

## ➤ Simulating innovative cropping systems aiming at producing biomass while reducing greenhouse gas emissions in the Hauts-de-France region

**F. Ferchaud<sup>1</sup>**, S. Drochon<sup>1</sup>, F. Chlebowski<sup>1</sup>, C. Gourdet<sup>2</sup>,  
J. Boissy<sup>2</sup>, M. Leclère<sup>3</sup>, C. Loyce<sup>3</sup> and L. Strullu

<sup>1</sup> *INRAE, UMR Transfrontalière BioEcoAgro*

<sup>2</sup> *Agro-Transfert Ressources et Territoires*

<sup>3</sup> *INRAE, AgroParisTech, Université Paris-Saclay, UMR Agronomie*

## > Introduction

- Biorefineries convert biomass to energy, chemicals and materials
  - Biomass supply must be local to ensure environmental sustainability
- ⇒ Creating a biorefinery in a territory will require an adaptation of the local agricultural systems
- **Case study:** project of a multi-feedstock biorefinery in Venette (Oise, Hauts-de-France)
  - **Objective:** to design and evaluate innovative cropping systems (CS) aiming at producing biomass while reducing greenhouse gas (GHG) emissions
  - **Approach:** *ex-ante* assessment using the STICS soil-crop model to compare innovative cropping systems to reference systems representative of the current agricultural practices

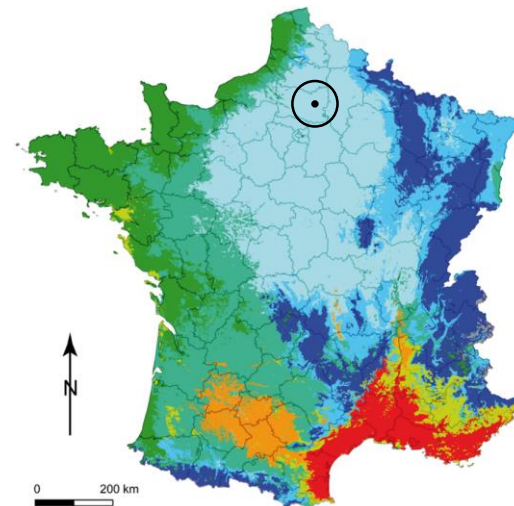


## ➤ Study area

- 50 km radius around Venette (Oise)
- Agriculture: intensive arable cropping systems
- Temperate climate:

$T_{\text{mean}} = 11 \text{ °C}$ ;  $P_{\text{mean}} = 640 \text{ mm yr}^{-1}$

- Soils: 2 soil types selected
  - ✓ Deep loamy soil (main soil type in the area)
  - ✓ Sandy loam (representing soil types with lower potential production)



	Deep loamy soil (DL)	Sandy loam (SL)
Max. depth (cm)	130	110
Water content at FC (mm)	476	187
Clay content 0-30 cm (%)	18	9
SOC content 0-30 cm (g kg <sup>-1</sup> )	11.2	9.0
Soil pH 0-30 cm	7.8	7.5

## ➤ Reference cropping systems

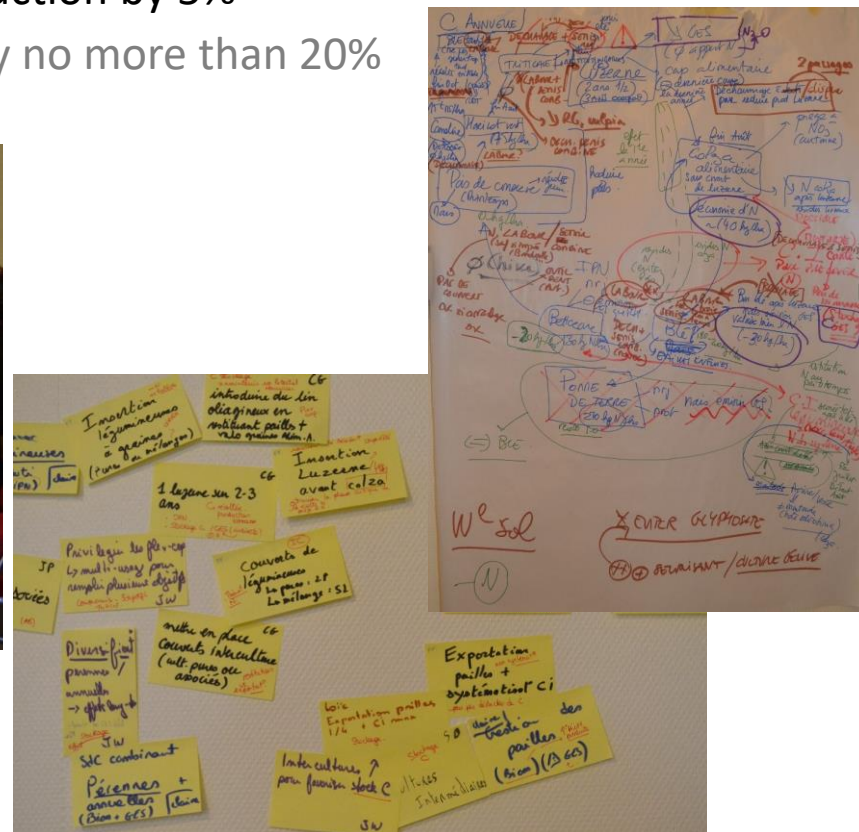
- Typology of current cropping systems
    - ✓ Based on agricultural surveys and expert knowledge
    - ✓ In each “small natural region” of the study area and per soil type
  - Selection of the most frequent systems, representing the crop diversity in the area
- ⇒ **9 reference cropping systems** and corresponding practices

N°	Crop rotation	Soil type
1	Sugar beet – wheat – rapeseed – wheat/CC	DL
2	Sugar beet – wheat – rapeseed – wheat – winter barley/CC	DL
3	Sugar beet – wheat – rapeseed – wheat/CC – spring barley/CC	DL, SL
4	Sugar beet – wheat/CC – potato – wheat/CC	DL
5	Sugar beet – wheat/CC – spring pea – wheat – winter barley/CC	DL
6	Sugar beet – wheat/CC – grain maize – wheat/CC	DL, SL
7	Grain maize – wheat/CC	SL
8	Rapeseed – wheat – winter barley	SL
9	Rapeseed – wheat/CC – spring barley	SL

*CC = catch crop (mustard)*

# ➤ Cropping system design

- Two workshops (one per soil type) involving researchers and local experts
- Aim: to design innovative cropping systems with the 3 targets
  - ✓ Reducing GHG emissions by 50%
  - ✓ Increasing total biomass production by 5%
  - ✓ Decreasing food production by no more than 20%



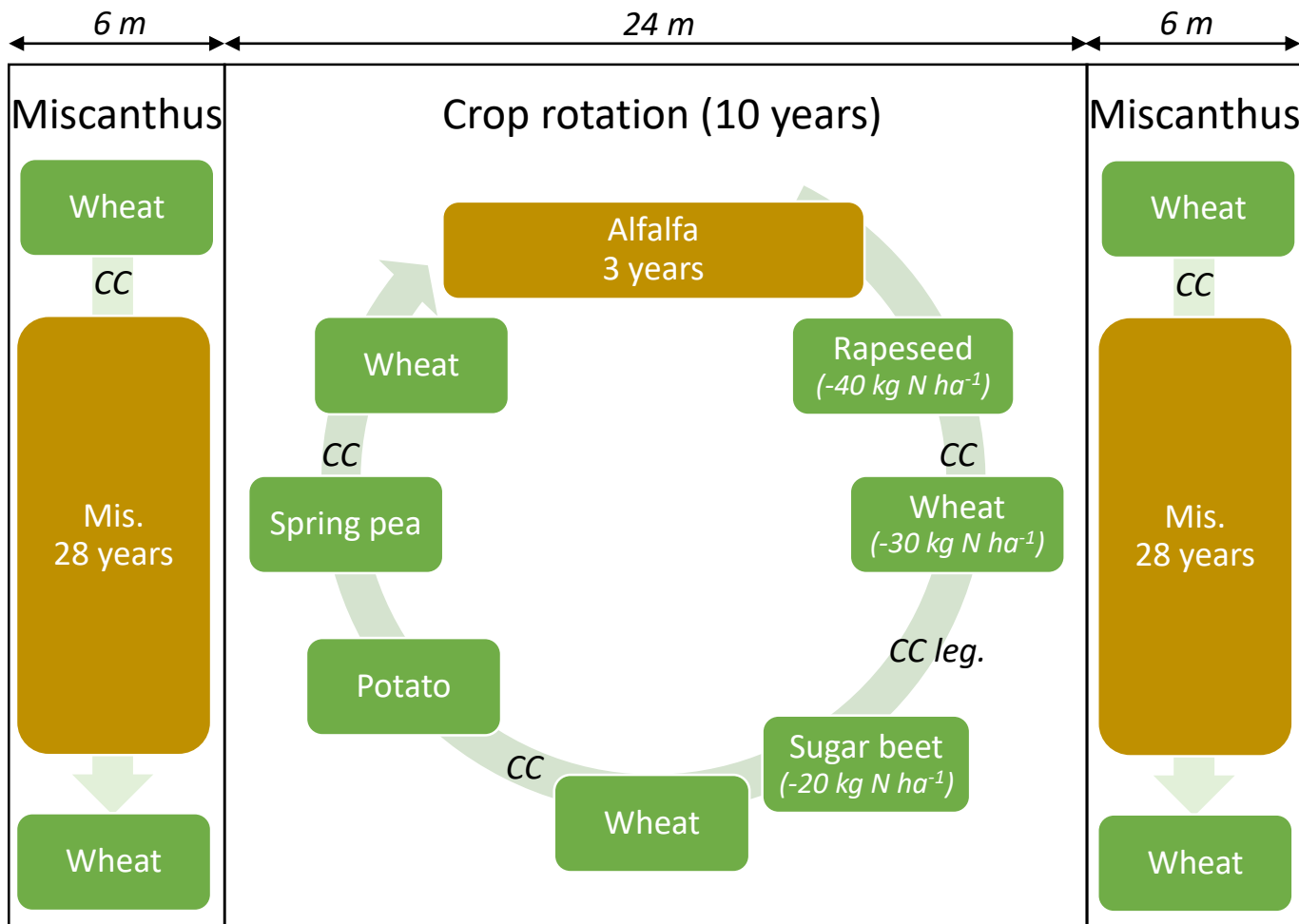
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Simulating innovative cropping systems aiming at producing biomass while reducing greenhouse gas emissions

7 February 2020 / STICS model workshop / F. Ferchaud *et al.*

# ➤ Simulated innovative cropping systems

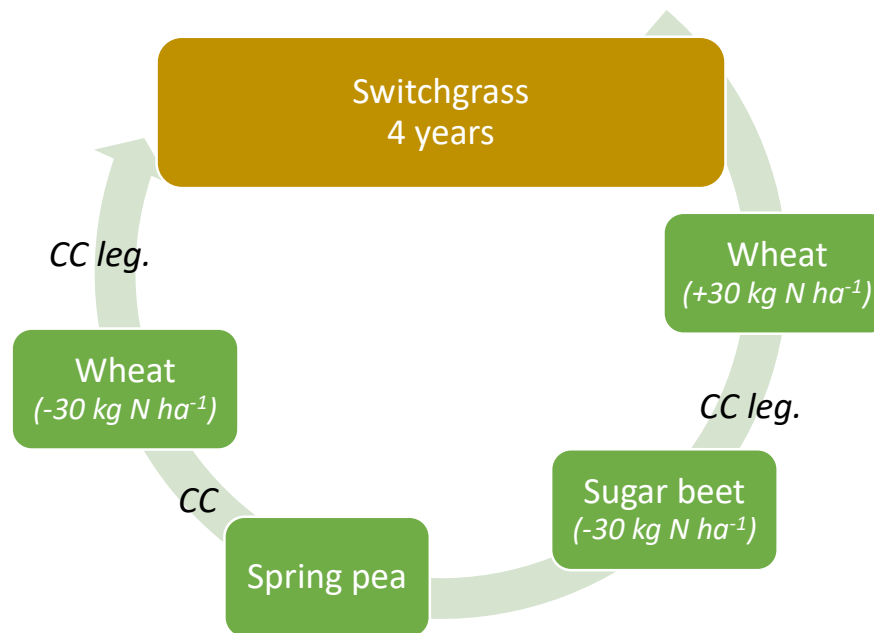
Deep loamy soil (DL):



# ➤ Simulated innovative cropping systems

Sandy loam (SL):

Crop rotation (8 years)



## ➤ Simulation procedure

- STICS research version to simulate rotations including perennial crops
- 32-year successive simulations (including 2 years of initialisation as winter wheat)
- Meteorological data:
  - ✓ 3 climatic series using randomly sampled years from 1984-2016 (data from the JRC database)
  - ✓ STICS outputs averaged between the 3 climatic series
- Mean production and C and N fluxes calculated for each system per hectare and year
- Partial GHG balance (from Autret *et al.*, 2019) calculated: includes N fertilizer synthesis, direct and indirect N<sub>2</sub>O emissions and changes in SOC stocks

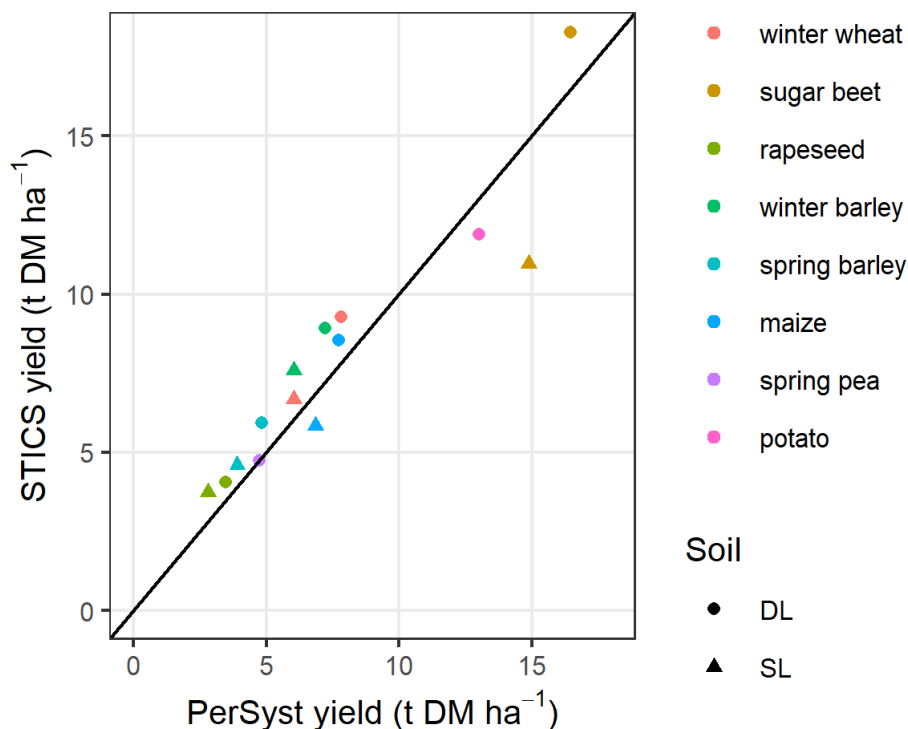




## ➤ Evaluation of the STICS outputs (1/3)

Outputs of the STICS simulations regarding reference cropping systems analysed to evaluate their reliability

- Yields: comparison of the mean simulated yield per crop and soil type with the PerSyst model (based on expert-knowledge)



✓ Good correlation ( $R^2 = 0.84$ )

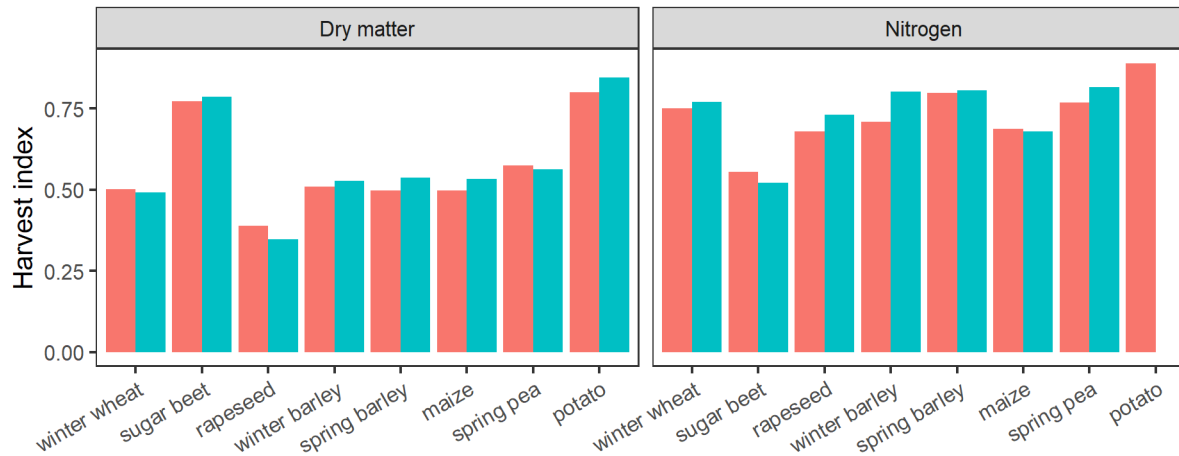
✓ General overestimation by STICS  
+0.4 t DM ha<sup>-1</sup>  
+10%

✓ Effect of soil type well reproduced  
by STICS (but overestimated for  
sugar beet)

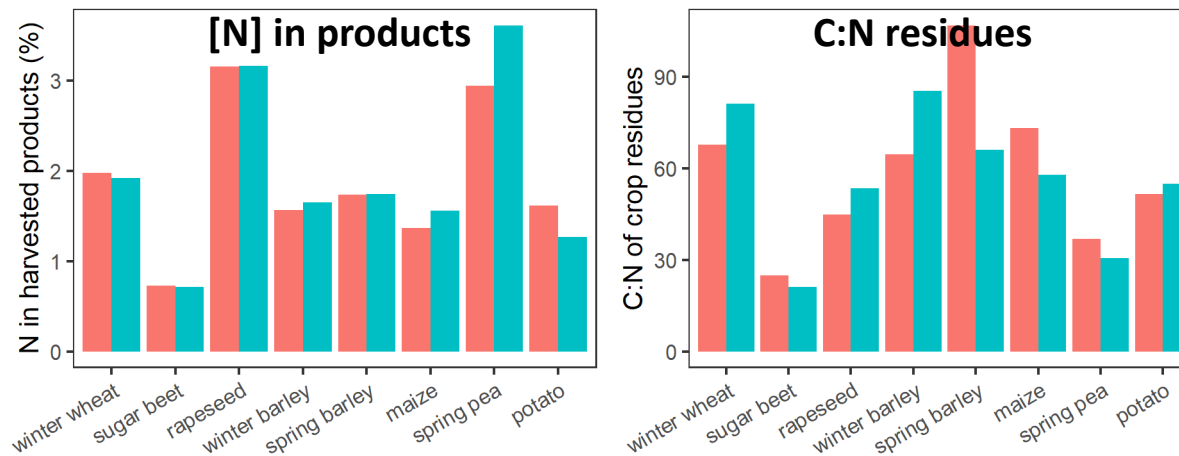
# ➤ Evaluation of the STICS outputs (2/3)

- Harvest index and N concentration: comparison with experimental references (Beaudoin *et al.*, 2008; Bolinder *et al.*, 2007; Machet *et al.*, 2017; Yin *et al.*, 2020)

**Harvest index**



✓ Consistent DM and N harvest index simulated for each species

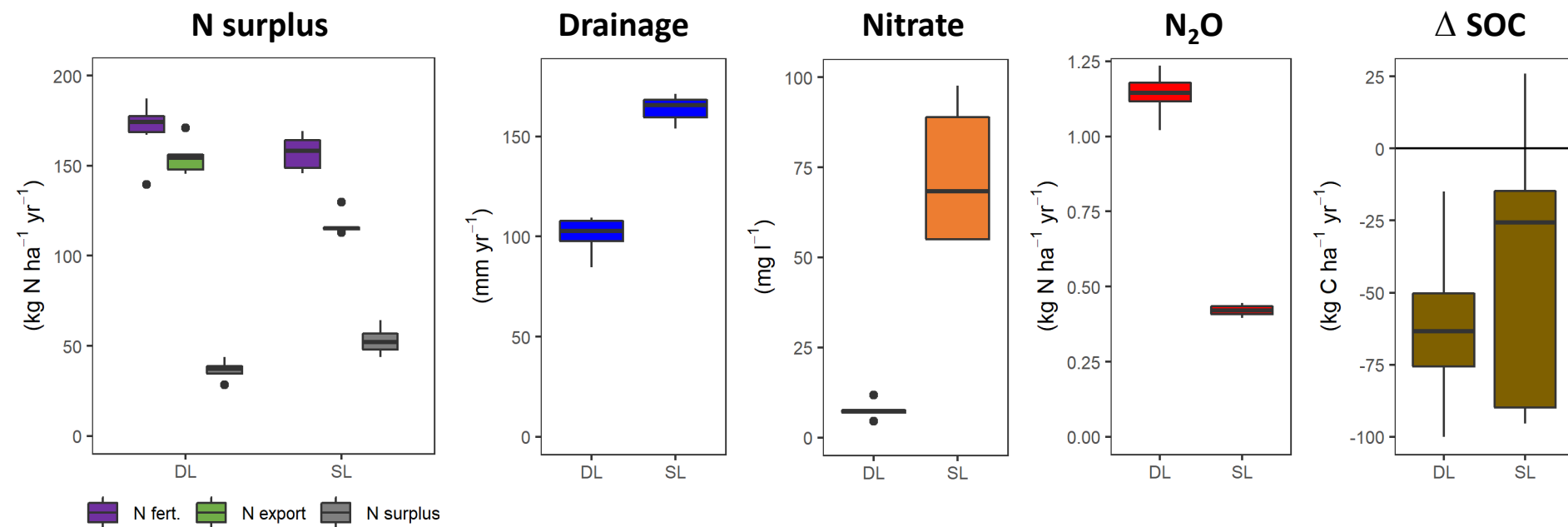


✓ Differences between species for N concentration (in exported products and residues) well reproduced

STICS References

## ➤ Evaluation of the STICS outputs (3/3)

- Environmental impacts of the reference cropping systems:

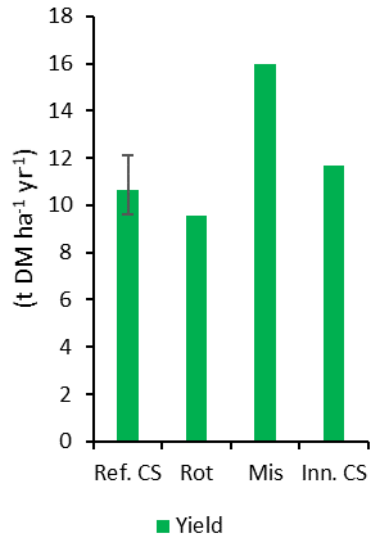


- ✓ Soil type effects: OK
- ✓ Order of magnitude: OK  
(DL: N leaching too low and N<sub>2</sub>O emissions too high?)

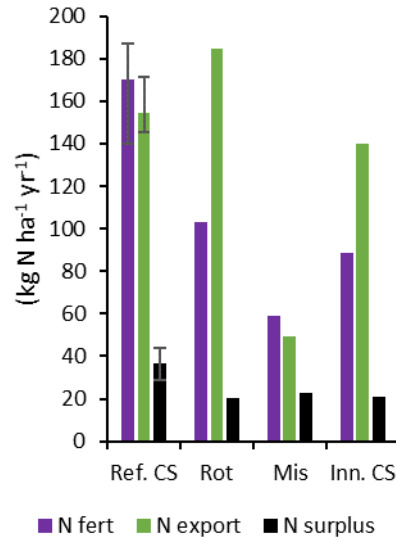
# ➤ Performances of innovative cropping systems (1/3)

## Deep loamy soil (DL)

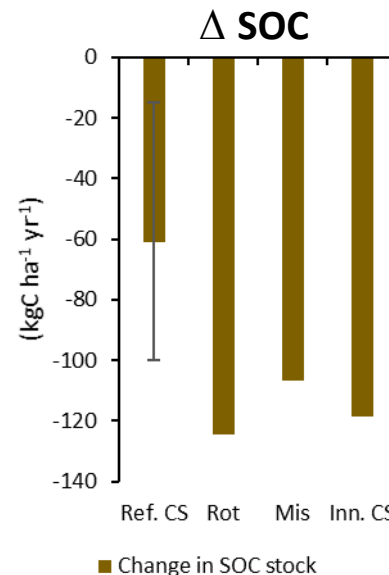
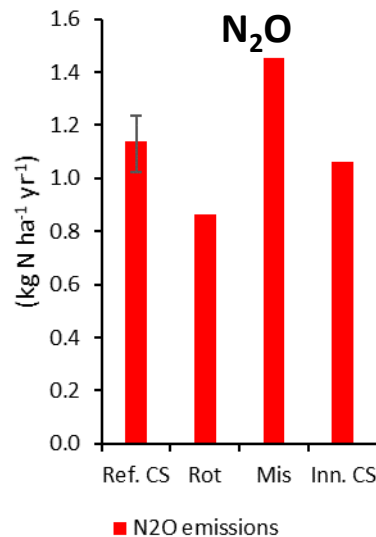
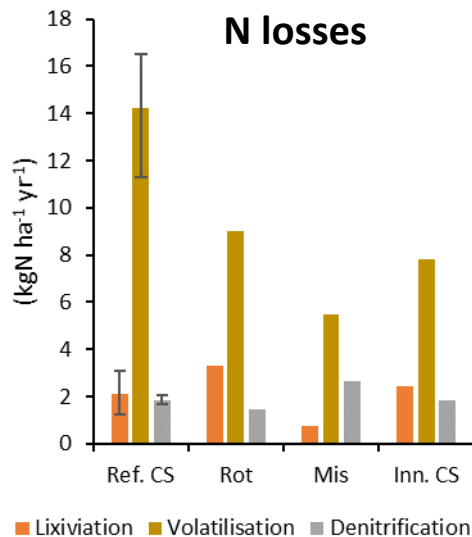
### DM production



### N surplus

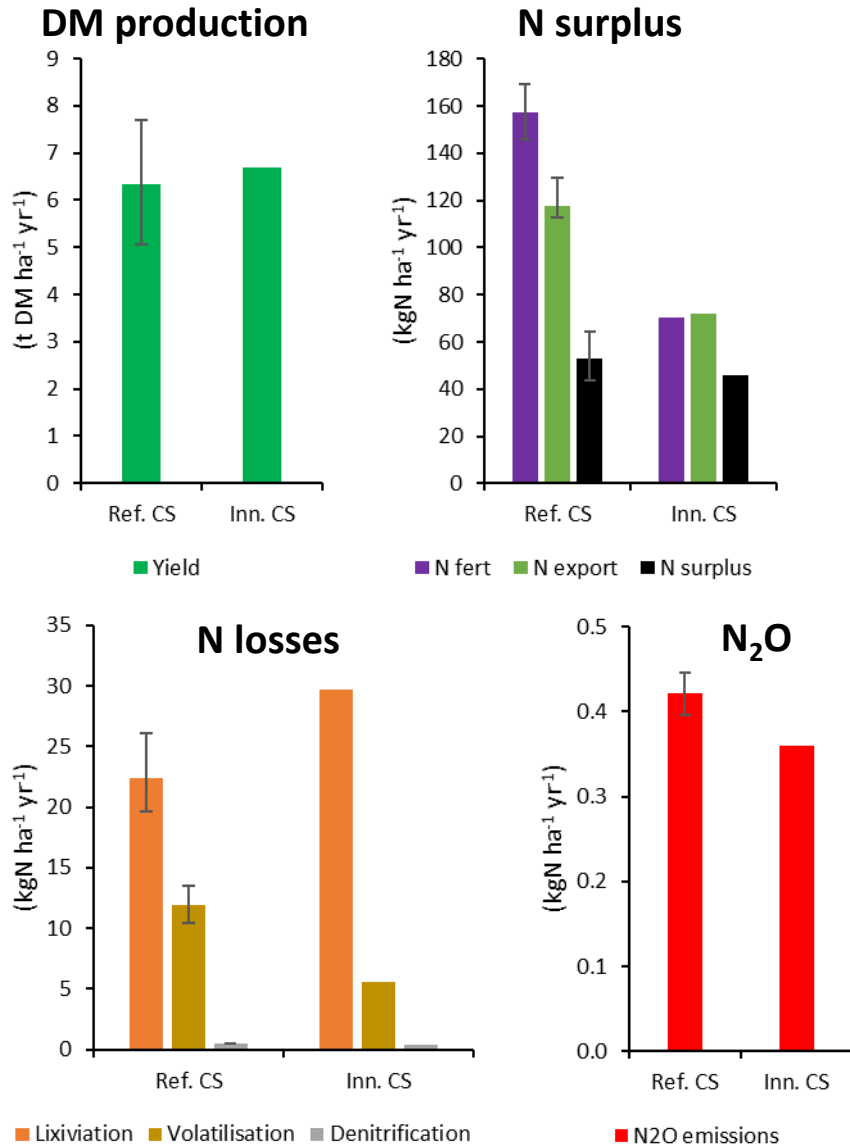


- ✓ Higher total biomass production (grains + lignocellulosic feedstock): +10%
- ✓ Much lower N fertilisation (-48%) and N surplus (-43%)
- ✓ Higher lixiviation (+17%)
- ✓ Much lower N volatilisation (-45%)
- ✓ Similar denitrification and N<sub>2</sub>O emissions
- ✓ Higher SOC decrease (+94%)



# ➤ Performances of innovative cropping systems (2/3)

## Sandy loam (SL)

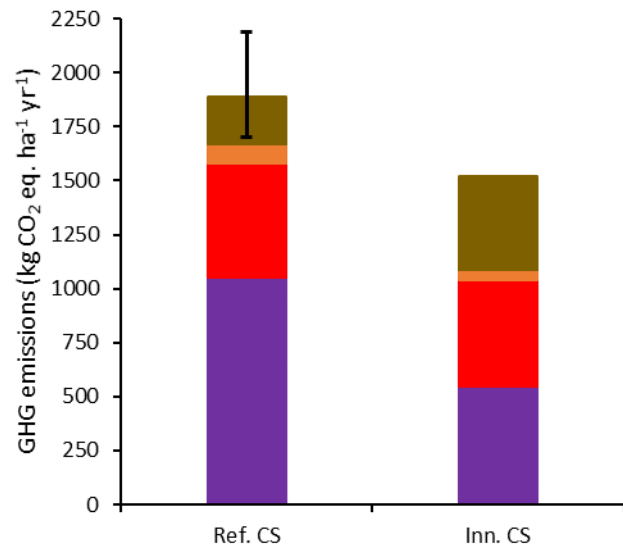


- ✓ Higher total biomass production (grains + lignocellulosic feedstock): +6%
- ✓ Much lower N fertilisation (-55%) and lower N surplus (-14%)
- ✓ Higher lixiviation (+32%)
- ✓ Much lower N volatilisation (-54%)
- ✓ Lower denitrification (-22%) and N<sub>2</sub>O emissions (-15%)
- ✓ Higher SOC decrease (+246%)

# ➤ Performances of innovative cropping systems (3/3)

## GHG balance

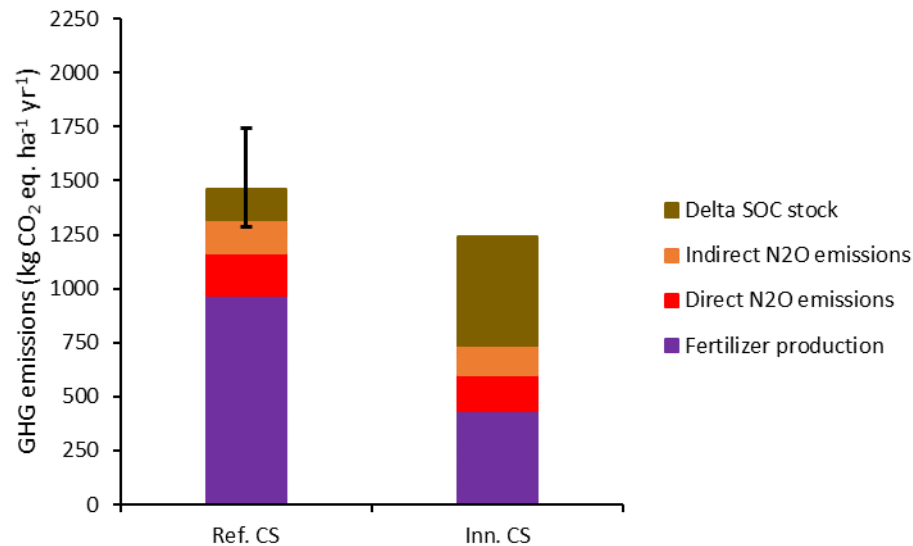
### Deep loamy soil (DL)



### ✓ Lower GHG emissions (-19%)

- Fertiliser synthesis: -48%
- Direct N<sub>2</sub>O emissions: -7%
- Indirect N<sub>2</sub>O emissions: -43%
- Δ SOC: +94%

### Sandy loam (SL)



### ✓ Lower GHG emissions (-15%)

- Fertiliser synthesis: -55%
- Direct N<sub>2</sub>O emissions: -15%
- Indirect N<sub>2</sub>O emissions: -10%
- Δ SOC: +246%

*Fuel combustion not taken into account: probably in favour of innovative cropping systems, but small relative impact (Autret et al., 2019)*

## > Conclusions

- STICS simulated satisfactorily production and environmental impacts of current cropping systems (CS) in the Hauts-de-France region
- According to STICS simulations and comparatively to the average of the reference CS, innovative CS were able:
  - ✓ To increase total biomass production by 6-10%
  - ✓ To decrease GHG emissions by 15-19%
- Innovative CS had a negative impact on simulated SOC stocks, but STICS performance for simulating SOC stocks under perennial crops (*e.g.* alfalfa, miscanthus and switchgrass) deserves further evaluation
- These innovative CS could probably be further improved (*e.g.* N fertilisation of miscanthus)



## ➤ Thank you for your attention

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