Crop residue management and N_2O emissions: is it worth worrying?

A 12-years experiment on arable cropping system in northern France

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Introduction

Carbon storage in agricultural soils might help to reduce our current excess atmospheric carbon while improving soil quality.

Attempts at increasing soil carbon often involve promoting residue restitution, *i.e.* the return of organic matter to the soil after harvest of a cash-crop or destruction of a cover-crop. This practice might lead to greater nitrous oxide (N_2O) emissions. N_2O is a greenhouse gas with a 273 times stronger global warming potential than carbon dioxide and the single greatest ozone-depleting substance. Recent meta-analysis on N_2O emissions during crop residue decomposition shows high-unexplained variability and a lack of long-term data on interactions between residue management and other agricultural practices.

Restitution of residue into the soil

Decomposition and storage

Gazeous losses: CO_2, N_2O, CH_4 | Bulk losses: Erosion, leaching

Fig. 1: crop residue managements decomposition, storage and N_2O emissions

Objectives

What is the relative contribution of crop residue management to N_2O emissions?

Using a 12-years field experiment and statistical models,

1. identify key variables driving N_2O emissions and,
2. assess the relative importance of different crop residue management practices, *i.e.* tillage, biomass (quantity, carbon and nitrogen content), on N_2O emissions, compared to other known drivers such as nitrogen fertilization or soil water content.

Materials & Methods

We used the ACBB long-term experiment located in northern France, cf. Table 1. The soil is a deep silt loam, with 9.8 g.kg^{-1} of organic carbon and a pH of 7.8.

Table 1: the eight experimental treatments of SOERE ACBB

Treatment	1	2	3	4	5	6	7	8
Plowing	✓	×	×	✓	✓	×	✓	✓
Exportation of cash crop residues	×	×	✓	×	×	✓	×	×
Mineral N (% of ref. dose)	100%	100%	100%	35%	35%	100%	0%	0%
Legumes' frequency	low	low	low	low	high	low	low	high
Perennial crops within succession	×	×	×	×	×	✓	×	×
Chemical protection	✓	✓	✓	✓	low	✓	×	×

N_2O emissions have been measured daily since 2011 with automatic chambers, cf Fig 2. and are summarized at the scale of restitution cycles, cf Fig. 3.

Fig. 2: the automatic chambers system measures N_2O emissions

N = 149

108 - 363 days

Restitution cycle → Time

Harvest N, Plot J — Harvest N+1, Plot J

Total N_2O emissions:

- Biomass (C, N, quantity)
- Nitrogen fertilization
- Weather conditions
- Soil environment (WFPS, T°C)

Fig. 3: spatiotemporal scales and variables of each individual in the analysis

Regression models LM / PLS / RF → Main variables → Relative importance of crop residue management

Fig. 4: general workflow to reach the objectives

Results & discussion

Visual assessment, such as the one in Fig 5, of the relationship between N_2O and all variables, gives an *a priori* indication of key drivers for the LM.

PLS and RF models are trained using the entire dataset.

Abbreviations:

LM: linear model

PLS: partial least square

RF: random forest

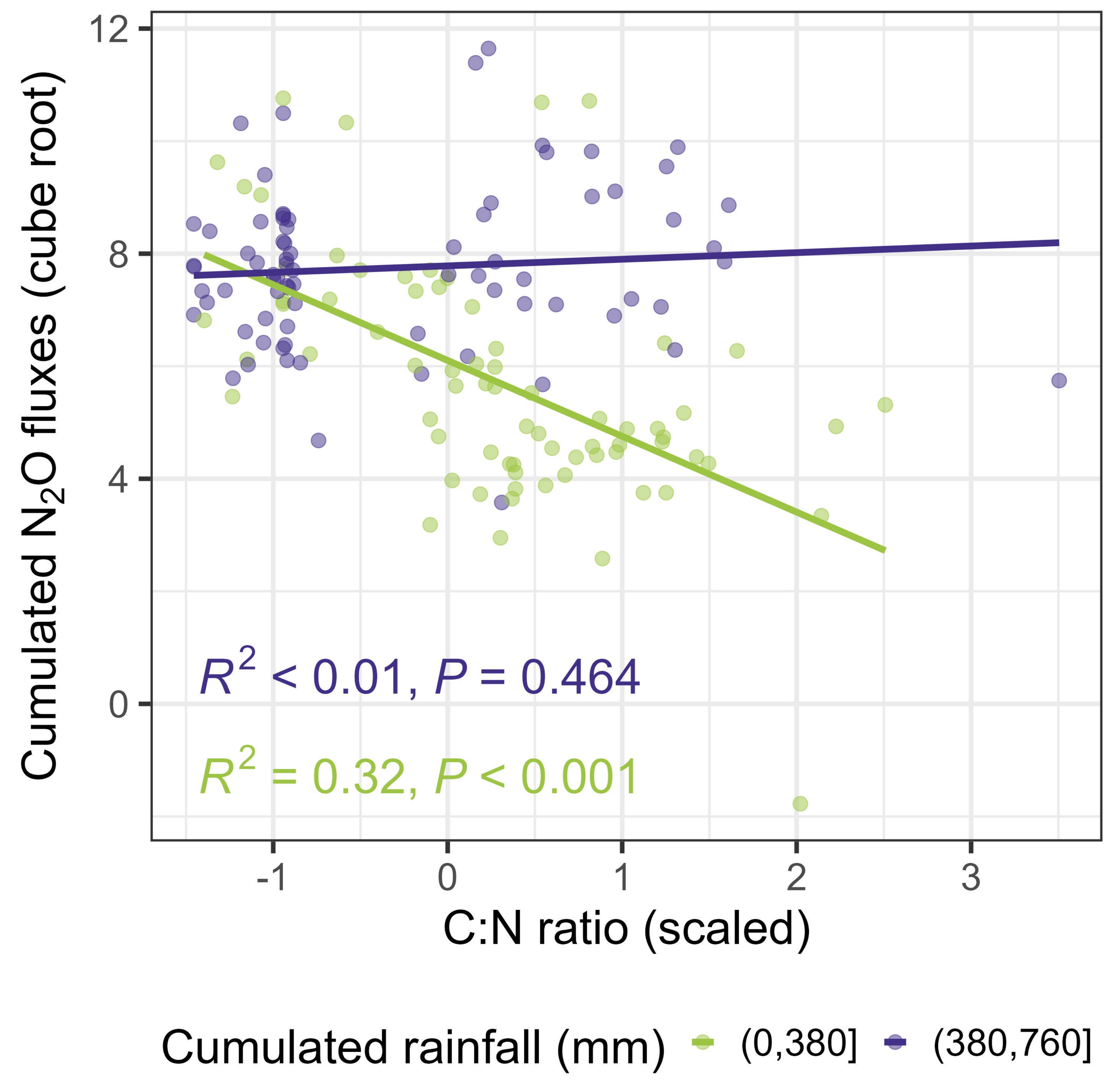

Fig. 5: visual exploration, here illustrating the interaction between C:N ratio and cumulated rainfall

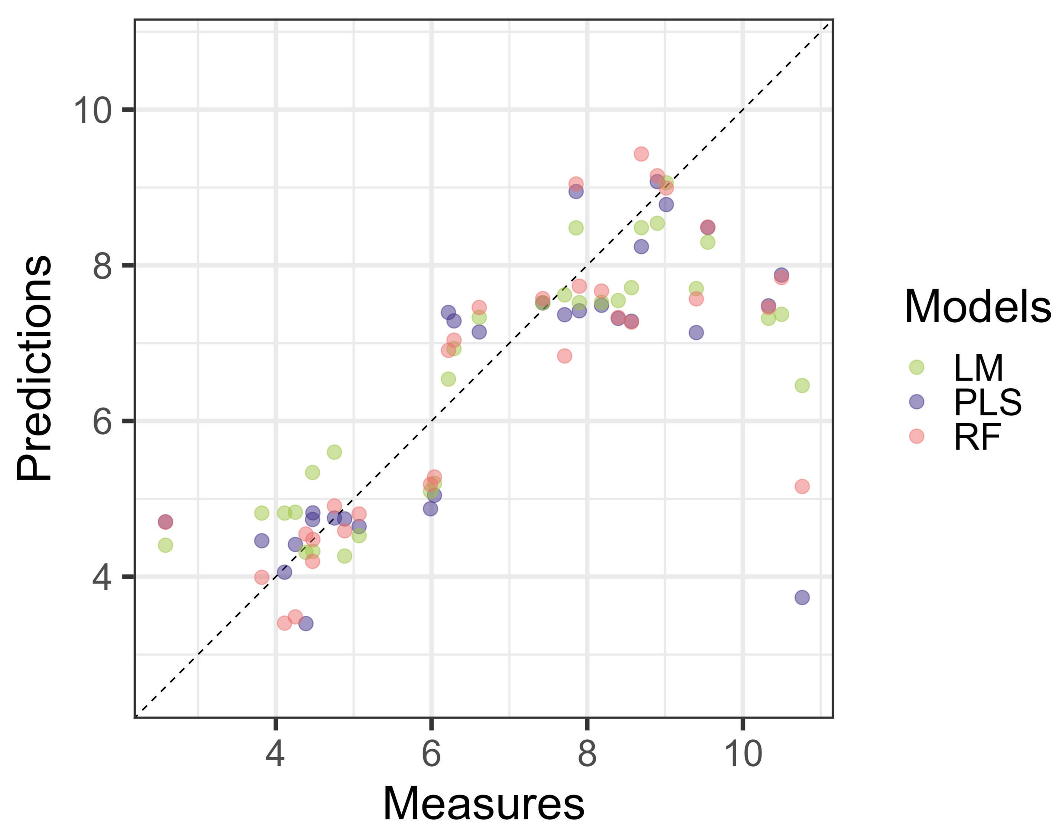

Fig. 6: models' predictions of cumulated N_2O fluxes (cube root) ***using test dataset****.*

The three tested models perform similarly on a test dataset (20% of the full dataset sampled), cf Fig. 6.

The analysis of these models give indications about the hierarchy of the drivers and the contribution of crop residue to N_2O emissions, cf Table 2.

Table 2: variable importance assessed on training dataset

Method	Importance of variables
LM	Cum. Rain. > C:N ratio ~ N Ferti.
RF	Cycle length ~ Cum. Rain ~ C:N ratio ~ N ferti.
PLS	Cycle length ~ Cum. Rain ~ N ferti. >> C:N ratio

- Cum. Rain., Cycle length and N Ferti. are the main influential variables.
- C:N ratio is the only variable directly related to residue in this list.
- None of the Soil-related or tillage-related variables are identified as "important" - which is surprising for the WFPS-related variables.
- Results are consistent with existing literature.

Conclusion & perspective

Crop residues and related management, within this pedoclimatic context, impact N_2O emissions through C:N ratio, when cumulated rainfall is low. Cumulated rainfall, cycle length and mineral nitrogen fertilization are the main drivers of N_2O emissions. Soil water content, surprisingly, is not a driver of N_2O emissions here. This work suggests that it is possible to aim for carbon storage, using crop residue, without causing extra N_2O emissions, especially if the C:N of the latter is high.