Using a long-term experiment with a wide range of management practices to challenge N2O emission modelling with the STICS model

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Introduction

- N_2O is a problematic gas when released into the atmosphere because of its global warming potential
  - Agriculture is one of the main sources of N_2O emissions worldwide
  - Cropping systems have different N_2O emission levels
- Modelling has great potential to synthetize existing knowledge and identify best cropping systems to mitigate N_2O emissions
- N_2O emissions are challenging to predict due to high spatiotemporal variability and complex interconnected drivers
- Our aim is to assess STICS ability to simulate long-term N_2O emissions for contrasted cropping systems and to describe and analyse the error

Method - N_2O modelling withing STICS

STICS models two processes which set-up the order of magnitude of the nitrogen possibly available for N_2O emissions:

- nitrification of NH_4^+ - driven by [NH_4^+], pH, T°C, water content - and
- denitrification of NO_3^- - driven by [NO_3^-], T°C, water filled pore space

N_2O-N emissions are described as a proportion of nitrification and denitrification rates:

- The share of N-nitrified emited as N_2O is driven by WFPS
- The share of N-denitrified emited as N_2O is driven by pH, water filled pore space, [NO_3^-]

Known limits:

- Carbon availability is not involved in the N_2O-module
- Instant, no-loss diffusion of N_2O from soil to the atmosphere

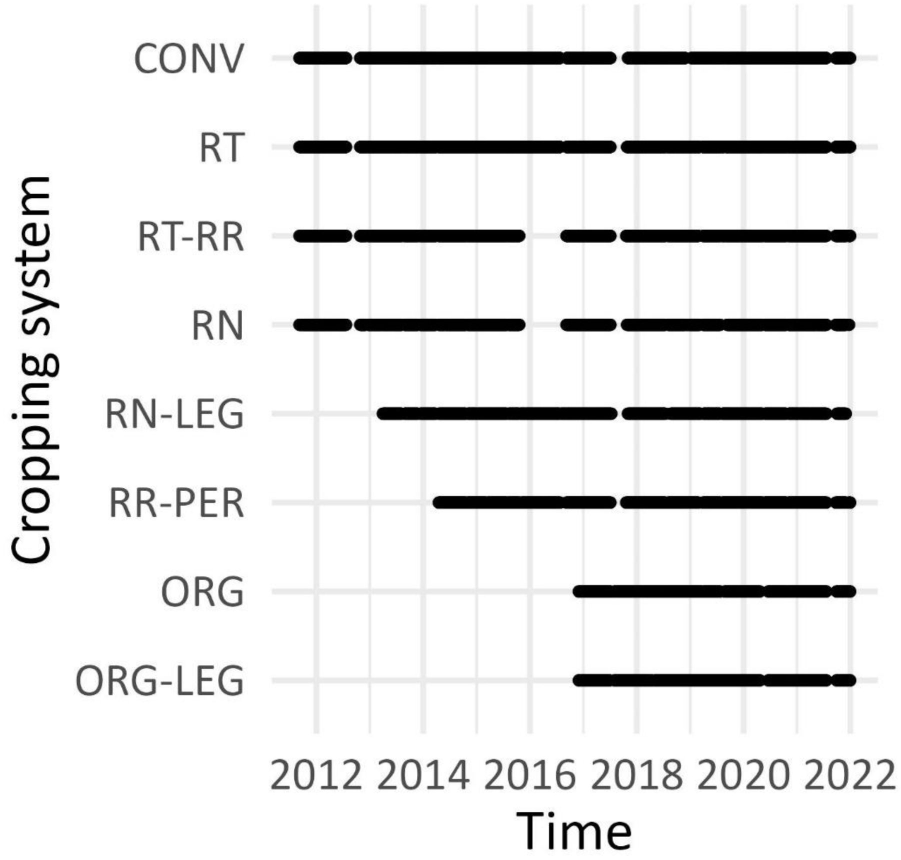
Method - Experimental site and treatments

- Estrées-Mons – deep silt loam – oceanic with continental influence
- 6 treatments in a randomized complete 4-blocks design (11 ha) + 2 treatments in another randomized complete 3-blocks design (3 ha).

Treatment	CONV	RT	RT-RR	RN	RN-LEG	RR-PER	ORG	ORG-LEG
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	✓	✗	✗

Method - Experimental site and treatments

Automatic chamber monitoring N_2O fluxes



Sampling effort through time

Method – STICS parameters

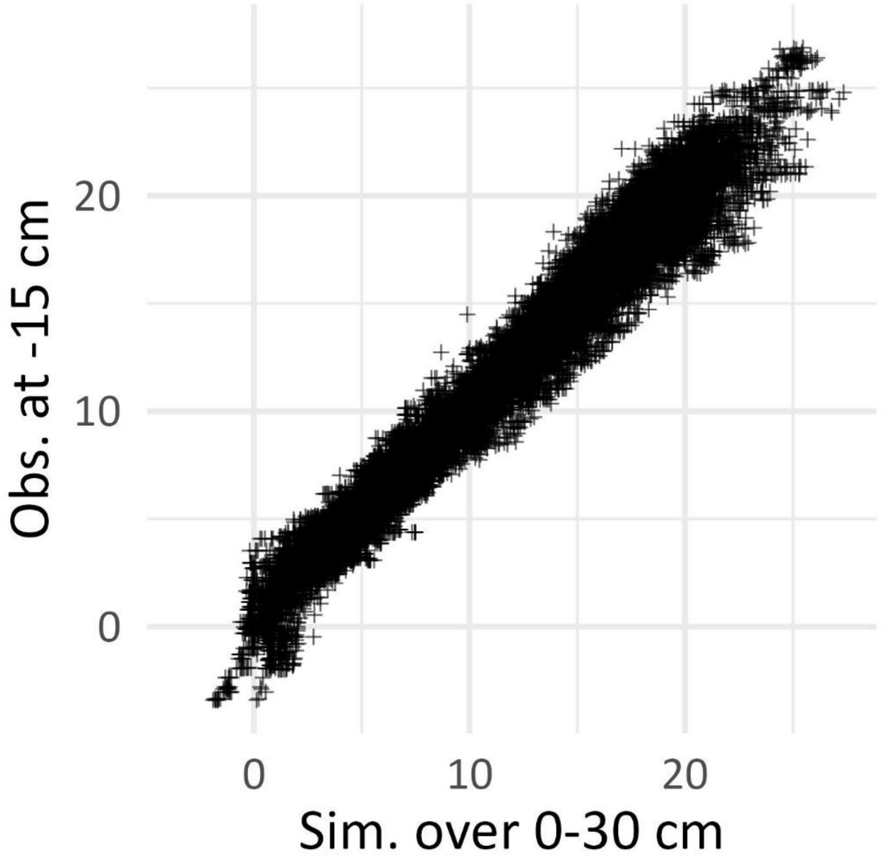
- Default parameters
- Gap in the order of magnitude of N_2O emissions → find a value for `vpotdenit` ($kg_N.ha^{-1}.day^{-1}$ over 0-20 cm) yielding in close cumulative emissions for CONV

$$vdenit = \boldsymbol{vpotdenit} \times f(NO_3^-) \times f(Td) \times f(WFPS)$$

Method - Simulation assessment and errors

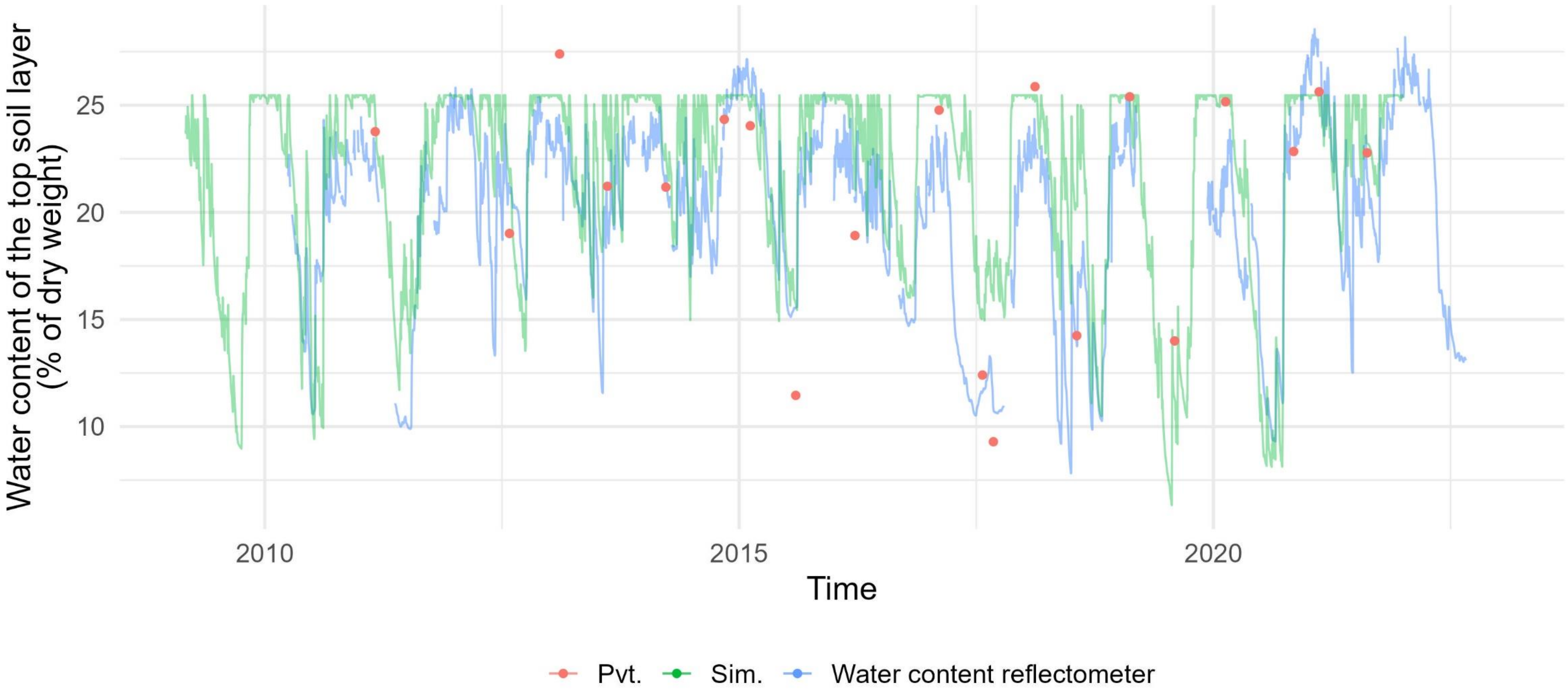
- Variables of interest
  - Soil moisture, temperature, $[NH_4^+]$ and $[NO_3^-]$ + N_2O emissions
- Simulations assessment
  - Simulations vs Observations: scatterplot, temporal dynamic, cumulatives, standard indicators (R^2, RMSE)
- Describe prediction error
  - Is the difference between observed and simulated values explained by other variables? Is it possible to « predict » the error from other simulated values, and better understand the limits of the model?

Results – Simulation of N_2O drivers



Obs. *vs*. Sim. Daily mean temperature (°C)

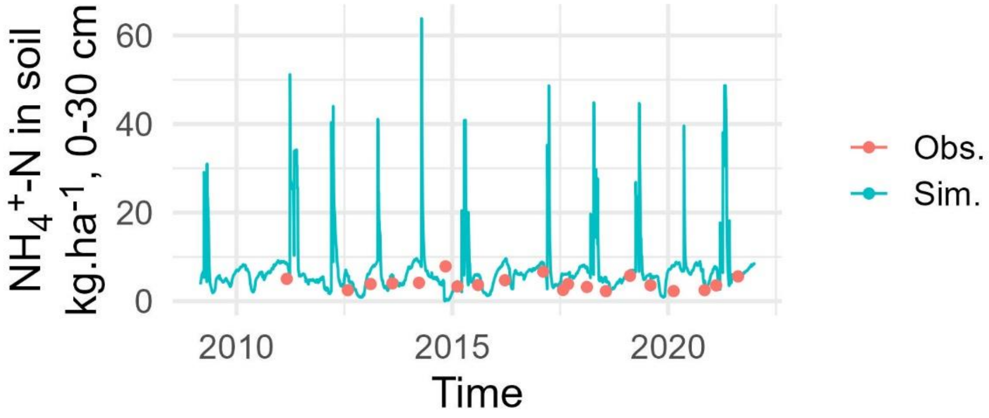
Results – Simulation of N_2O drivers



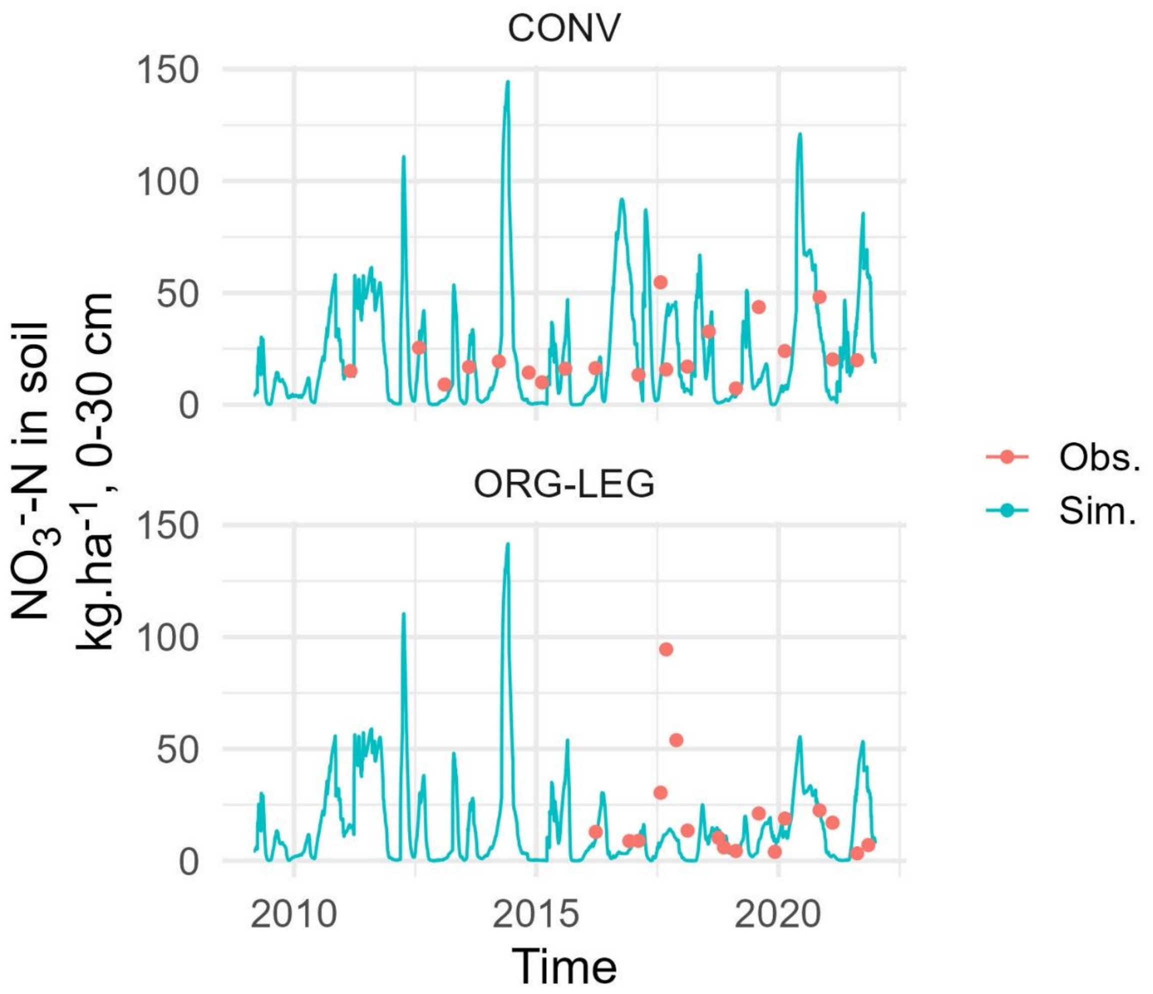
Comparison of three data sources for the estimation of the topsoil water content of the CONV treatment

Results – Simulation of N_2O drivers

NH_4^+ and NO_3^-



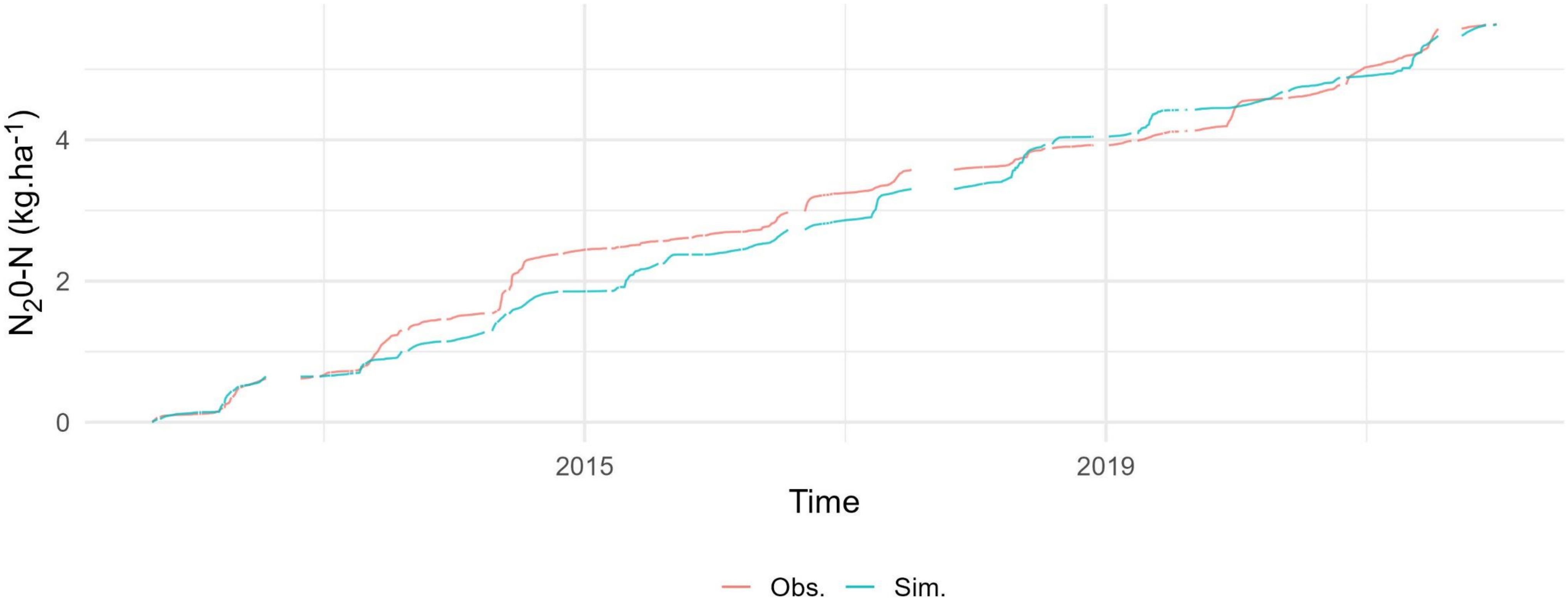
Ammonium-nitrogen in soil through time for the CONV treatment



Nitrate-nitrogen in soil through time for the CONV and the ORG-LEG treatments

Results – Adjusting the value of vpotdenit

$\texttt{vpotdenit}_S = \texttt{0.07}$ $kg_N.ha^{-1}.day^{-1}$ over 0-20 cm (default is 2)

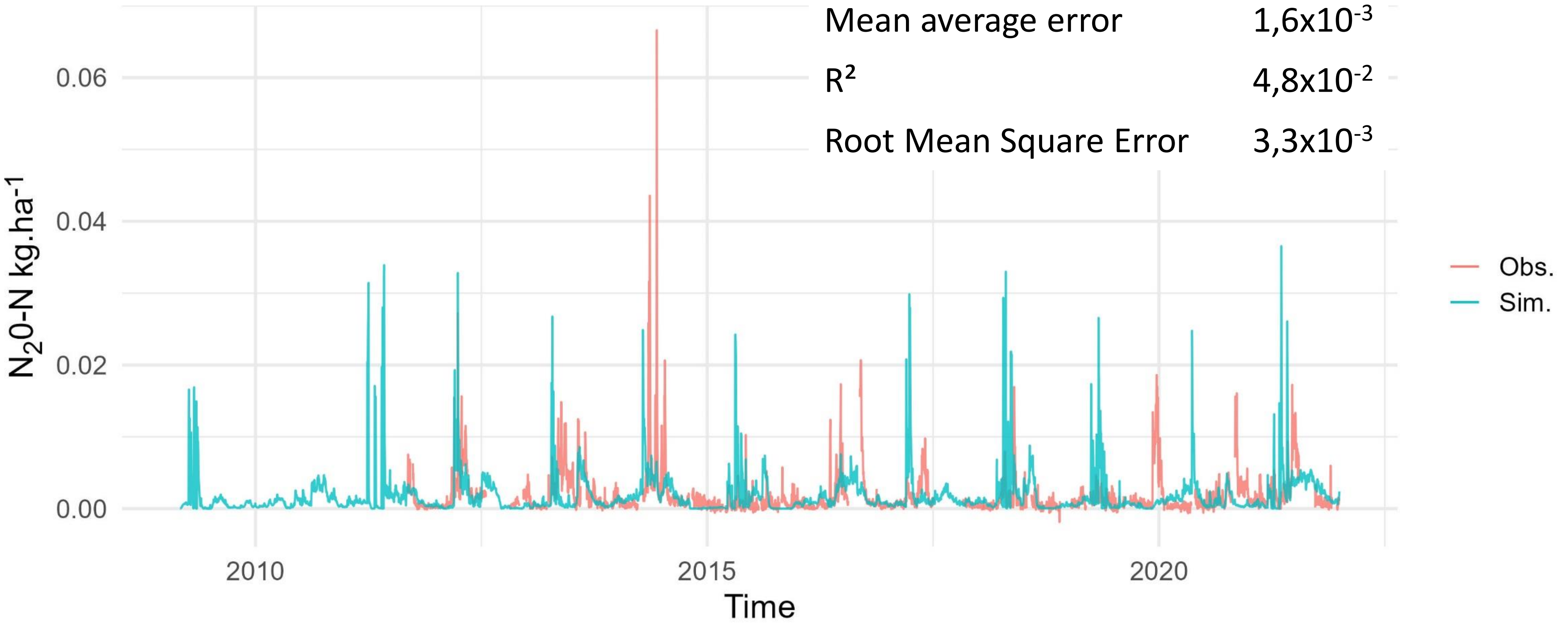


Cumulated N_2O-N emissions for the CONV treatment using vpotdenit = 0,07

Results – Simulations of N_2O emissions

`vpotdenit_S = 0.07` $kg_N.ha^{-1}.day^{-1}$ over 0-20 cm (default is 2)

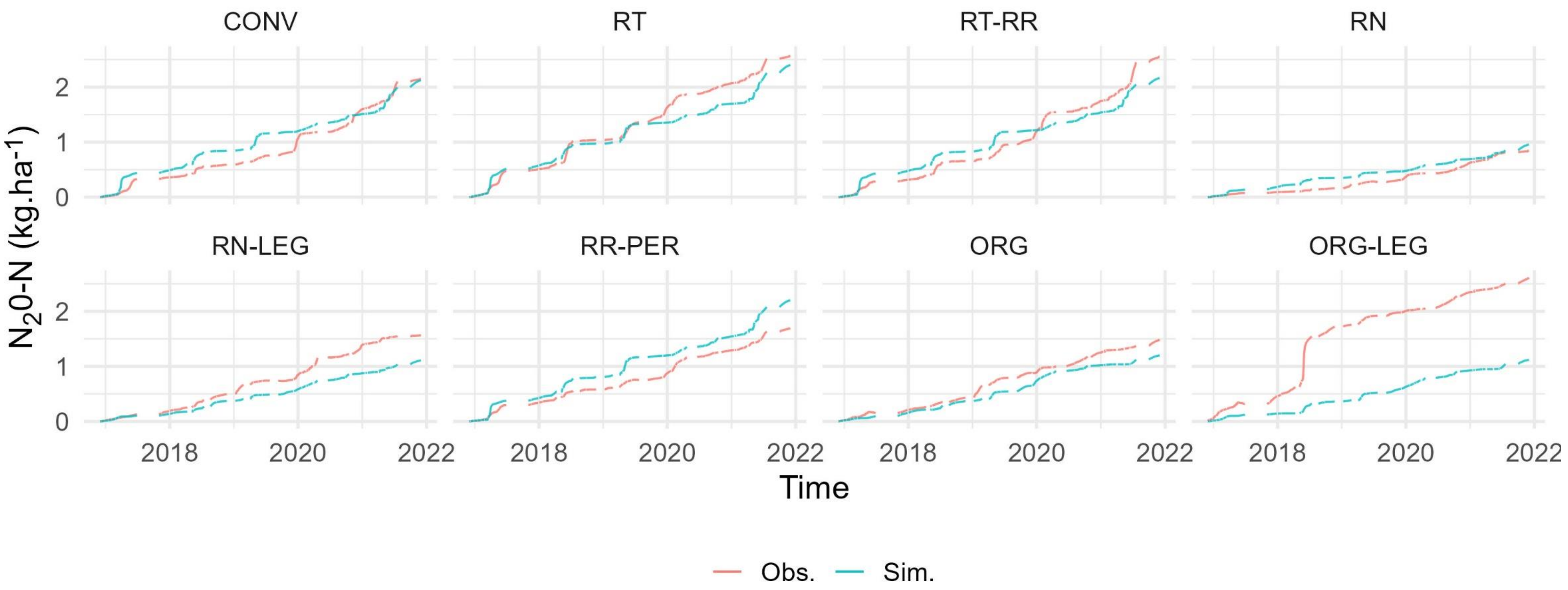
Mean average error	$1,6\times10^{-3}$
R^2	$4,8\times10^{-2}$
Root Mean Square Error	$3,3\times10^{-3}$



Observed and simulated N_2O-N emissions through time for the CONV treatment

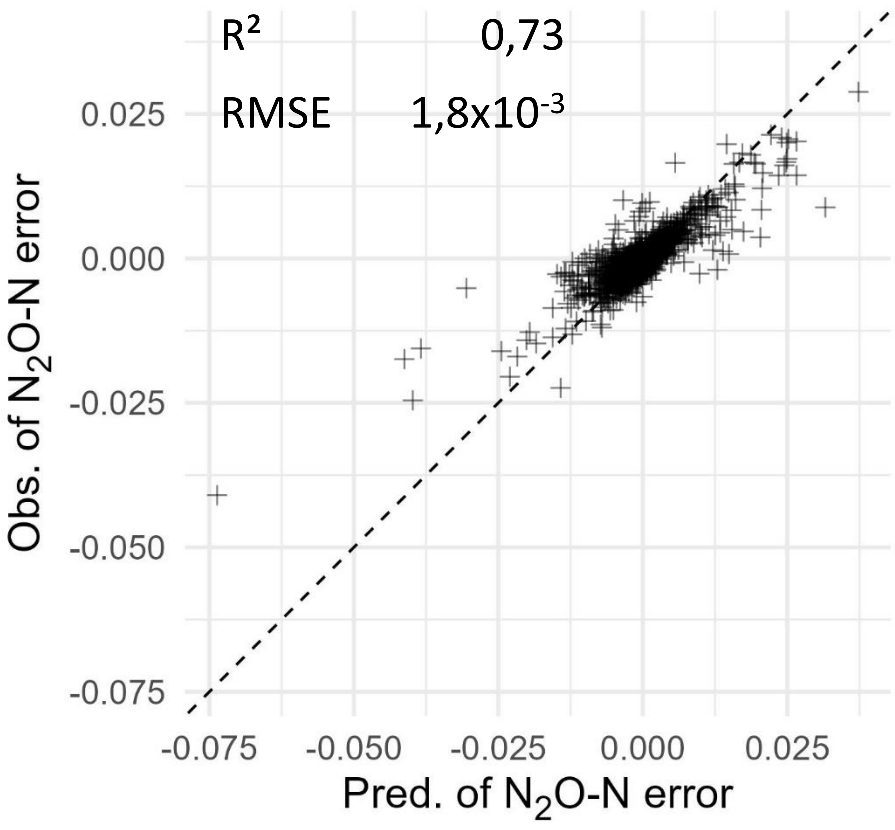
Results – Simulations of N_2O emissions

`vpotdenit_s = 0.07` $kg_N.ha^{-1}.day^{-1}$ over 0-20 cm (default is 2)

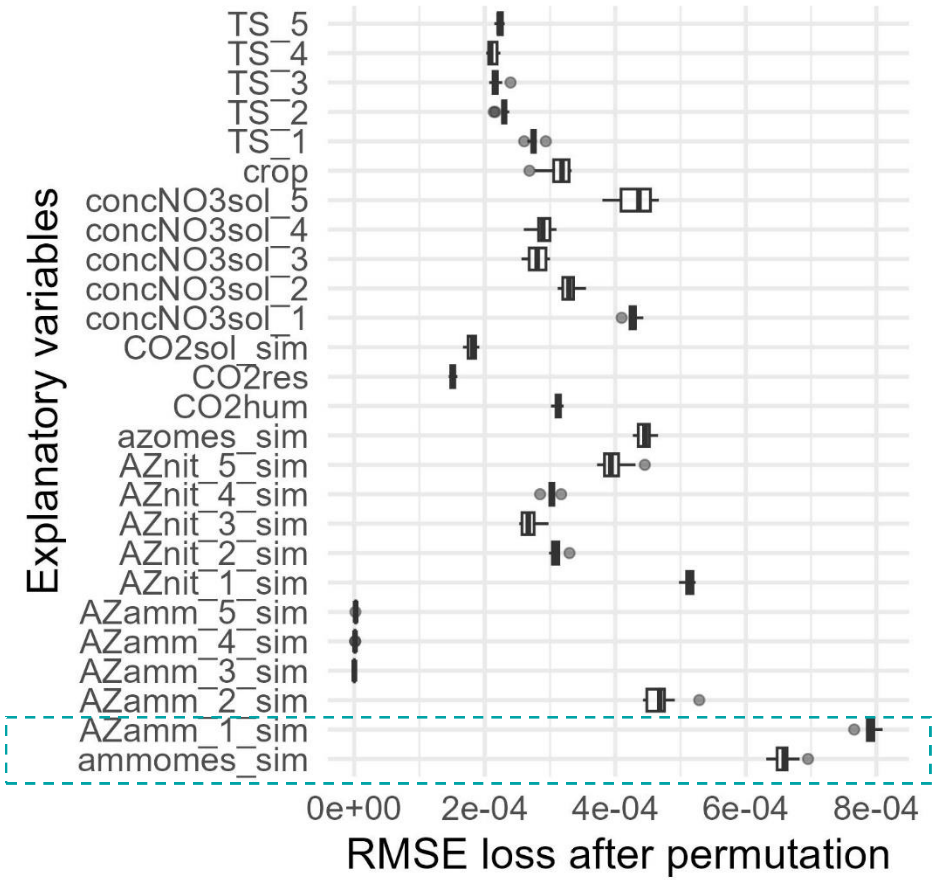


Cumulated N_2O-N emissions for all treatments

Result – Predict STICS error on N_2O emissions

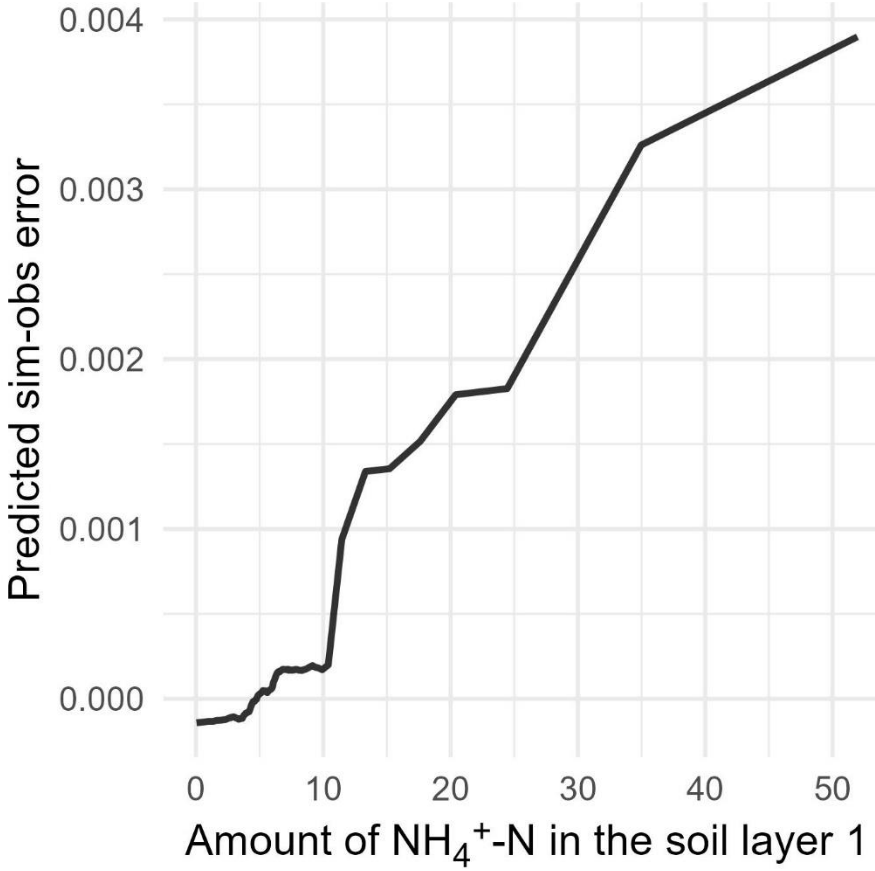


Prediction of N2O-N sim-obs error using Random Forest model on test dataset



Assessment of the variable importance for predicting the sim-obs error

Results – Interpreting the random forest model



Accumulated-local profile of the main variable influencing the error

Conclusion

- Simulation of N_2O emissions drivers
  - Soil temperature and soil moisture are considered as good enough
  - $[NO_3^-]$ is treatment-dependent
  - $[NH_4^+]$ is good for low concentration values but unknown for high concentration values.
- Simulation of N_2O
  - Despite bad R^2, the RMSE is low and the overall seasonality is simulated
  - Cumulative values are good except for the ORG-LEG treatment
- Understanding the error:
  - STICS error can be estimated using a random forest model fuelled by simulated variables
  - The amount of NH_4^+ is the main variable contributing to the random forest

Thank you for your attention!

5 mins for questions