

Greenhouse gas emissions (CO_2 & N_2O) of an acid soil after adding liming products, observed at 2 experimental scales (*in situ* and undisturbed cylinders)

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Context

GHG emissions rising

« Earth is warming, glaciers are collapsing »
(Source: National Geographic)

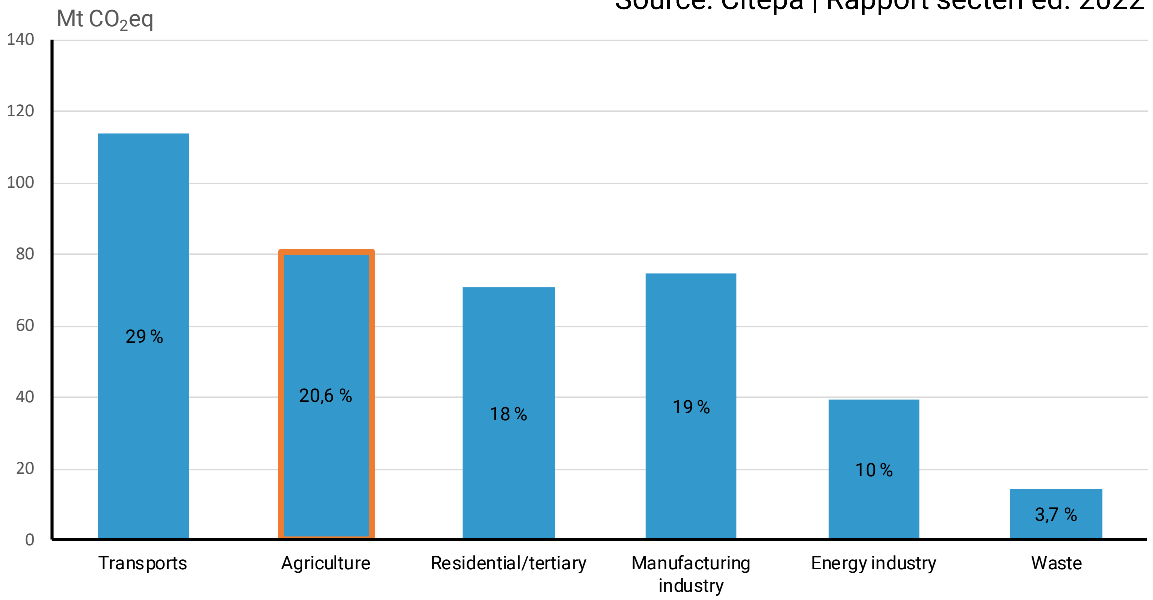
Annual mean concentrations at the word's surface in 2020 and evaluation of the main greenhouse gases. Data from the GAW *in situ* observational network.

	CO_2	CH_4	N_2O
Concentration moyenne mondiale en 2020	413,2±0,2 ppm	1889±2 ppb	333,2±0,1 ppb
Concentration en 2020 par rapport à 1750[a]	149 %	262 %	123 %
Augmentation en valeur absolue entre 2019 et 2020	2,5 ppm	11 ppb	1,2 ppb
Augmentation en % entre 2019 et 2020	0,61 %	0,59 %	0,36 %
Augmentation annuelle moyenne en valeur absolue depuis 10 ans	2,40 ppm/an	8,0 ppb/an	0,99 ppb/an

[a] Selon l'hypothèse d'une fraction molaire préindustrielle de 278 ppm pour le CO_2, de 722 ppb pour le CH_4 et de 270 ppb pour le N_2O. Nombre de stations utilisées pour les analyses: 139 pour le CO_2, 138 pour le CH_4 et 105 pour le N_2O.

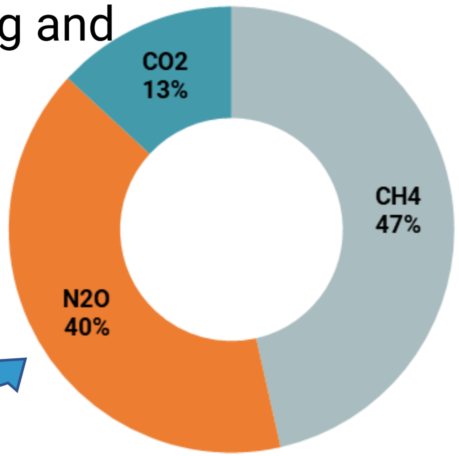
In 2020, France emitted 393 Mt CO_2e (estimation)
(Source: Citepa | Rapport Secten éd. 2022)

Percentage of GHG emissions in France per sector (year 2020)
Source: Citepa | Rapport secten éd. 2022



In 2020, the estimation for the Farming and Forestry sector is **81 Mt CO_2e**

In 2020, this sector is a major contributor to national N_2O emissions (90%)



GHG distribution from Forestry and Farming sectors in 2020 (Source: Citepa | Rapport Secten éd. 2022)

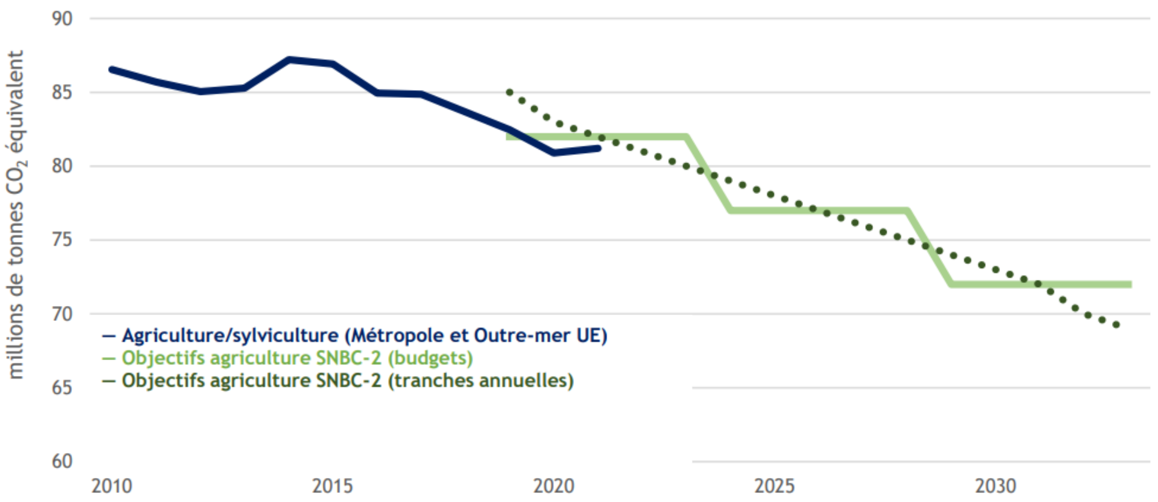
Stratégie Nationale Bas-Carbone (Low Carbon National Strategy)

→ A French roadmap towards the fight against climate change

A successful low-carbon transition towards carbon neutrality by 2050 implies, at the scale of the French territory, to:

- Decarbonise the energy used by 2050 (except in the airplane transportation)
- Decrease the energy consumption by half in all sectors (higher performance equipment, energy sobriety…)
- Maximum reduction of the non-energy emissions, mostly from the agricultural sector and industrial processes
- Increase and secure carbon sinks (natural ecosystems, processes and materials capable of capturing a significant amount of CO_2…)

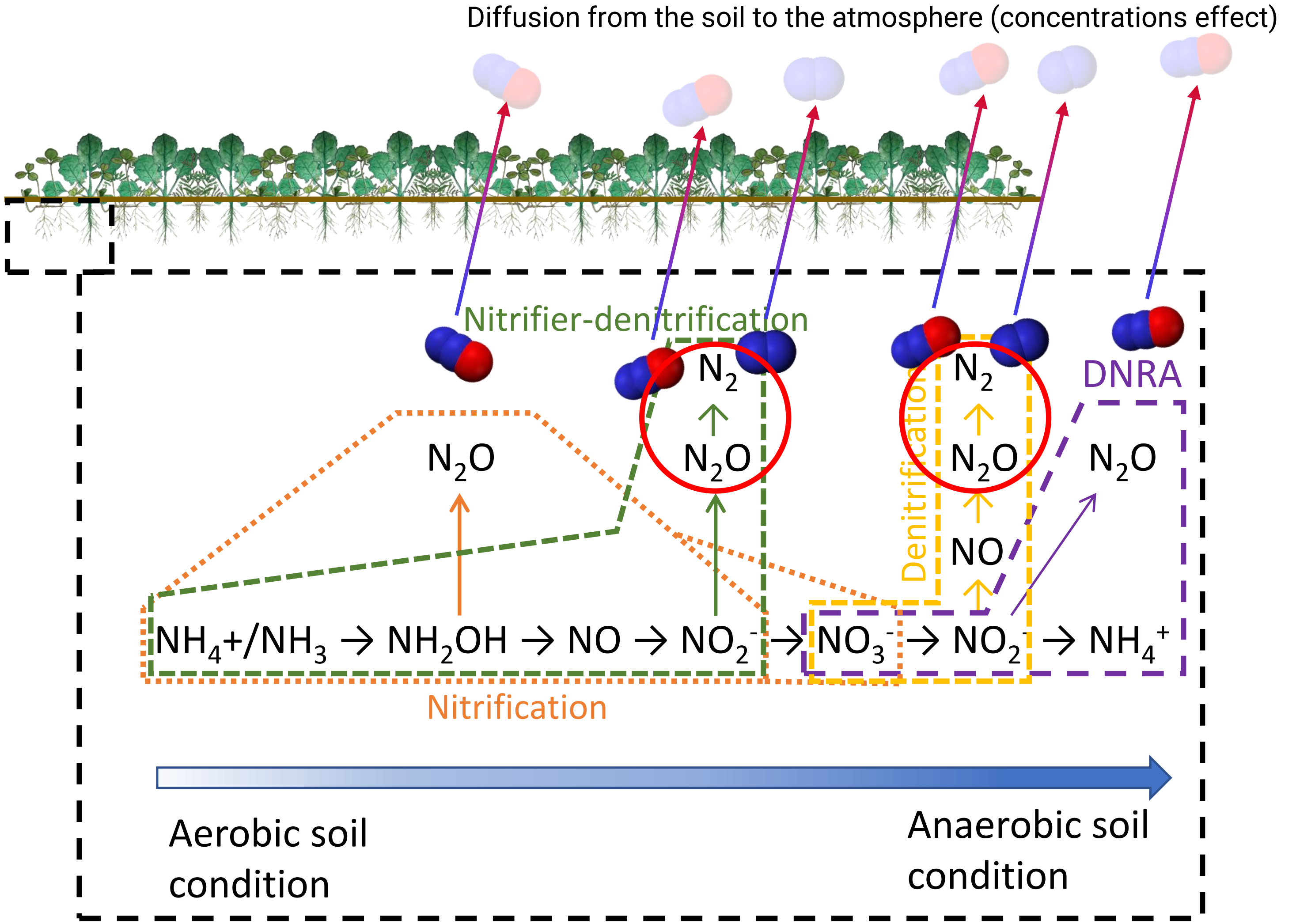
Agriculture/Forestry GHG emissions and SNBC objectives



Source: Citepa | Rapport Secten éd. 2022

For agriculture, the strategy aims to reduce emissions by 18% in 2030 compared to 2015, then by 46% in 2050
→ Decrease direct or indirect N_2O and CH_4 emissions

N_2O sources across the N cycle in the soil



Global warming potential (Source : IPCC 2021 | 6th assessment report)

	CO_2	N_2O	CH_4
GWP_{100} (molar basis)	1	273	27.9

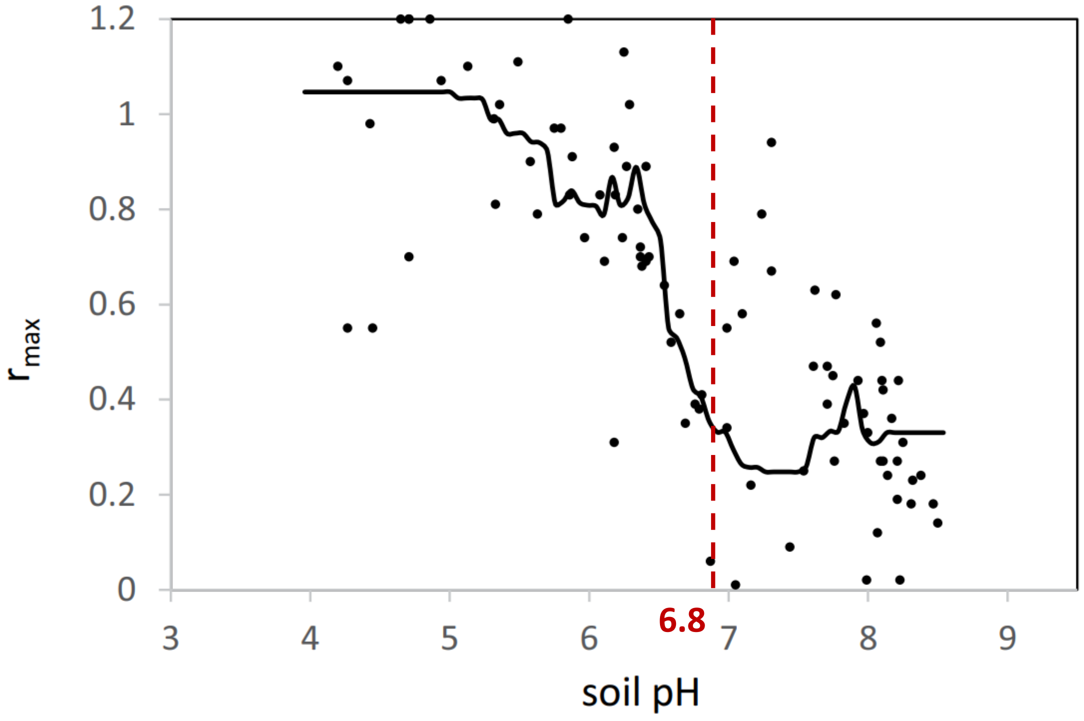
2 strategies could be undertaken:

1. Inhibit the microbial processes (e.g. optimisation of N fertilisation, nitrification inhibitors, reduce high anaerobic condition…)
2. Promote N_2O reduction into N_2

Although agriculture is a significant contributor to GHG emissions, there are several opportunities to reduce them!

Climate liming: a promising way for N_2O reduction

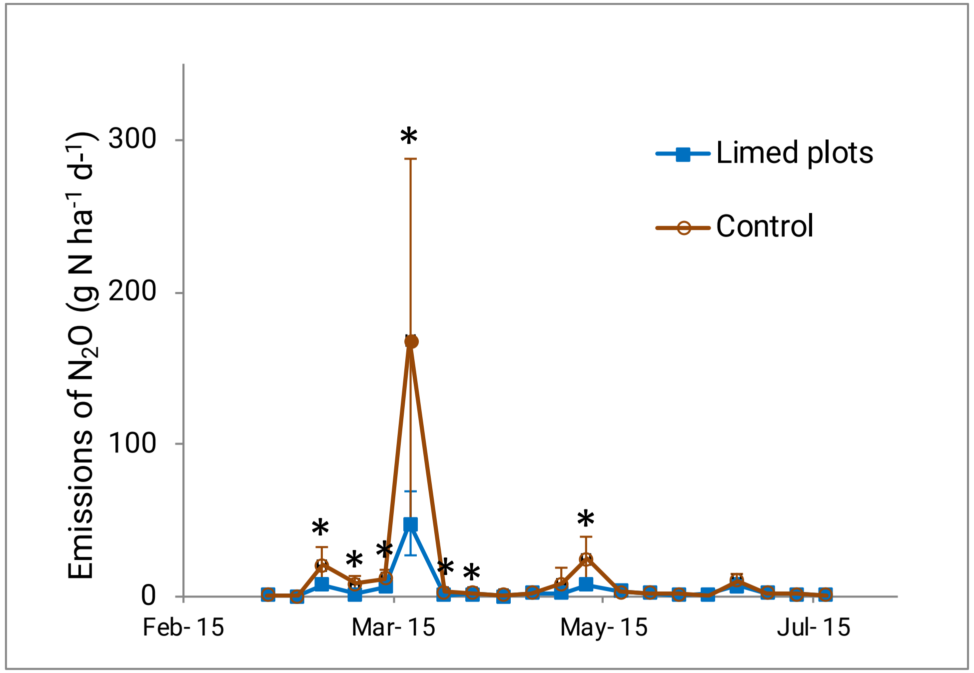
The experimental points of r_{max} against soil pH and the function relating r_{max} and soil[1]



1. Hénault, C. et al. Management of soil pH promotes nitrous oxide reduction and thus mitigates soil emissions of this greenhouse gas. Sci Rep **9**, 20182 (2019)

Climate liming: a promising way for N_2O reduction

In situ N_2O emissions measured in one-year experiment[1]



Liming: Adopted in the methodology of the low-carbon label for field crops in France

Objective n°1: Getting more data on the effect of liming products application on N_2O emissions

CaCO₃

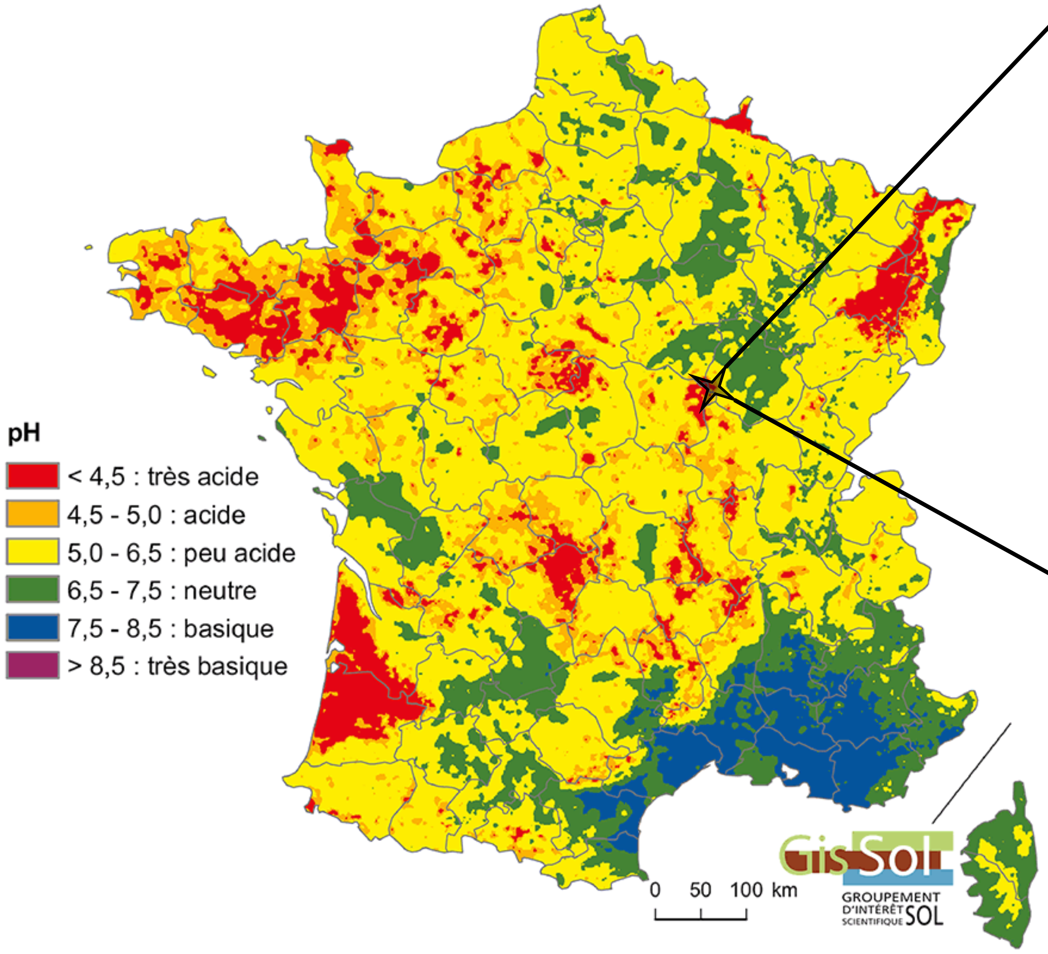
In 2001, the IPCC has suggested that “all the carbon provided by liming products is eventually emitted in the form of CO_2 into the atmosphere”

Objective n°2: Taking into account the CO_2 emissions, as the addition of liming product could lead to an increase in soil CO_2 emissions.

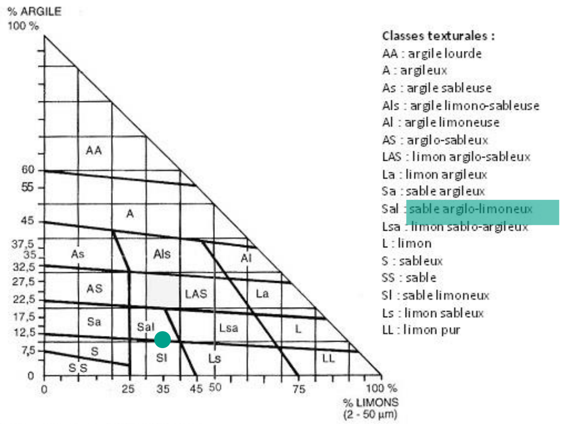
1. Hénault, C. et al. Management of soil pH promotes nitrous oxide reduction and thus mitigates soil emissions of this greenhouse gas. Sci Rep **9**, 20182 (2019)

Materials & Methods

Soil and liming products characteristics



Source : © accord AgroParisTech-Engref (UMR LERFOB) - IFN n°2007-CPA-2-072



Triangle du GEPPA (1963)

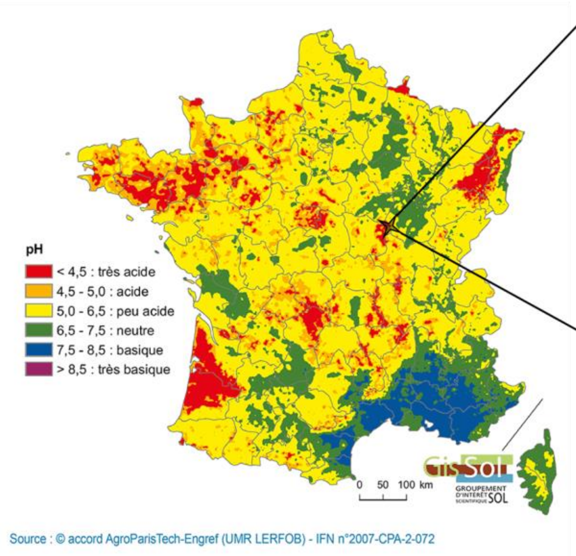
Source : BAIZE D., 1995. Guide pour la description des sols, INRA Editions.

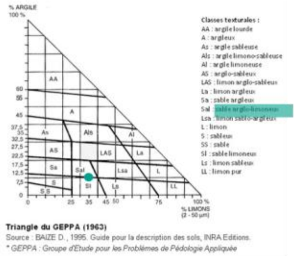
* *GEPPA : Groupe d'Etude pour les Problèmes de Pédologie Appliquée*

- Initial pH = 5.6
- High organic matter content (42.8 g kg^{-1})
- Low CEC (130 mé kg^{-1})
- Low capacity to reduce N_2O into N_2 (Hénault *et al.* 2001)

Hénault, C. *et al.* Laboratory kinetics of soil denitrification are useful to discriminate soils with potentially high levels of N_2O emission on the field scale. *Agronomie* **21**, 713–723 (2001).

Soil and liming products characteristics





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Non-linear model Rémy et Marin Laflèche (1974)

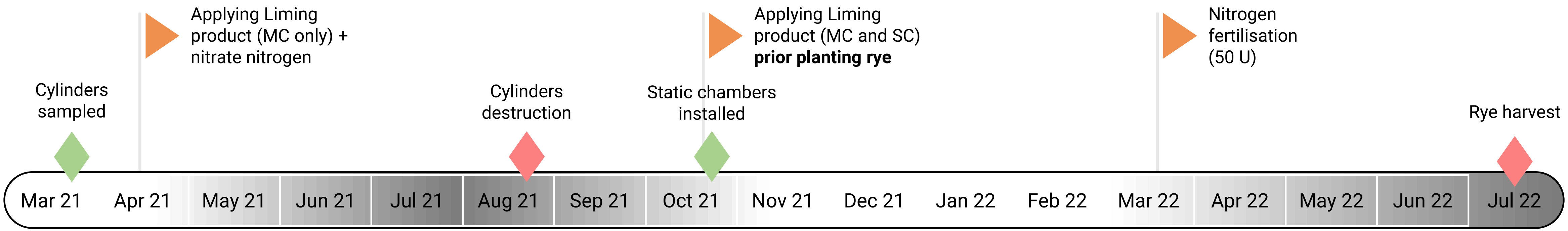
$$BEB_{red} = [0.055 \times (ARG + 5 \times MO) \times (exp^{pHs/1.5} - exp^{pHa/1.5})] \times PTF / 1000$$

pHs = 6.8

2 types of $CaCO_3$

Hénault, C. *et al.* Laboratory kinetics of soil denitrification are useful to discriminate soils with potentially high levels of N_2O emission on the field scale. *Agronomie* **21**, 713–723 (2001).

Timetable



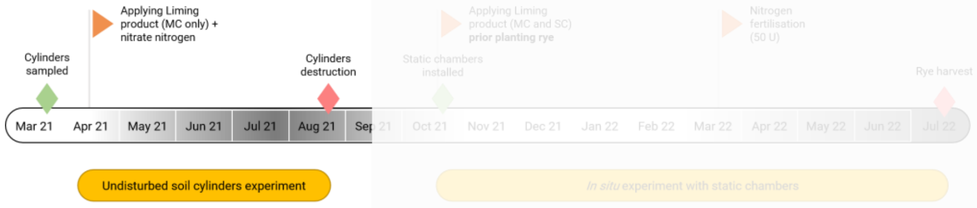
Undisturbed soil cylinders experiment

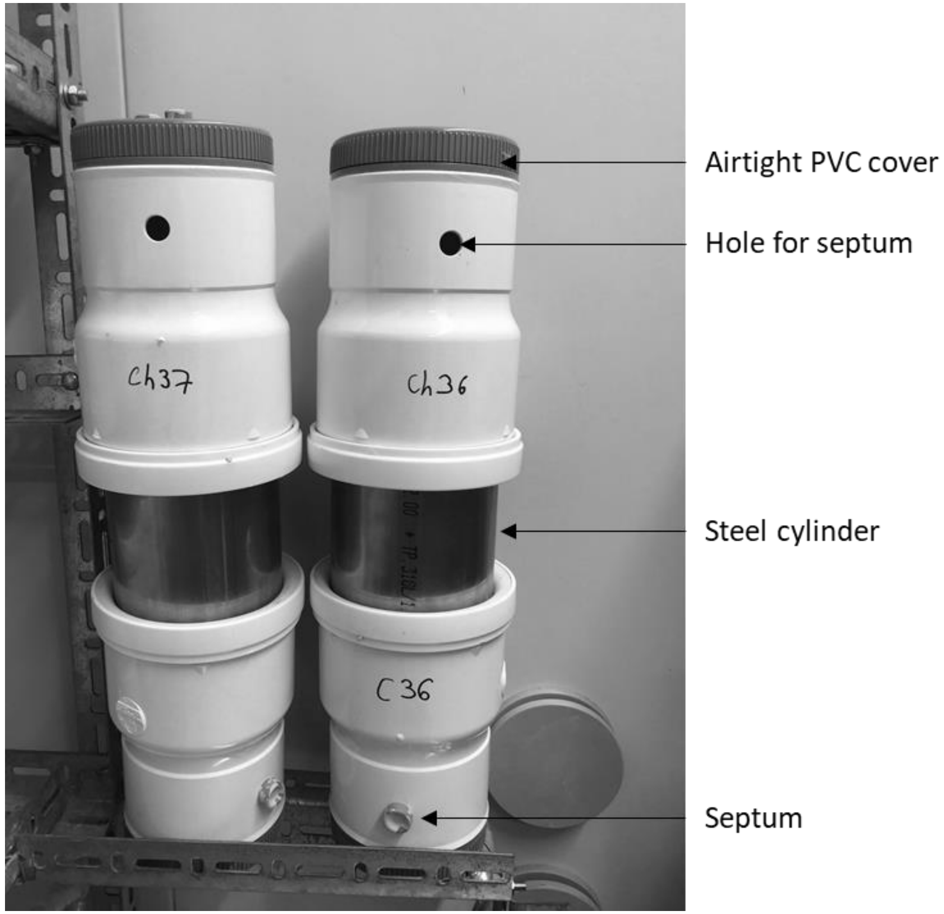
Gas measurements period

In situ experiment with static chambers

Gas measurements period

Undisturbed soil cylinders experiment





Incubated at 20°C for 107 days and were divided into 2 batches:

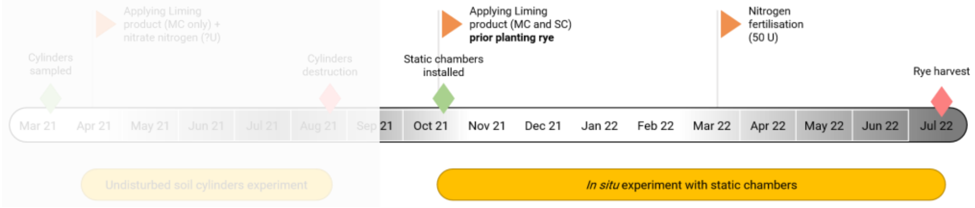
- Control treatment (no liming product only 0.08 g NO_3-N)
- MC treatment (1.45g of $CaCO_3$ + 0.08 g NO_3-N)

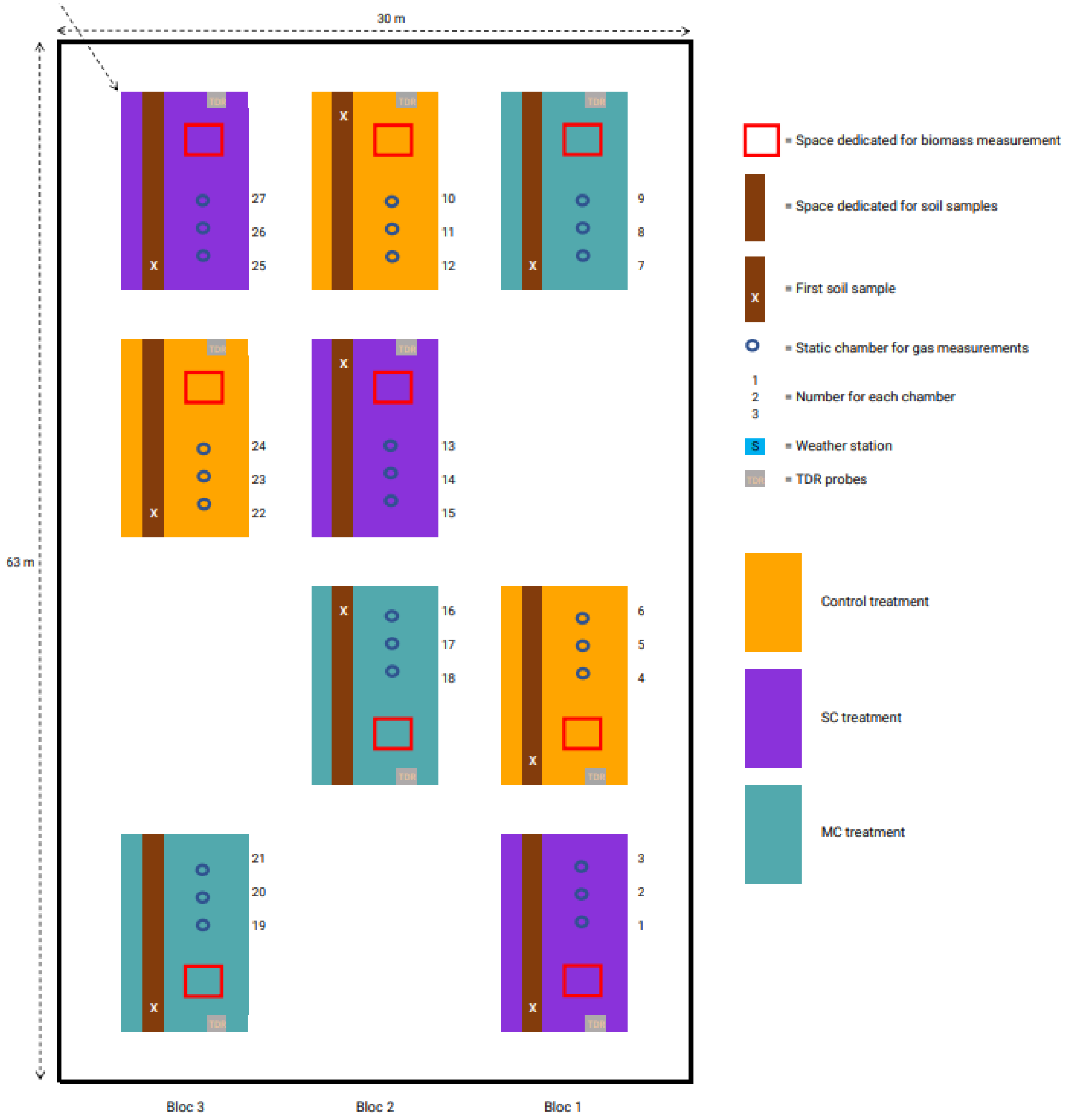
$$Flux_{gas} = \frac{\Delta\, Q_{N2O}}{\Delta\, t} + \frac{\Delta\, Q_{CO2}}{\Delta\, t}$$

→ Gas fluxes are specified in CO_2 equivalent considering the global warming potential of each gas in order to perform a GHG balance calculation

$$Abatement\ (\%) = \frac{(Flux_{control} - Flux_{limed})}{Flux_{control}} * 100$$

In situ experiment





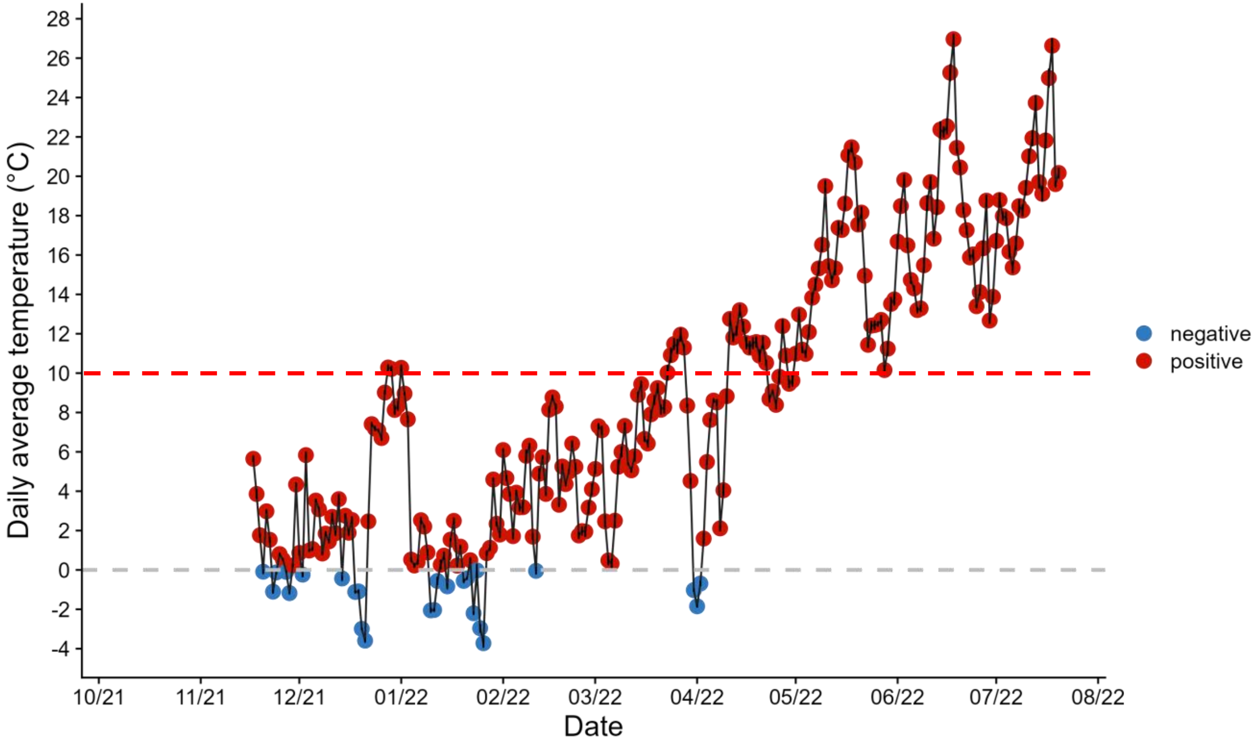
Emissions monitored during the rye cultivation period until harvest, using the static chamber method for:

- Control treatment (no liming product)
- MC treatment (52.9 kg/subplot)
- SC treatment (40.69 kg/subplot)

Video link double click on the vignette:

Soil physical properties and experimental conditions

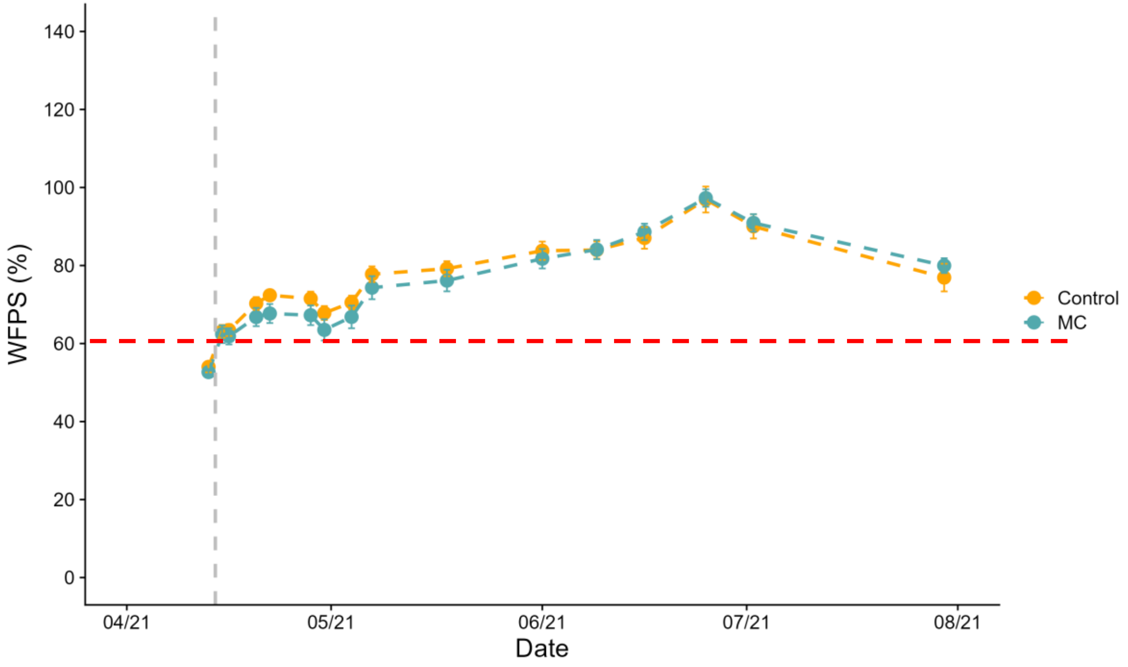
Constant temperature at 20°C



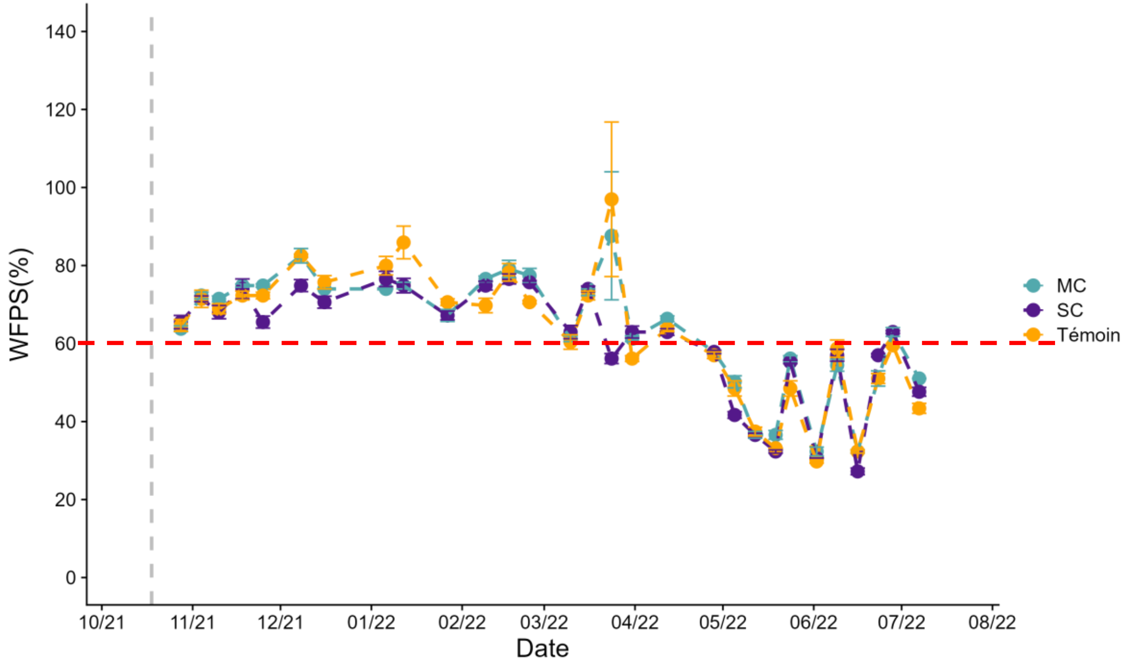
Limiting temperatures in winter for the denitrification process with an optimum known to be between 25°C and 35°C in soil[2]

[2] Braker, G. et al. Influence of temperature on the composition and activity of denitrifying soil communities. FEMS Microbiology Ecology **73**, 134–148 (2010)

Soil physical properties and experimental conditions



WFPS conducive to denitrification process[3]



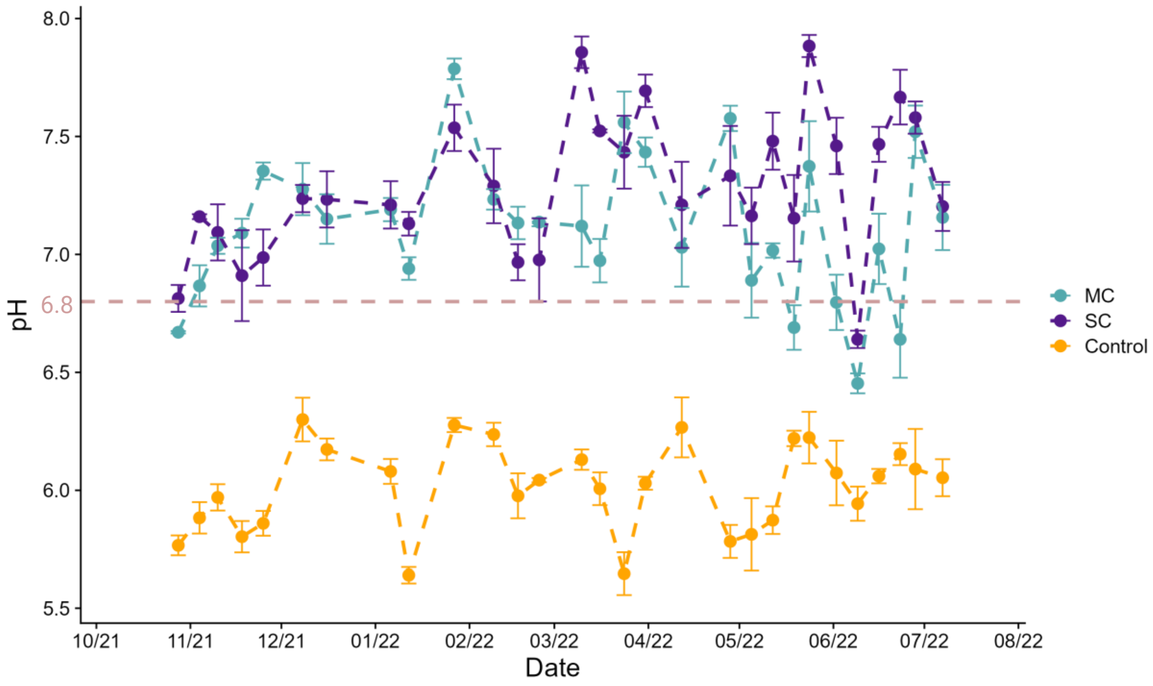
WFPS only conducive to denitrification process during the winter[3]

[3] Butterbach-Bahl, K. et al. Nitrous oxide emissions from soils: how well do we understand the processes and their controls? Philosophical Transactions of the Royal Society B: Biological Sciences **368**, 20130122 (2013).

Results

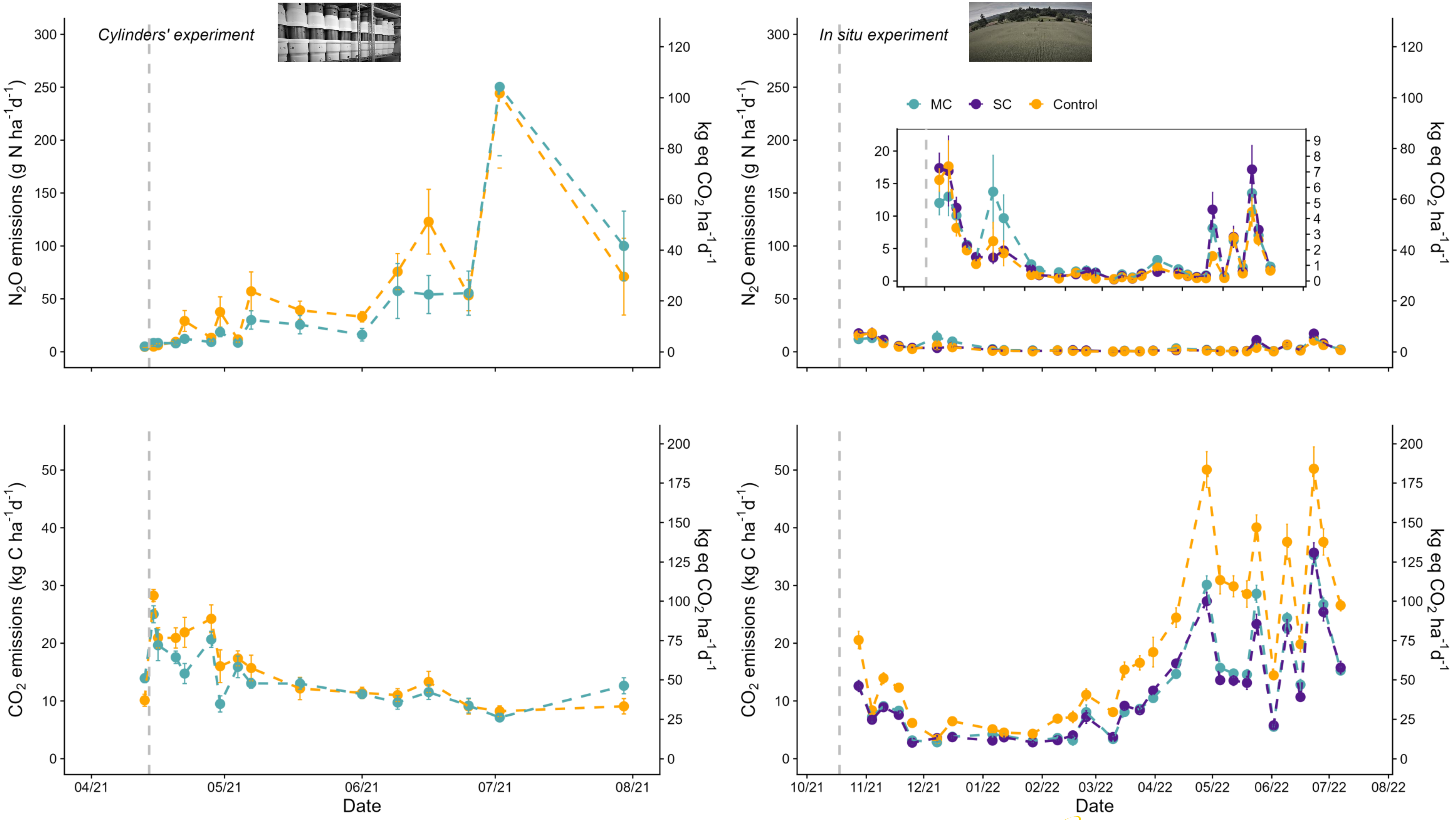
Liming effect on the soil pH

Not measured to avoid disturbing the cylinders

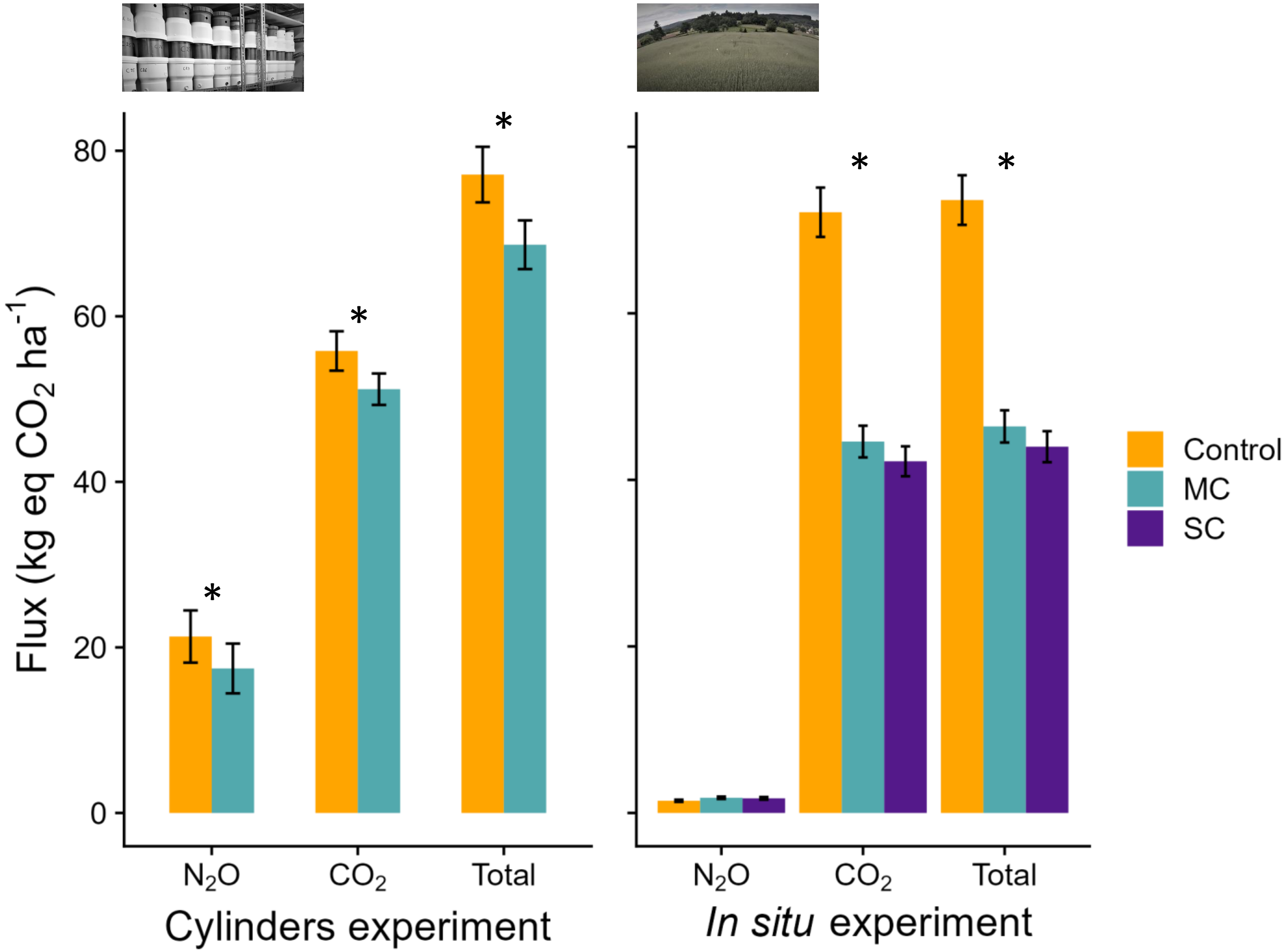


Liming product increased significantly soil pH above the N_2O reductase activation threshold (6.8)

N_2O & CO_2 emissions evolution



Greenhouse gas ($CO_2 + N_2O$) balance

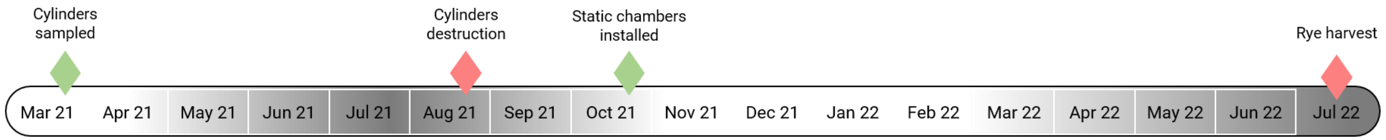


Key numbers

>10% reduction in cumulative GHG emissions for the cylinder experiment

>37% *In situ* (for both limed treatments)

Conclusion & perspectives



BACK TO THE FUTURE

- Both liming products tested (MC & SC) have similar effect on soil pH and GHG emissions
- Liming products increased significantly soil pH above the N_2O reductase activation threshold of 6.8
- Under conducive environmental conditions (T°, WFPS...), liming products decrease significantly N_2O emissions
- Consistent in both experimental designs, the CO_2 emissions were significantly lower in the limed treatments (MC and SC) compared to the control treatment

→ The liming strategy for acid agricultural soils to mitigate GHG emissions, adopted in the methodology of the low-carbon label for field crops in France, could be refined with respect to the CO_2 emissions component

- Future studies need to ensure that those results are sufficiently generalizable
- Calcium carbonate being a source of carbon, this unexpected reduction of CO_2 emissions in the limed treatments, now requires to be understood in a mechanistic point of view
- Acquisition of in-depth knowledge of the evolution of the C brought to the soil by carbonate liming products would be necessary

Acknowledgements

The NatAdGES team is working hard toward a reduction of soil-induced **GHG** emissions by **Natural Additive**

Financers

Collaborators