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FRANCE 2030 PROGRAMME DE RECHERCHE CARBONE ET ÉCOSYSTÈMES CONTINENTAUX

CrosyeN

Cropping System experiment Network

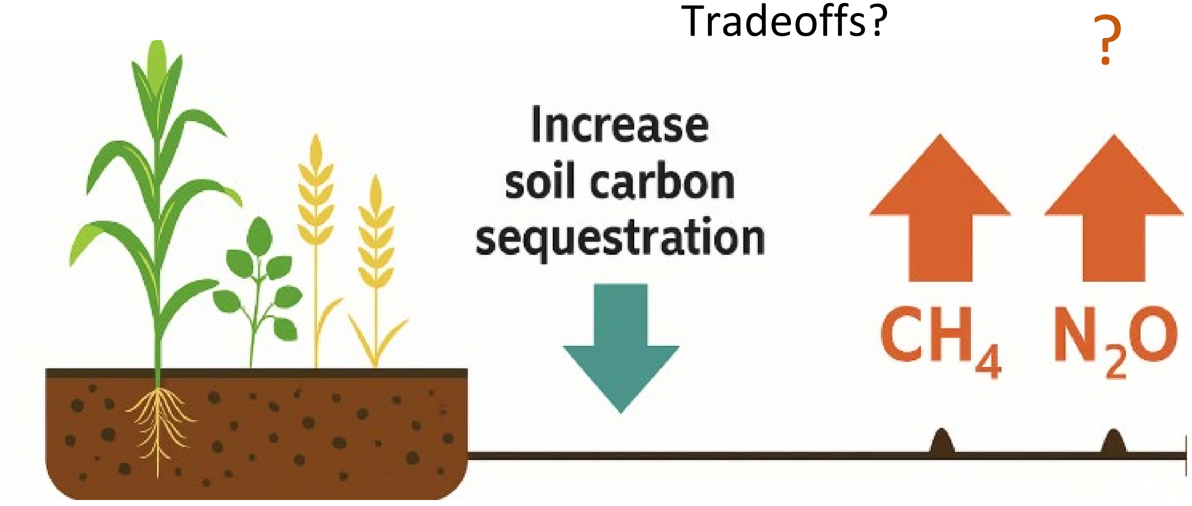
Focus: N2O emissions

CNRS INRAE

Introduction

- The **CrosyeN project** aims to **connect and support long-term cropping-system experiments** to design and assess innovative agroecological systems that are more **climate-neutral, environmentally friendly, resilient, and productive** (8 experimental sites, including 4 in tropical countries)
- Among the agronomic practices promoted in innovative agroecological systems — such as **crop diversification, reduced tillage, permanent soil cover, residue retention, and legume integration** — several can **enhance soil carbon sequestration**. However, their positive effect on the overall carbon balance may be **partly offset by higher CH_4 and N_2O emissions**.

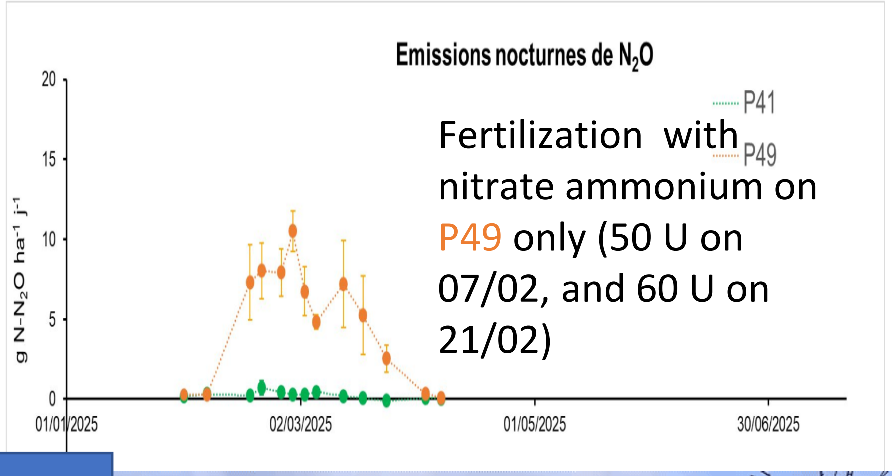
Tradeoffs?



Tradeoff between soil C sequestration and N20 emissions?

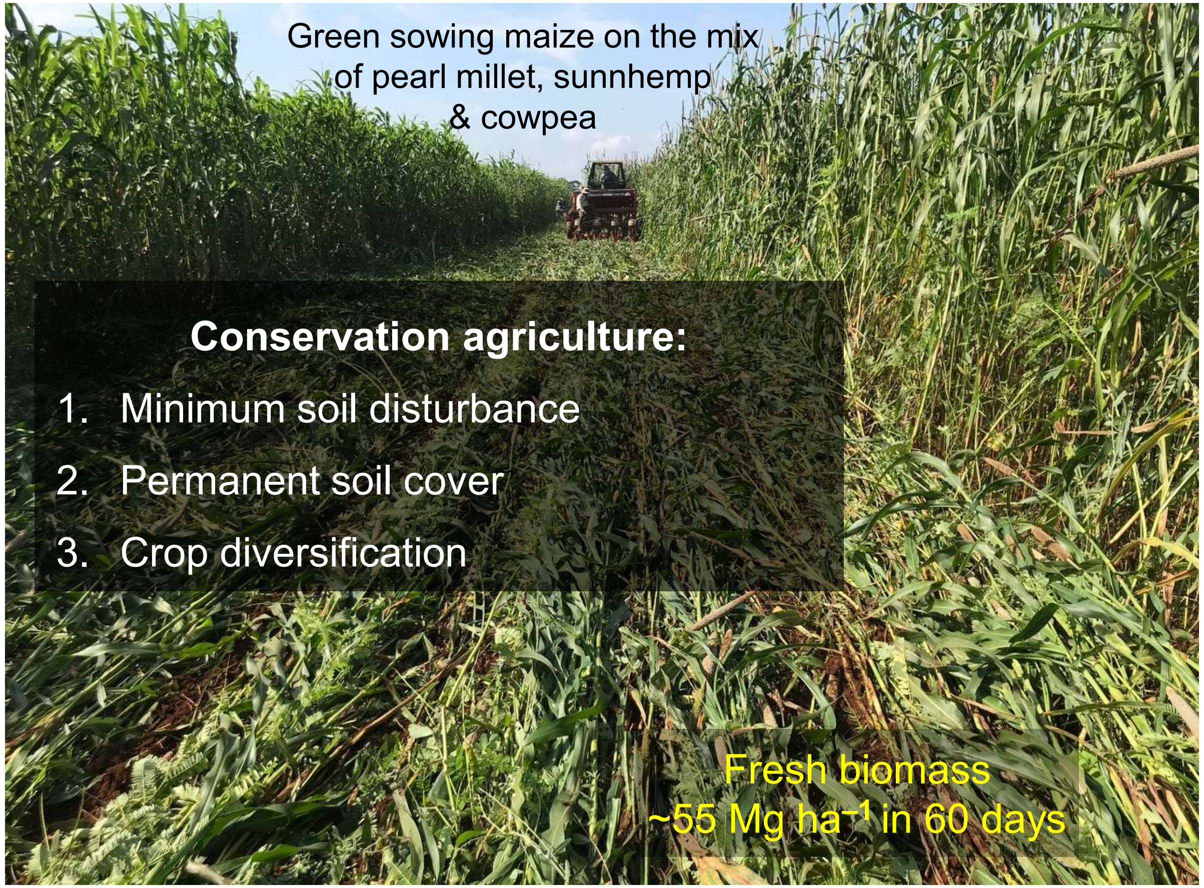
Results from 3 CrosyeN experimental sites (Bos Khnor, Zimbabwe, and Estrées-Mon

- **N_2O** is mostly produced through **microbial nitrification and denitrification** driven by nitrogen availability, soil moisture, and organic inputs.
- The **relationship between nitrogen fertilization and N_2O emissions** is well established – emissions rise strongly beyond crop N demand. Example from **Ca-Sys** (France): **strong N_2O peaks immediately following ammonium nitrate application** (2024–25 data).→ Confirms the direct and immediate N_2O response to mineral N inputs).
- But: **effects of other practices — residue management, no-tillage, cover crops — are less predictable** and can vary with soil type, moisture regime, and organic C/N ratio.
- **3 case studies from CrosyeN experimental sites** : **Bos Khnor** (Cambodia)=> Conservation agriculture; **Zimbabwe**=> mulching, fertilization, intercropping with legumes; **Estrées-Mons** => Fertilization, residue management, legumes, …



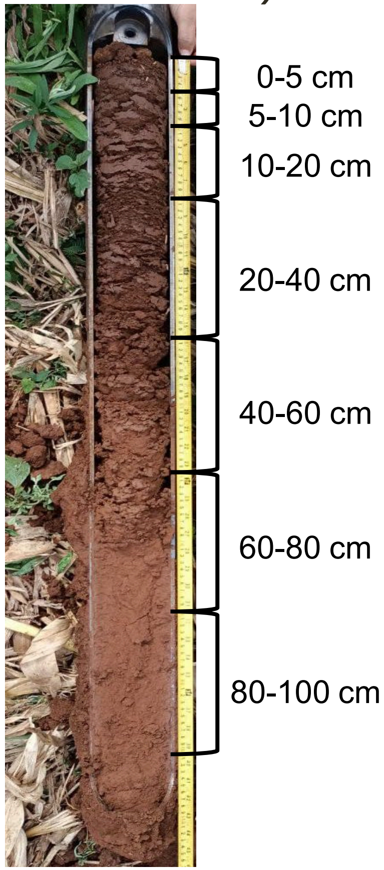
Bos Khnor: comparison of the greenhouse gas balance of CA (Conservation Agriculture) and CT (Conventional tillage) systems

Red Oxisol, Bos Khnor CA station

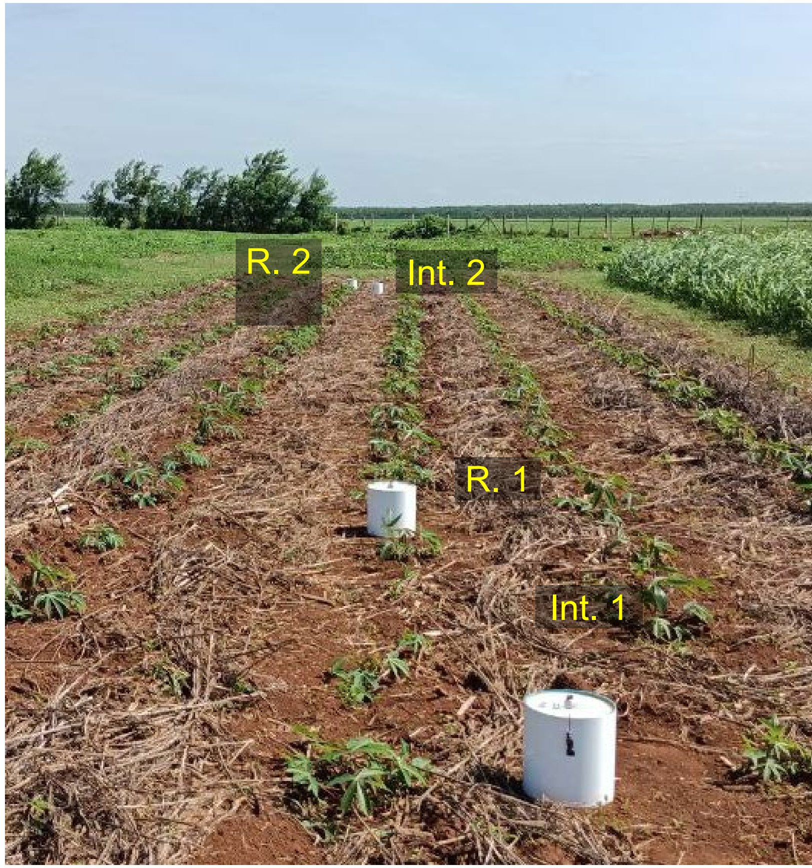


Long-term cassava experiment, **quantifying** impacts on:

1. **Soil Carbon stocks**: 10 yr (2011-2021)

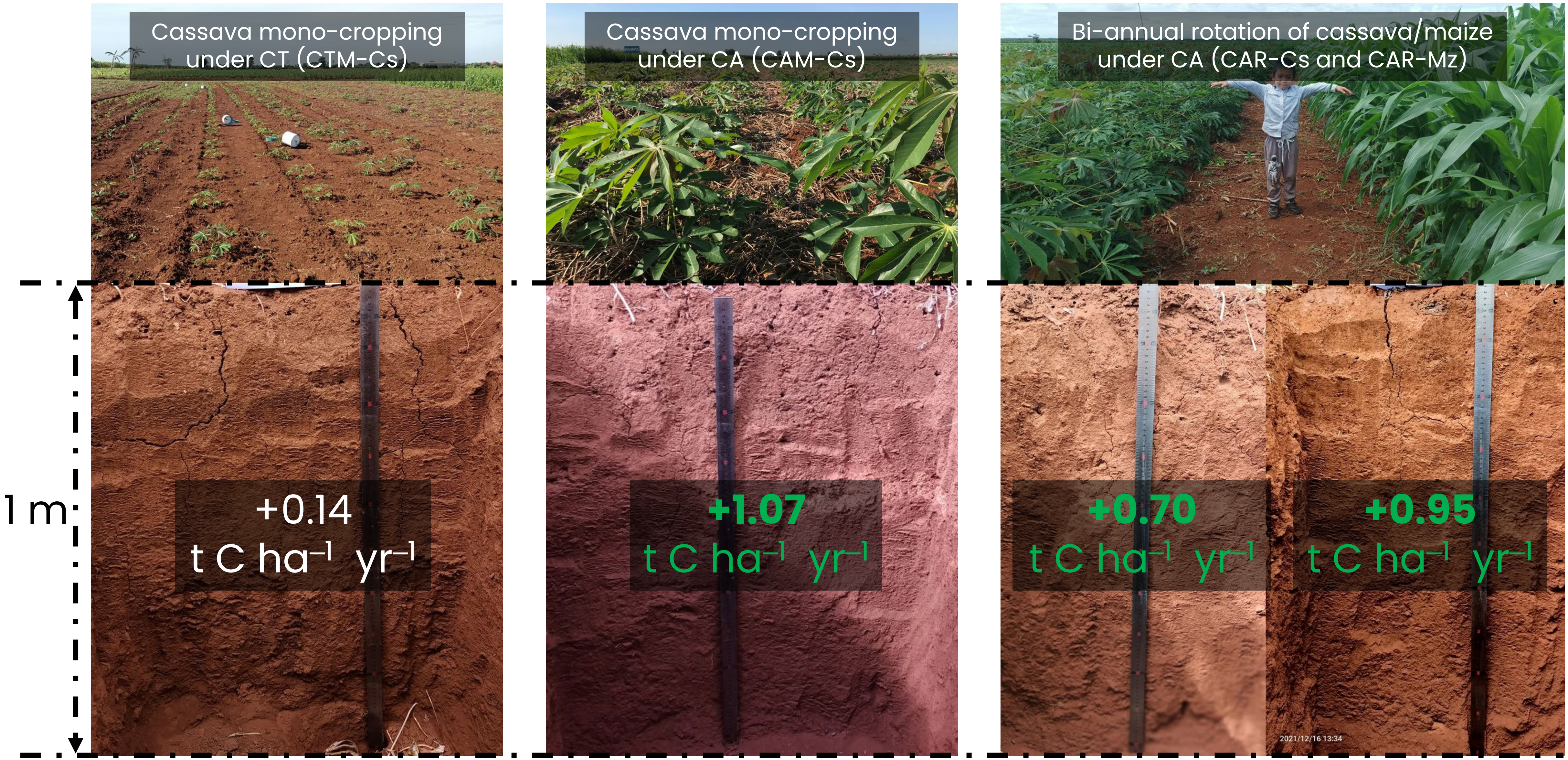


2. **N_2O emissions**: from Apr 2022 to Apr 2024

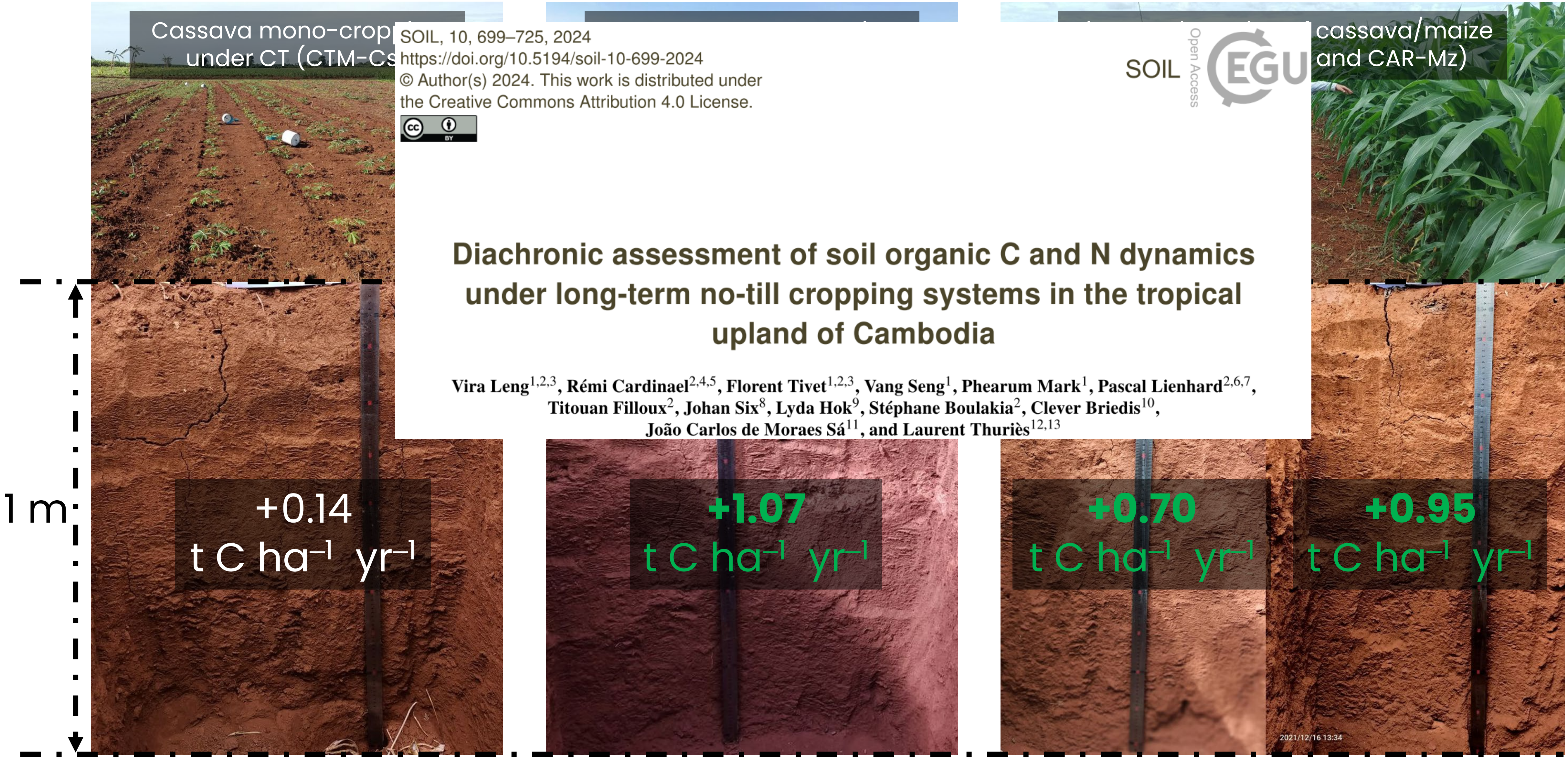


Vira Leng PhD Thesis. Leng et al. (2024) SOIL.
Leng et al., (in revision).

SOC accumulation under CA: 10 yrs (2011-21)



SOC accumulation under CA: 10 yrs (2011-21)



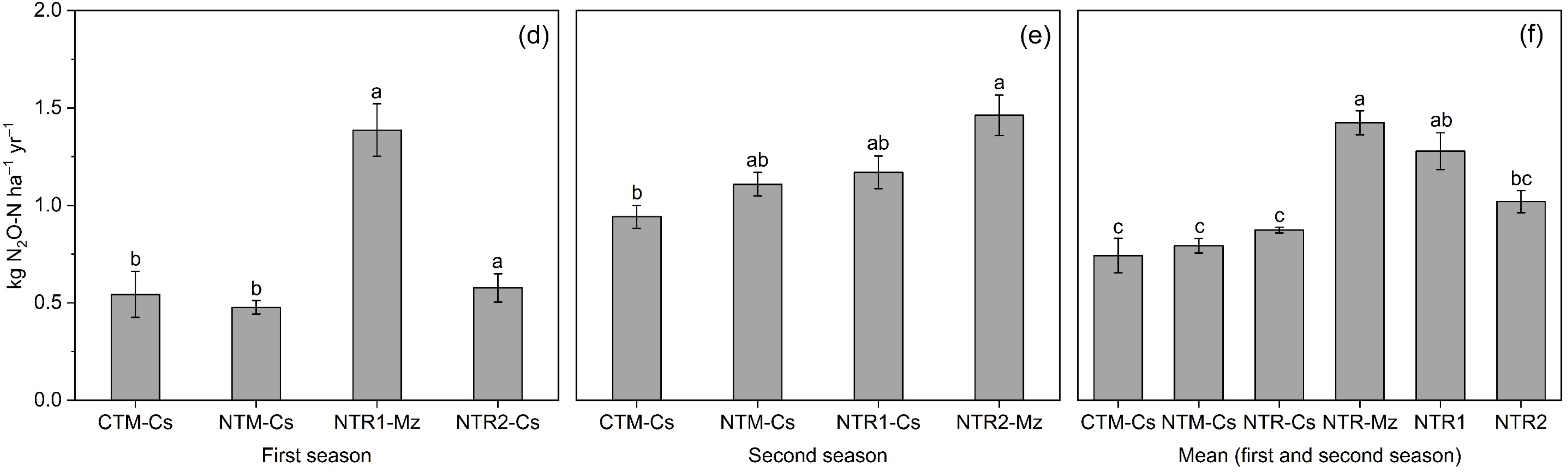
SOIL, 10, 699–725, 2024
https://doi.org/10.5194/soil-10-699-2024

SOIL Open Access EGU

Diachronic assessment of soil organic C and N dynamics under long-term no-till cropping systems in the tropical upland of Cambodia

Vira Leng[1,2,3], Rémi Cardinael[2,4,5], Florent Tivet[1,2,3], Vang Seng[1], Phearum Mark[1], Pascal Lienhard[2,6,7], Titouan Filloux[2], Johan Six[8], Lyda Hok[9], Stéphane Boulakia[2], Clever Briedis[10], João Carlos de Moraes Sá[11], and Laurent Thuriès[12,13]

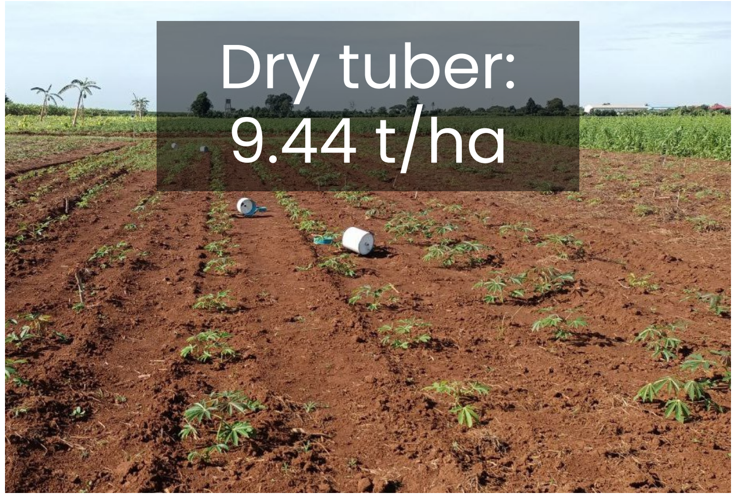
Cumulative N2O emissions



Leng et al., (in revision).

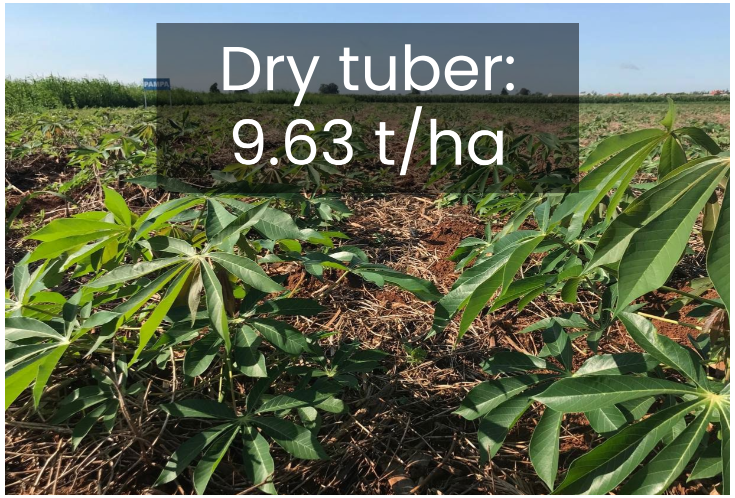
Crops' yield and N2O emissions: 2 years (2022–24)

Cassava mono-cropping under CT (CTM-Cs)



0.74 kg N_2O-N ha^{-1} yr^{-1}

Cassava mono-cropping under CA (CAM-Cs)



0.79 kg N_2O-N ha^{-1} yr^{-1}

Bi-annual rotation of cassava/maize under CA (CAR-Cs and CAR-Mz)

0.87 kg N_2O-N ha^{-1} yr^{-1}

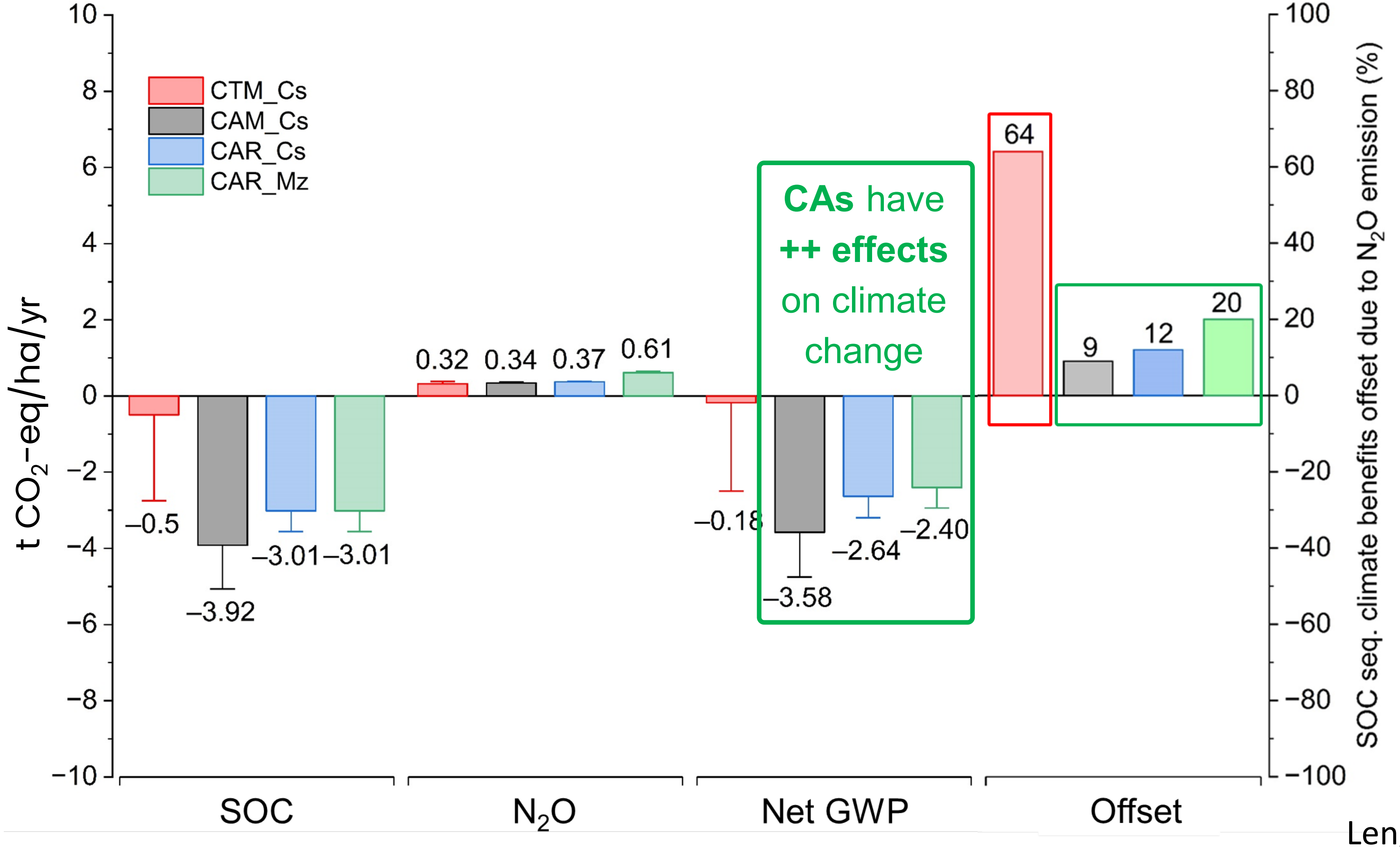
1.42 kg N_2O-N ha^{-1} yr^{-1}

CA-rotational systems had **+18%** higher tuber yield than **CT** with **similar cumulative N_2O emissions**.
Higher emissions under maize in the rotation

Leng et al., (in revision).

Climate benefits: CA systems vs. CT

Global warming potential at 100-year time scale **(GWP_{100})** due to **SOC accumulation** and **N_2O emissions** expressed as CO_2 equivalent **(CO_2-eq)**



Leng et al., (in revision).

Zimbabwe: Agronomic and environmental performances of cropping systems (mulching, fertilization, intercropping) under extreme rainfall (drought, flooding) events

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Field Crops Research 334 (2025) 110126

Contents lists available at ScienceDirect

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ELSEVIER

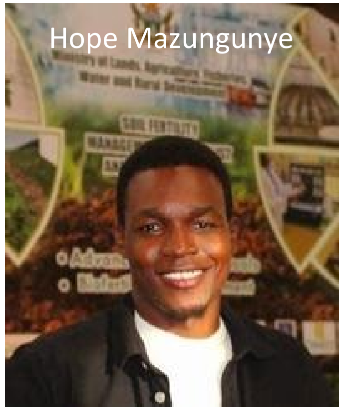
Intra-seasonal rainfall patterns and extremes drive maize productivity and nitrogen use in sub-humid Zimbabwe

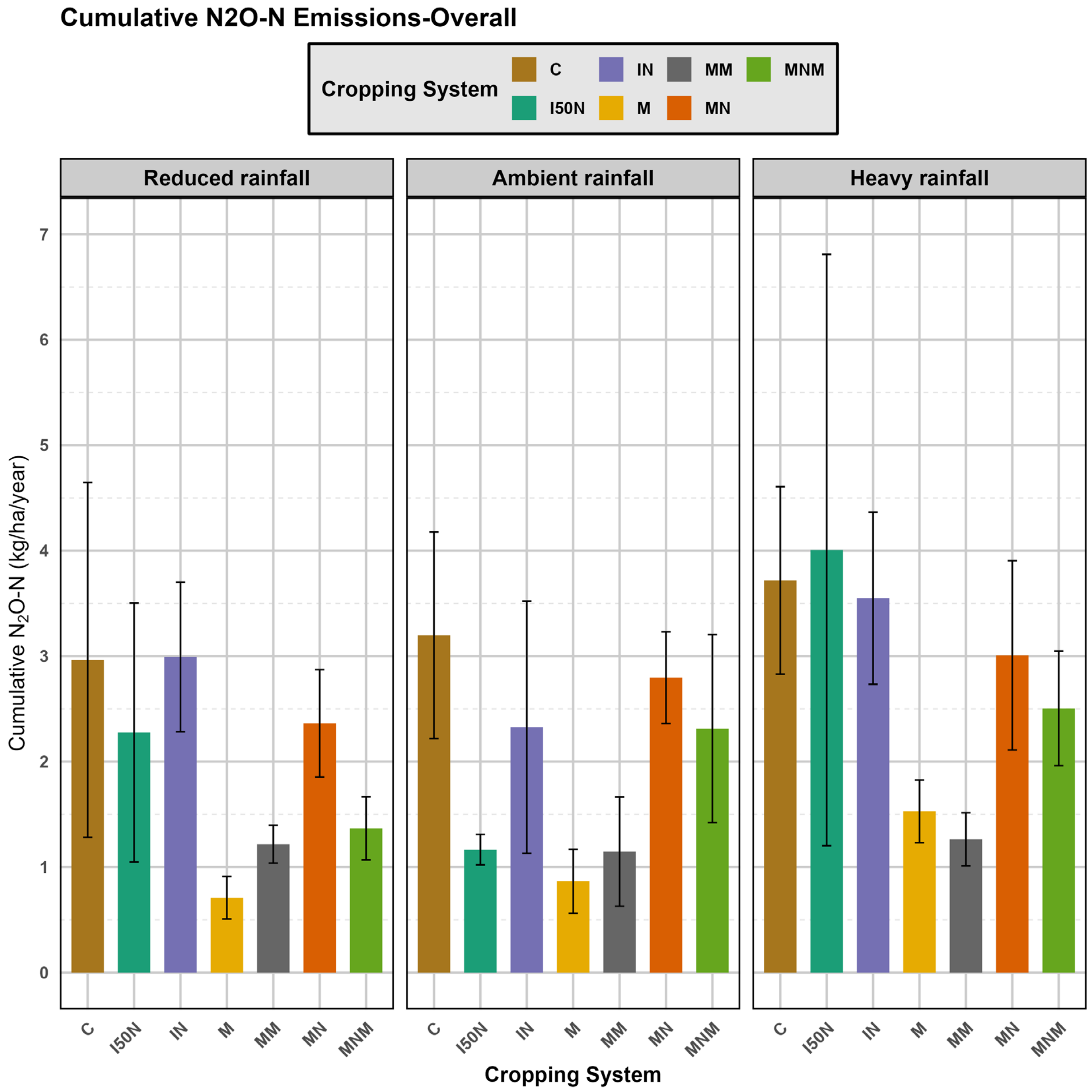
Abderrahim Bouhenache[a,b,c], Gwenaëlle Lashermes[a], Hugues Clivot[a], Sylvie Recous[a], Regis Chikowo[d,e], Armwell Shumba[c,d,f], Hope Mazungunye[c,d], Emmanuel Matimba[c], Gonzague Alavoine[a], Olivier Delfosse[a], Gatien N. Falconnier[b,c,d,e], François Affholder[b,g], Marc Corbeels[b,h,i], Rémi Cardinael[b,c,d,*]

- GHG (CO_2, N_2O, CH_4) monitoring in 7 cropping systems during 2 years (2023-2025):

  - Sole cowpea (C), sole maize (M)
  - fertilized maize (MN), maize with mulch (MM), fertilized maize with mulch (MNM)
  - maize-cowpea intercropping half fertilization (I50N), maize-cowpea intercropping full fertilization (IN)

- 3 rainfall treatments * 7 cropping systems * 3 replicates * 2 chambers per plot = 126 chambers

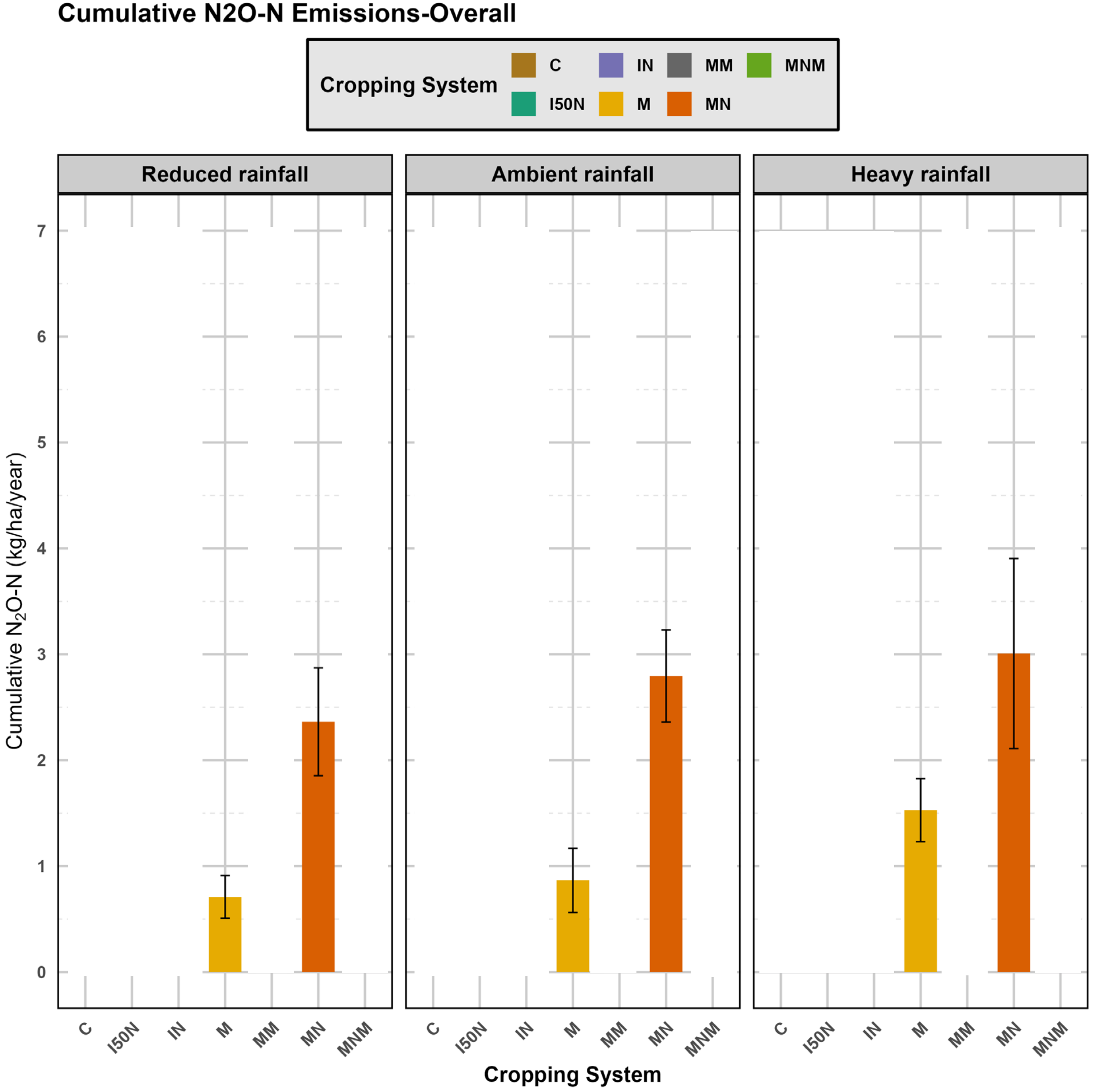




- N_2O emissions are high
- From 0.8 to 4 kg N_2O-N /ha /yr

Average cumulative N_2O emissions (2023-24 and 2024-25)

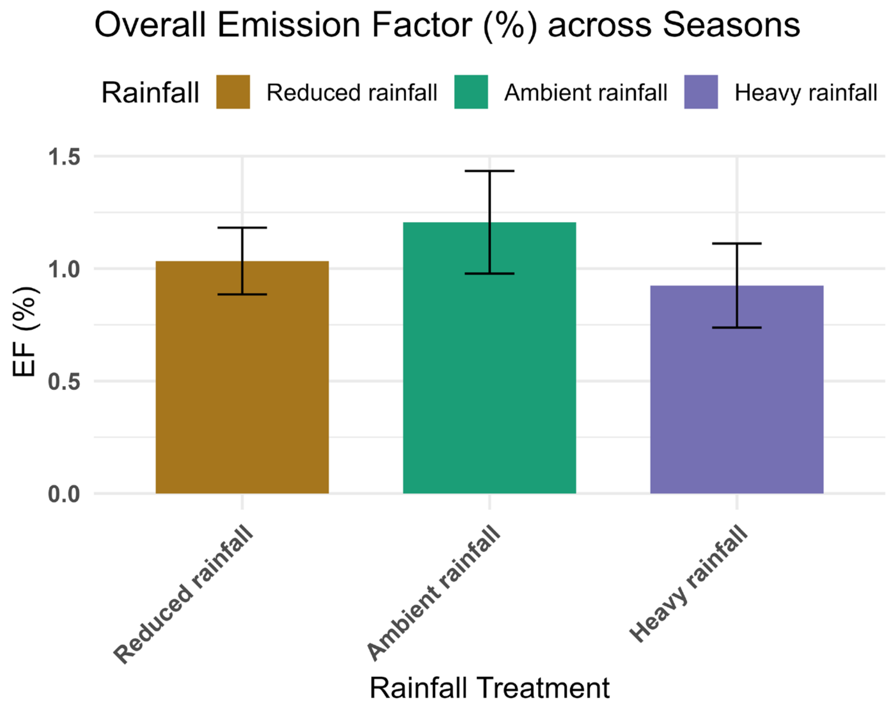
Mazungunye et al., (in prep).



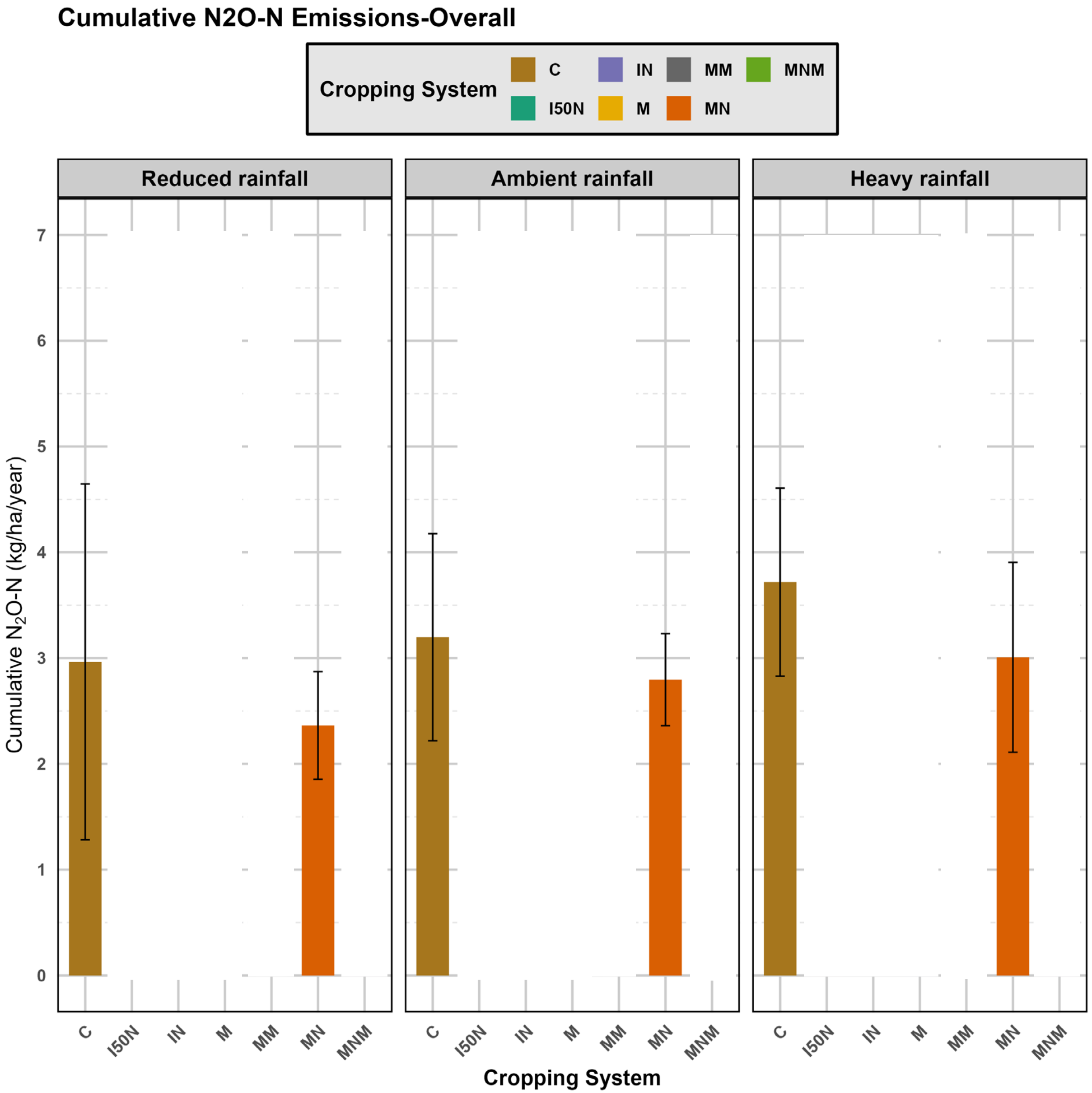
Average cumulative N_2O emissions (2023-24 and 2024-25)

Mineral N fertilization (80 kgN/ha/yr):

- Increases N2O emissions by 2-3 tim



Mazungunye et al., (in prep).

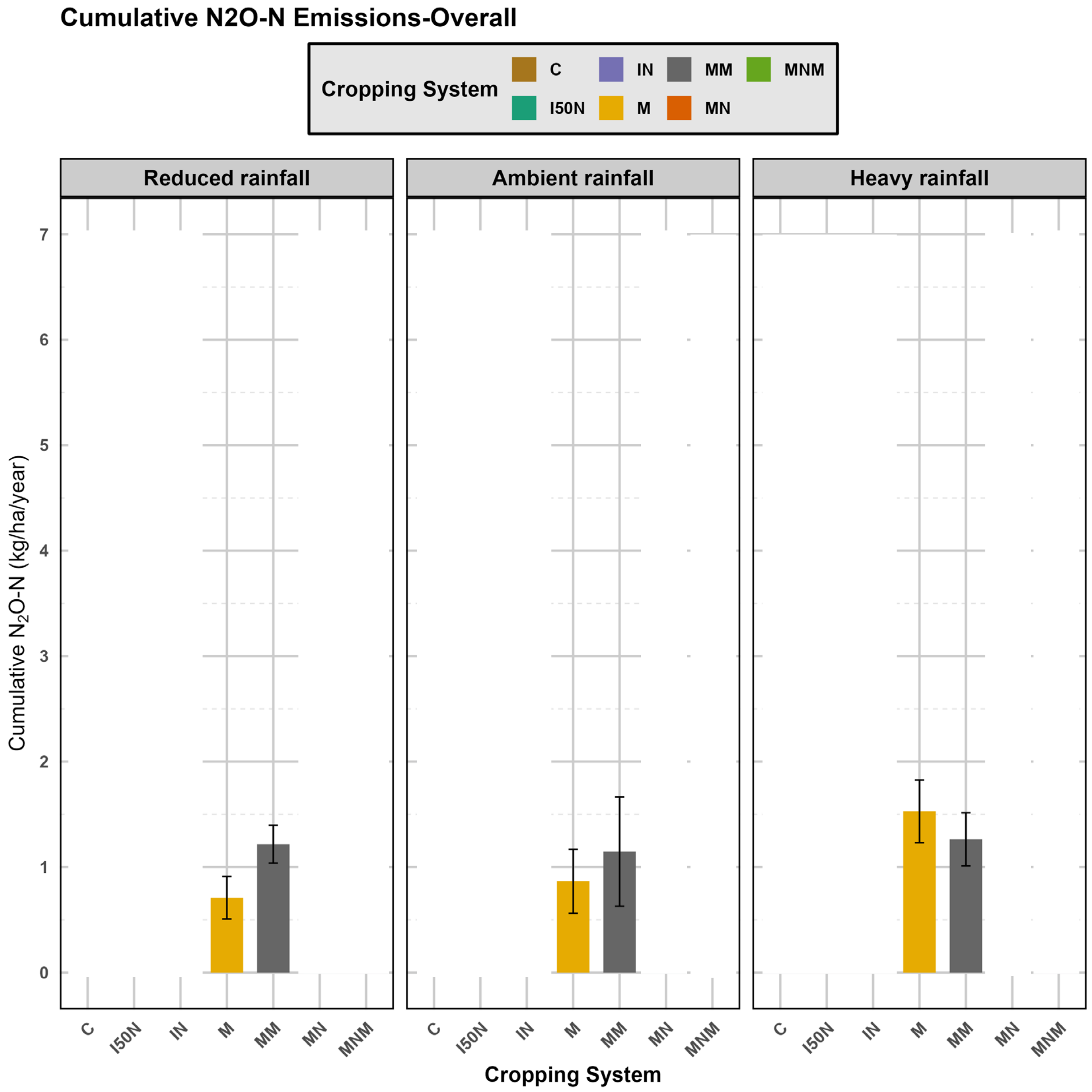


Average cumulative N_2O emissions (2023-24 and 2024-25)

Sole cowpea (C) (legume crop):

- Emits as much N2O (if not more) as fully fertilized sole maize (MN) !

Mazungunye et al., (in prep).

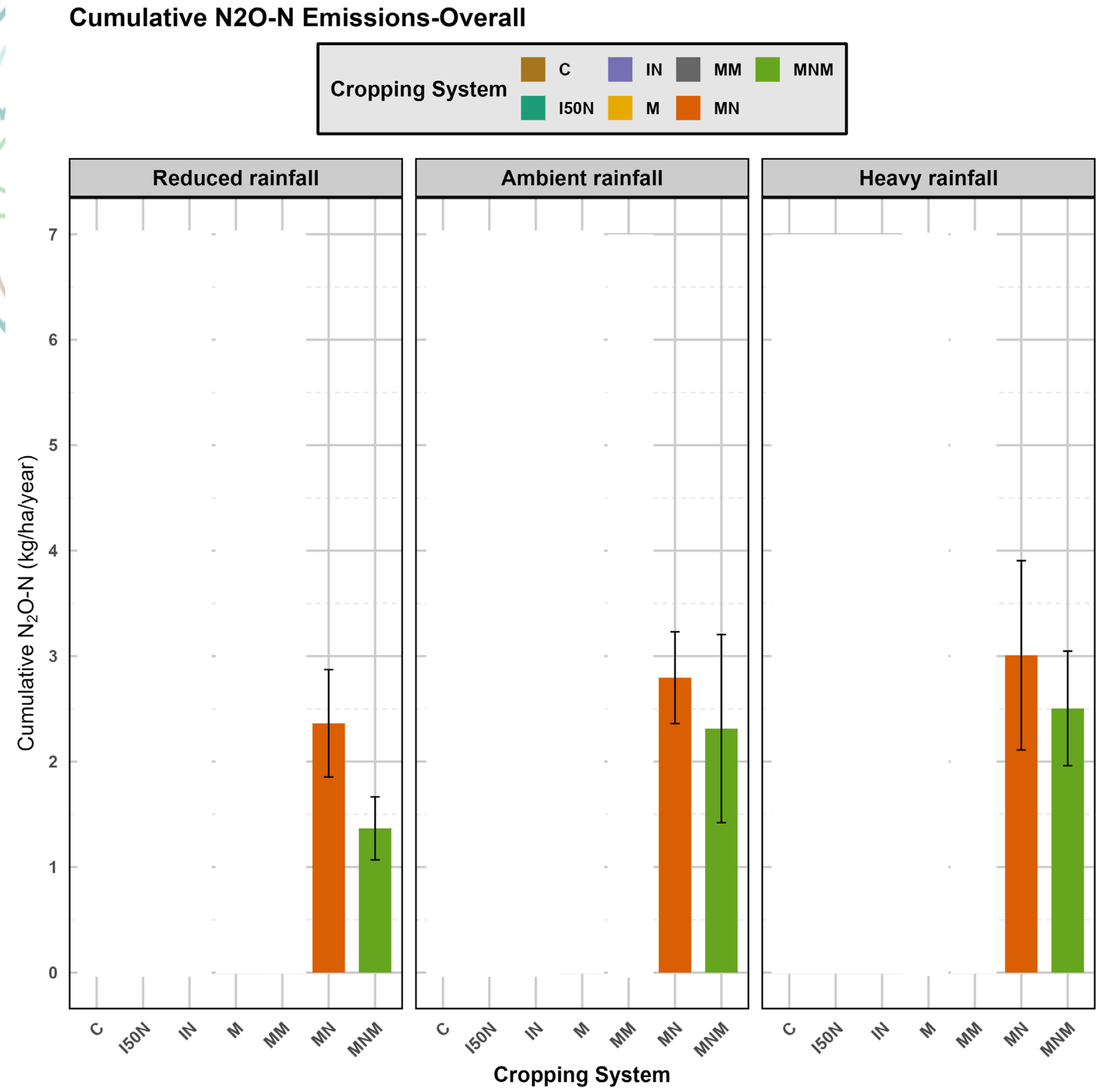


Average cumulative N_2O emissions (2023-24 and 2024-25)

Mulch without fertilizers:

- No big change
- Slight increase in N2O emissions under reduced rainfall
- No change under ambient and heavy rainfall

Mazungunye et al., (in prep).

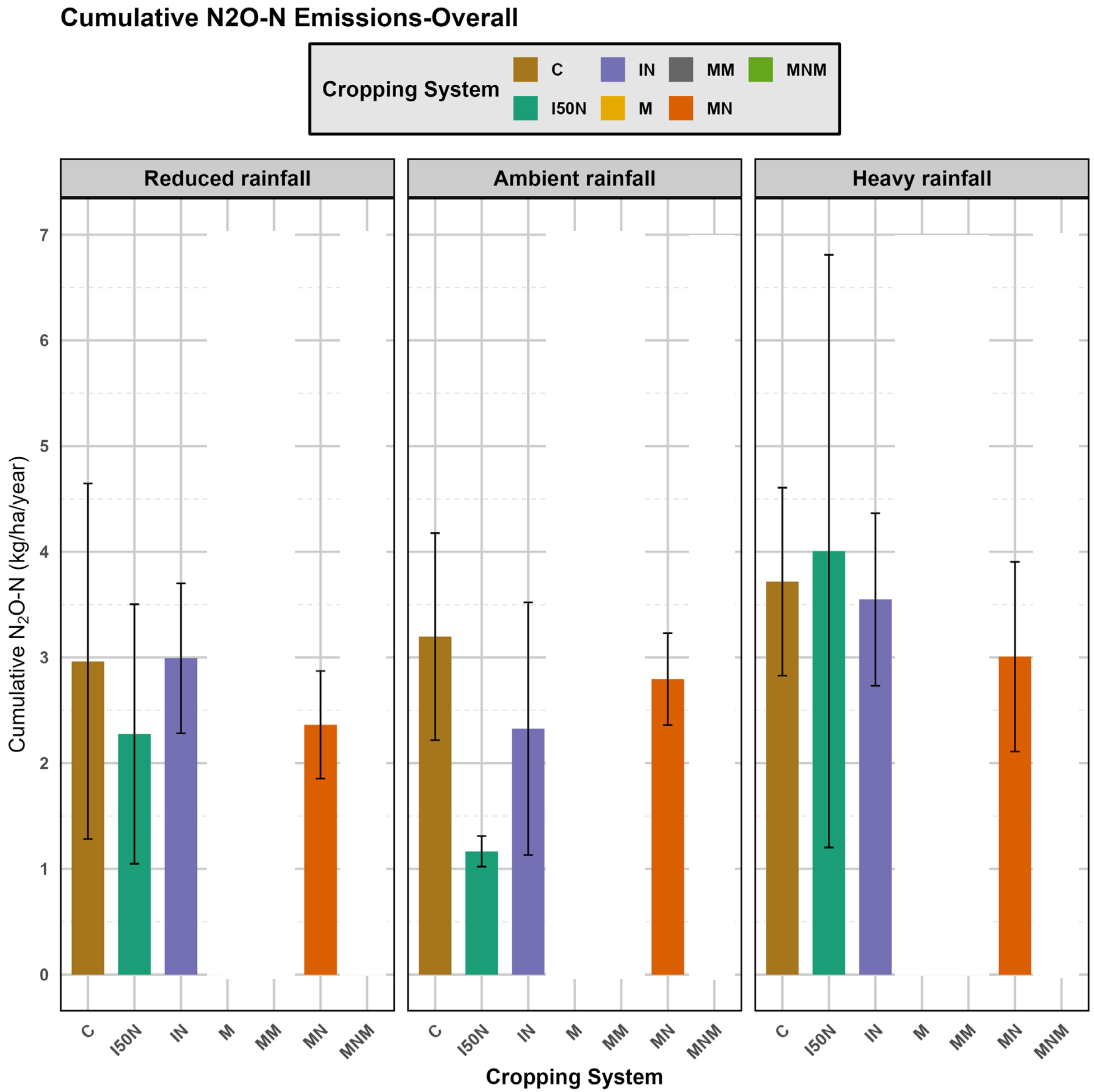


Average cumulative N_2O emissions (2023-24 and 2024-25)

Mulch with fertilizers:

- Decrease in N2O emissions under reduced rainfall
- Slight decrease in other rainfall treatments, but probably not significant

Mazungunye et al., (in prep).



Average cumulative N_2O emissions (2023-24 and 2024-25)

Maize-cowpea intercropping:

- Reduces N2O emissions compared to C and MN, but only under ambient rainfall.
- Rainfall extremes compromise the capacity of intercropping to reduce N2O emissions.

Mazungunye et al., (in prep).

ACBB grande culture Estrées-Mons

Agroécosystèmes, Cycles Biogéochimiques et Biodiversité

Frida Keuper, Guillaume Vitte, Joël Léonard, Paul Belleville, Célestin Valentin

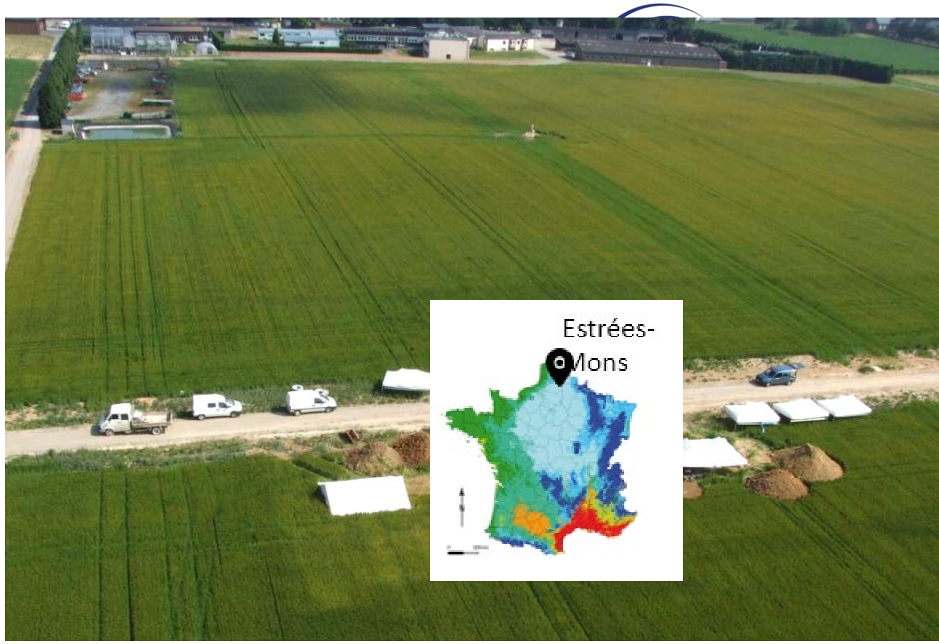


Table 3.1 – experimental treatments of the study site, CONV: conventional, RT: reduced tillage, RT-RR: reduced tillage and residues removal, RN: reduced nitrogen, RN-LEG: reduced nitrogen and leguminous crops, RR-PER: residues removal and perennial crops, ORG: organic agriculture, ORG-LEG: organic agriculture and alfalfa.

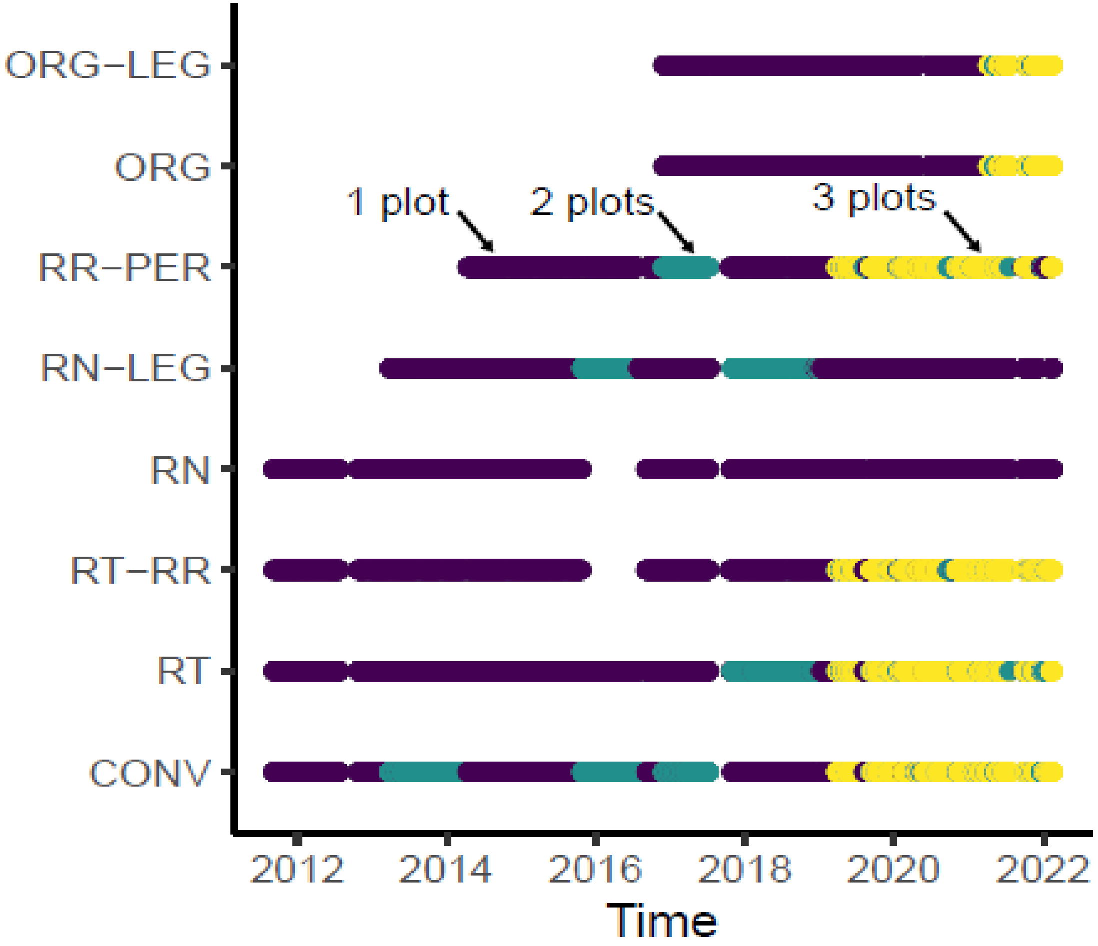
Treatment	CONV	RT	RT-RR	RN	RN-LEG	RR-PER	ORG	ORG-LEG
Number of replicates	4	4	4	4	4	4	3	3
Moldboard plowing	Yes	No	No	Yes	Yes	No	Yes	Yes
Cash crop residue exportation	No	No	Yes	No	No	Yes	No	No
Mineral nitrogen (% of reference dose)	100 %	100 %	100 %	35 %	35 %	100 %	0 %	0 %
Legumes frequency in crop succession	Low	Low	Low	Low	High	Low	Low	High
Perennial crops within succession	No	No	No	No	No	Yes	No	No
Chemical protection	Yes	Yes	Yes	Yes	Low	Yes	No	No

Long-term monitoring of N20 fluxes at Estrées-Mons

- PhD Thesis **Paul Belleville**
- Belleville, P., Keuper, F., Ferchaud, F., Mary, B., Heinesch, B., Dumont, B., and Léonard, J. (2025). **Crop residues moderately influence cumulative N2O emissions through their carbon to nitrogen ratio in a 12-year experiment in Northern France**. Agronomy for Sustainable Development (2025).

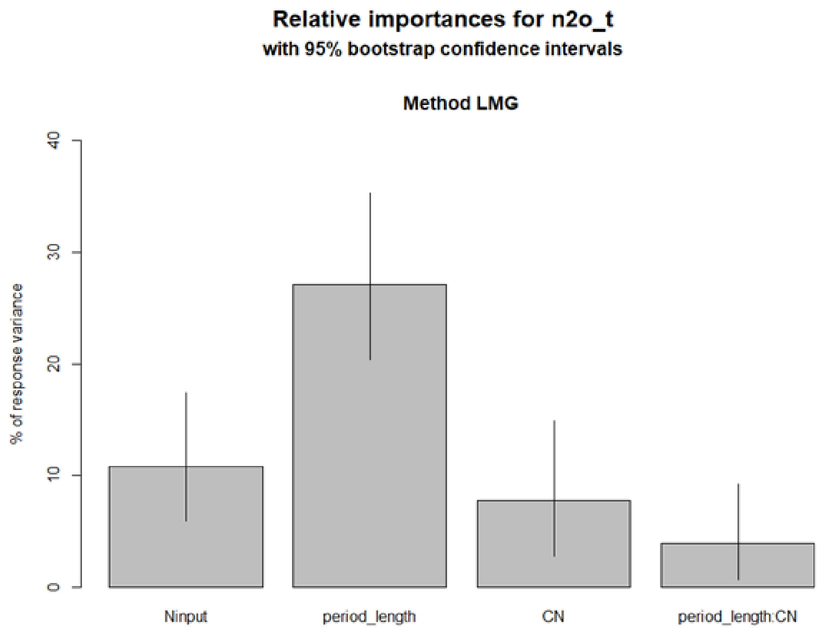
Figure 3.1 – field view showing residue returned to the soil after crop harvest, together with the automatic chambers used for measuring N_2O emissions (Photocredit: Joël Léonard).

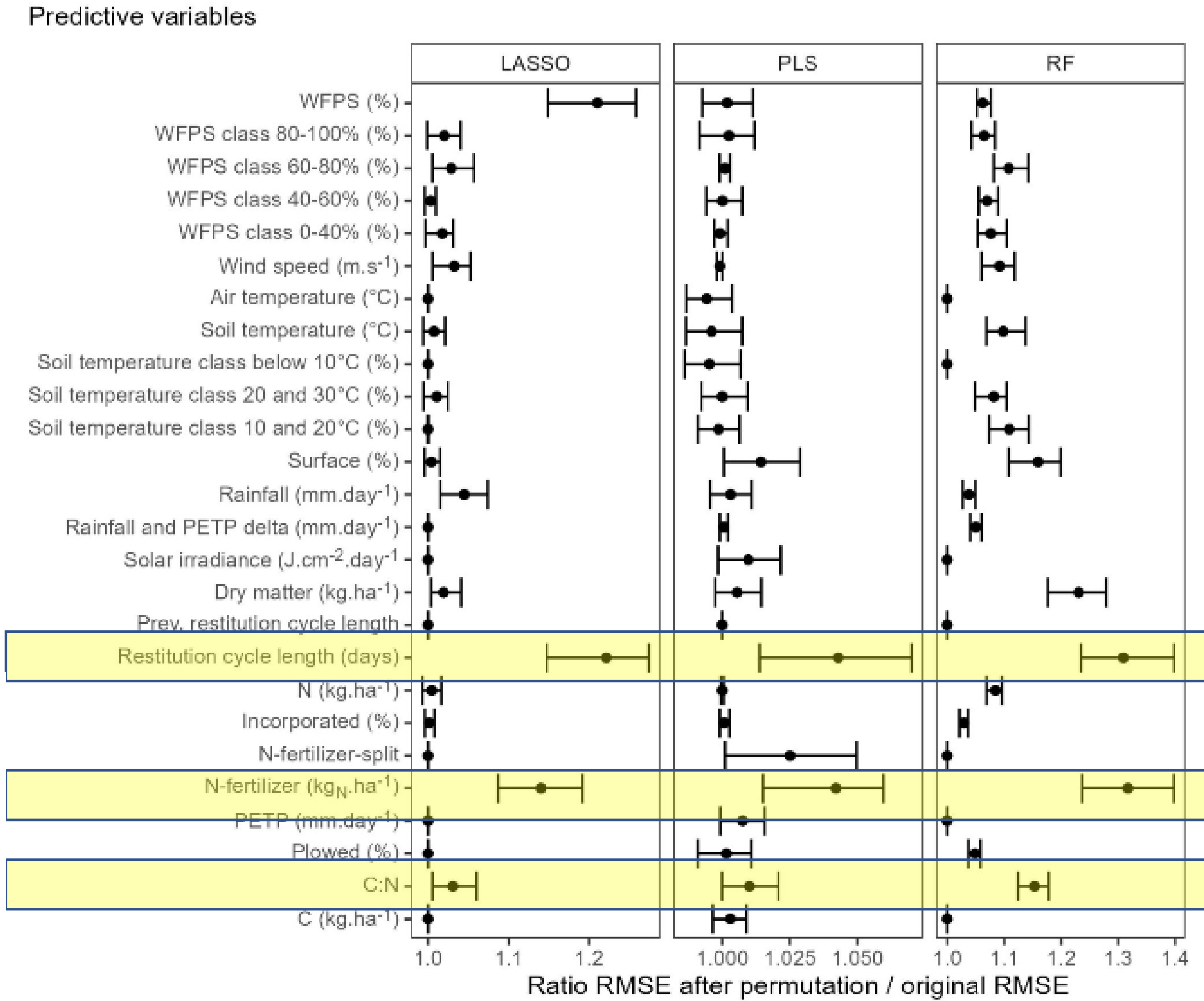
Experimental treatments



Estrées-Mons: Main conclusions (Belleville et al.)

- Crop residues and their management have a limited influence on cumulative N_2O emissions compared to the **restitution cycle length or mineral fertilization** (> 20 % of the explained variance)
- Although crop residue quality or quantity contributed relatively little, **a consistent impact associated with crop residue C:N ratio**





- Cumulative N2O emissions increased with lower crop residue C:N and this effect was more pronounced when the restitution cycle was short.
- the amount of N from crop residues had no impact on N2O emissions

General conclusions

- **Estrées-Mons**: **little effects of crop residue management on N2O emissions** from arable cropping systems in Northern France => decision-makers can focus on the **ecosystem services provided by crop residues** without concern for unintended trade-offs
- **Bos Khnor:** For cassava-based cropping systems, **conservation agriculture (CA) increases soil C sequestration** (compared to conventional tillage systems). **Despite slight increases in N20 emissions, the overall effect on climate change remains positive** (only 10 to 15% of the SOC sequestration climate benefits are offsets by increased N20 emissions)
- **Zimbabwe**: **Large effects of N fertilization** on N2O emissions, and **large N2O emissions from monocultures of the legume crop cowpea**. Little effects of mulch. **Maize-cowpea intercropping reduces N20 emissions** compared to cowpea monocrops and fertilized maize
- Perspectives: extend these studies to agroforestry systems (DIAMS site) and rice cropping systems (Vietnam and Cambodia)... but needs additional