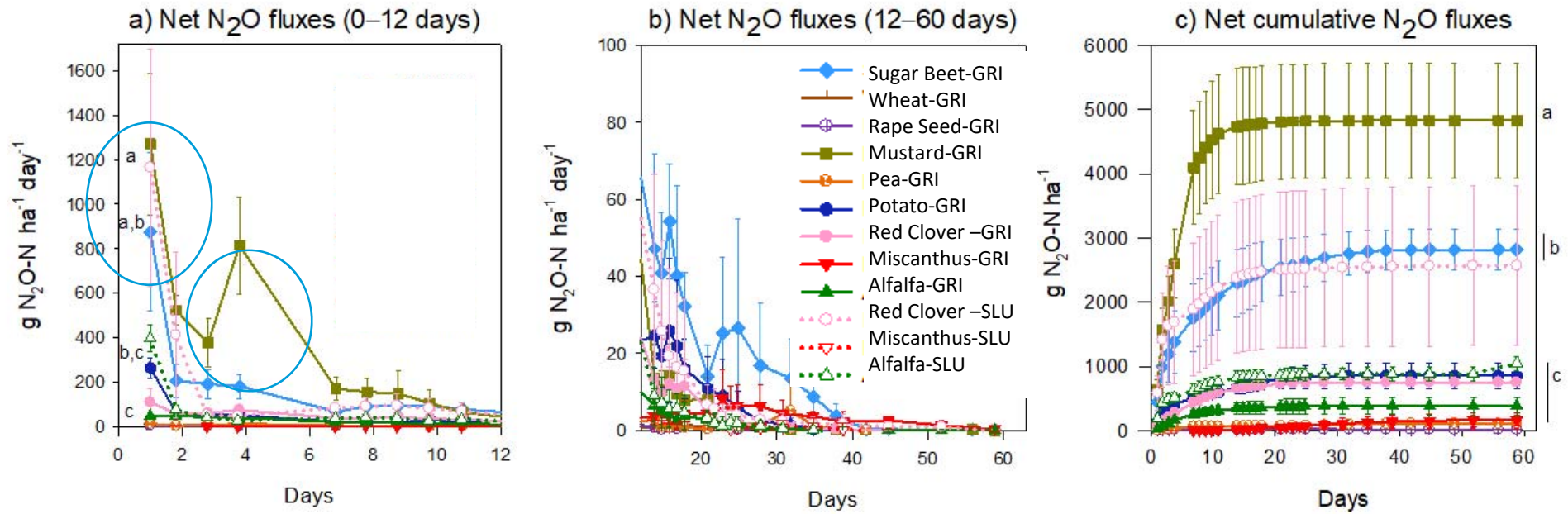
Soil mineral N dynamics: NO_3^- and NH_4^+



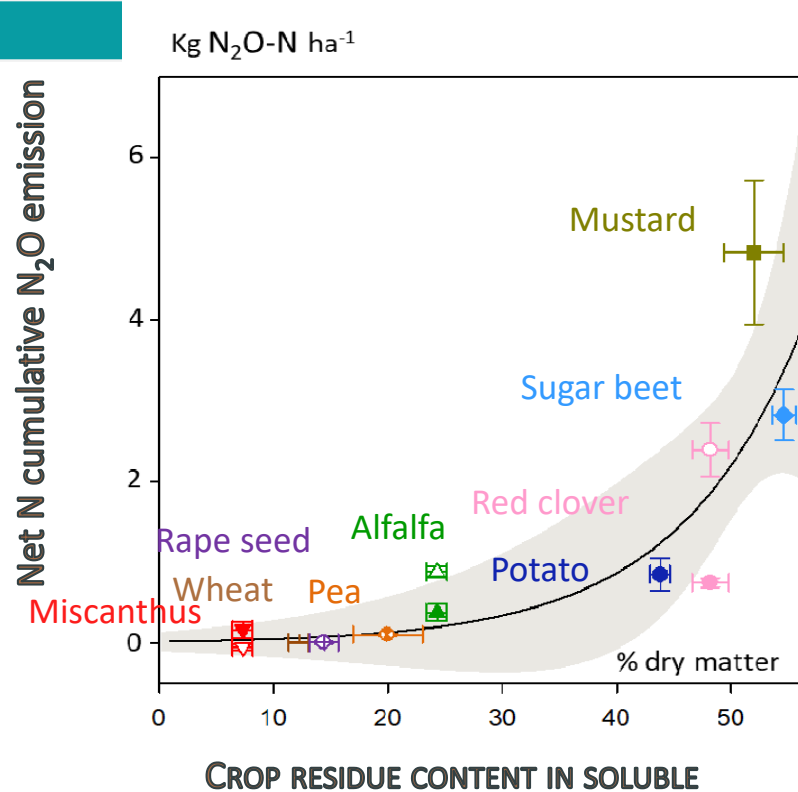
These higher soil NH_4^+ contents were related to CO_2 and N_2O emitting situations

Results

Daily and cumulative N₂O 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 N₂O emissions

These residues were also non-senescent and promoted high N₂O 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

N₂O 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 **N₂O emissions representing 1–5% of applied N >> 0.6 %** the current recommended values for residue *EF-N₂O* in national inventories (IPCC, 2019).

Differentiated emission factors are strongly needed!

More studies are needed **to objectively weigh the other benefits these non-senescent residues** could bestow upon C storage, NO₃⁻ retention, and erosion limitation by soil cover.



Destruction of cover crop

Conclusions

The data are available on the Data INRAE repository

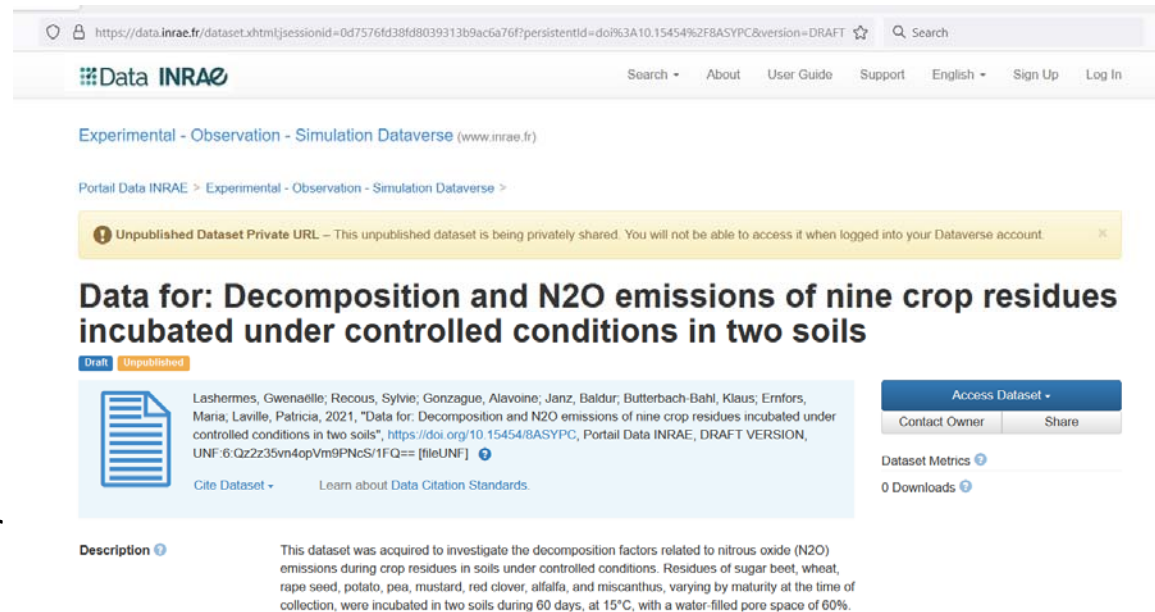
<https://doi.org/10.15454/8ASYPC>

More information about the projet :

<https://projects.au.dk/residuegas/>

We thank Sylvie Millon, Pascal Thiébeau, Olivier Delfosse, Rachid Benabdallah, Hugues Clivot for their help... and you for your attention

This work was supported by the ERA-NET FACCE ERA-GAS from the European Union's Horizon (No. 696356). The French funding grant number was ANR-17-EGAS-0003.



The screenshot shows a web browser displaying the Data INRAE repository page. The URL is <https://data.inrae.fr/dataset.xhtml?sessionId=0d7576fd38fd8039313b9ac6a76f?persistentId=doi%3A10.15454%2F8ASYPC&version=DRAFT>. The page header includes the Data INRAE logo and navigation links: Search, About, User Guide, Support, English, Sign Up, and Log In. Below the header, there is a breadcrumb trail: Portail Data INRAE > Experimental - Observation - Simulation Dataverse >. A yellow warning banner indicates: "Unpublished Dataset Private URL - This unpublished dataset is being privately shared. You will not be able to access it when logged into your Dataverse account." The main title of the dataset is "Data for: Decomposition and N2O emissions of nine crop residues incubated under controlled conditions in two soils". The dataset is marked as "Draft" and "Unpublished". The authors listed are Lashermes, Gwenaëlle; Recous, Sylvie; Gonzague, Alavoine; Janz, Baldur; Butterbach-Bahl, Klaus; Ernfors, Maria; Laville, Patricia, 2021. The citation information includes the DOI: <https://doi.org/10.15454/8ASYPC>, the repository name "Portail Data INRAE, DRAFT VERSION", and the UNF identifier: UNF:6.Qz2z35vn4opVm9PNcS/1FQ== [fileUNF]. There are buttons for "Cite Dataset" and "Learn about Data Citation Standards". On the right side, there is an "Access Dataset" button with sub-options "Contact Owner" and "Share", and "Dataset Metrics" showing "0 Downloads". The description of the dataset is: "This dataset was acquired to investigate the decomposition factors related to nitrous oxide (N2O) emissions during crop residues in soils under controlled conditions. Residues of sugar beet, wheat, rape seed, potato, pea, mustard, red clover, alfalfa, and miscanthus, varying by maturity at the time of collection, were incubated in two soils during 60 days, at 15°C, with a water-filled pore space of 60%."