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➤ 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

- N₂O is a problematic gas when released into the atmosphere because of its global warming potential
 - Agriculture is one of the main sources of N₂O emissions worldwide
 - Cropping systems have different N₂O emission levels
- Modelling has great potential to synthesize existing knowledge and identify best cropping systems to mitigate N₂O emissions
- N₂O 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 N₂O emissions for contrasted cropping systems and to describe and analyse the error



➤ Method - N₂O modelling withing STICS

STICS models two processes which set-up the order of magnitude of the nitrogen possibly available for N₂O emissions:

- nitrification of NH₄⁺ - driven by [NH₄⁺], pH, T°C, water content - and
- denitrification of NO₃⁻ - driven by [NO₃⁻], T°C, water filled pore space

N₂O-N emissions are described as a proportion of nitrification and denitrification rates:

- The share of N-nitrified emitted as N₂O is driven by WFPS
- The share of N-denitrified emitted as N₂O is driven by pH, water filled pore space, [NO₃⁻]

Known limits:

- Carbon availability is not involved in the N₂O-module
- Instant, no-loss diffusion of N₂O from soil to the atmosphere

➤ Method - Experimental site and treatments

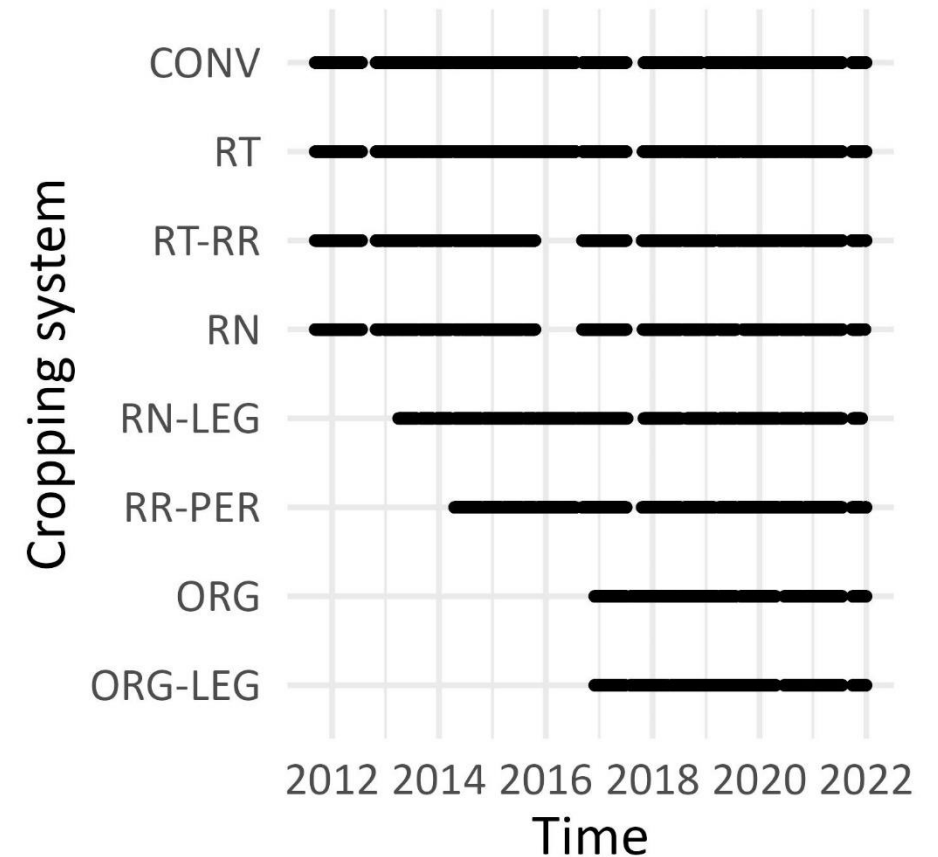
- Estrées-Mons – deep silt loam – oceanic with continental influence
- 6 treatments in a randomized complete 4-blocks design (11 ha) + 2 treatments in another randomized complete 3-blocks design (3 ha).

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 N₂O fluxes



Sampling effort through time

➤ Method – STICS parameters

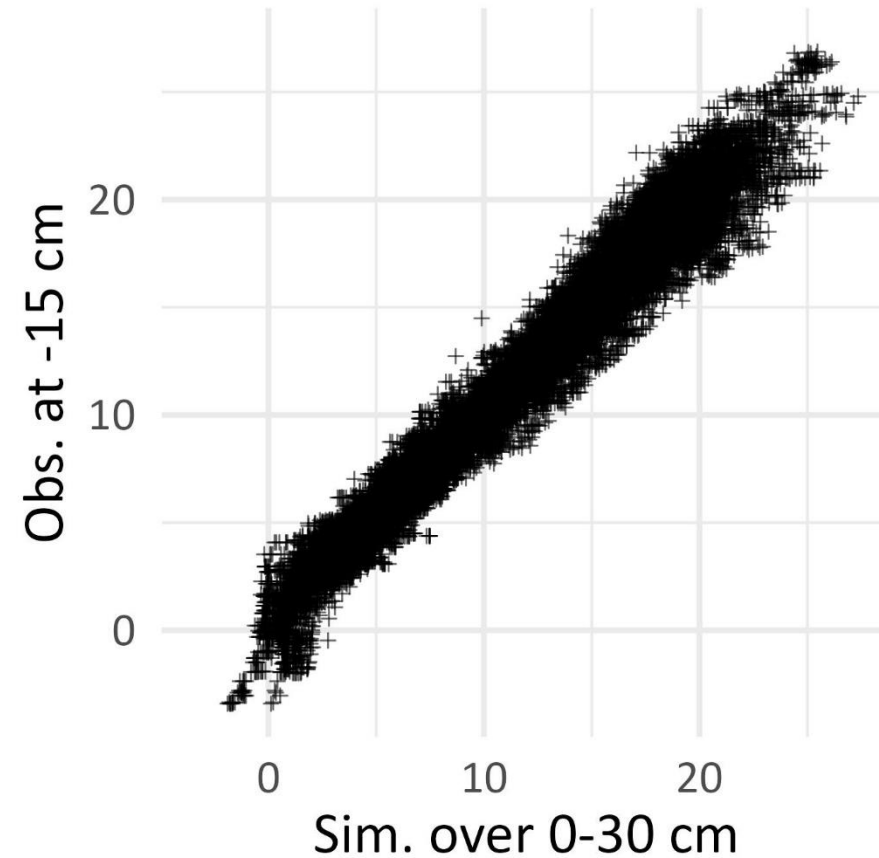
- Default parameters
- Gap in the order of magnitude of N₂O emissions → find a value for **vpotdenit** (kg_N.ha⁻¹.day⁻¹ over 0-20 cm) yielding in close cumulative emissions for CONV

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

➤ Method - Simulation assessment and errors

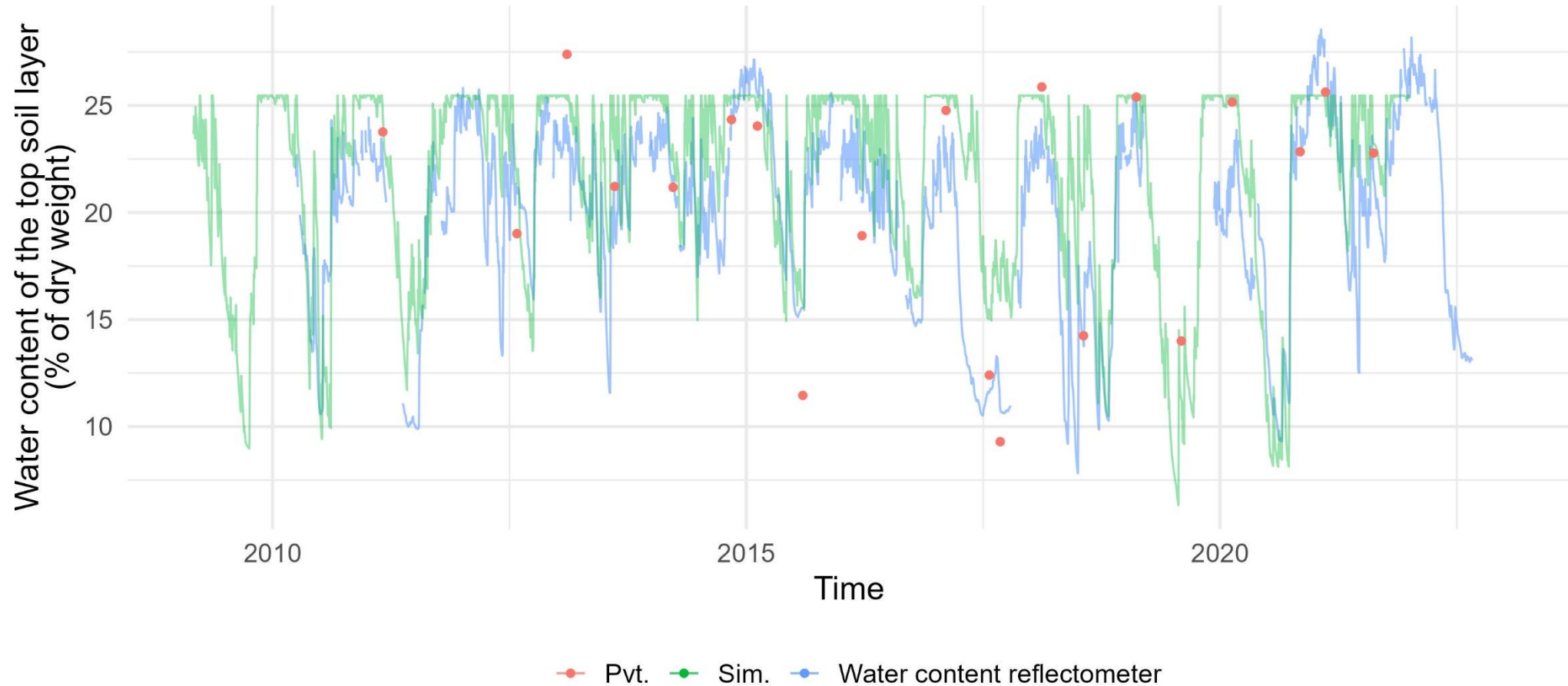
- Variables of interest
 - Soil moisture, temperature, $[\text{NH}_4^+]$ and $[\text{NO}_3^-]$ + N_2O emissions
- Simulations assessment
 - Simulations vs Observations: scatterplot, temporal dynamic, cumulatives, standard indicators (R^2 , RMSE)
- Describe prediction error
 - Is the difference between 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 N₂O drivers



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

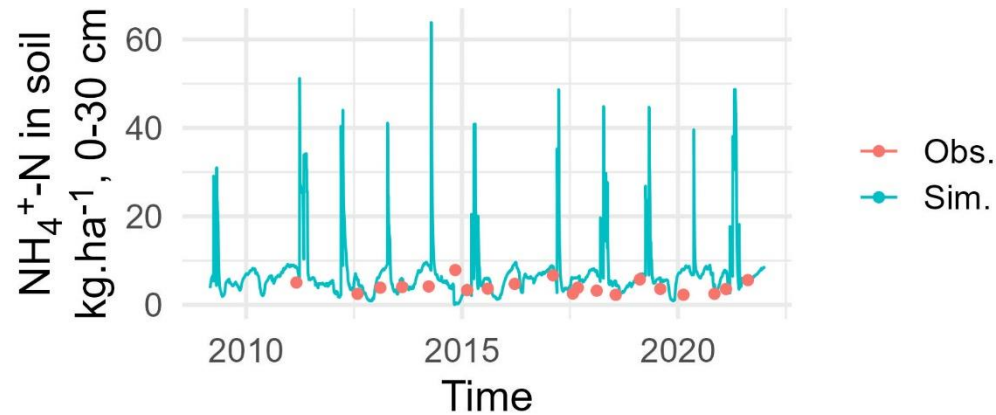
➤ Results – Simulation of N₂O drivers



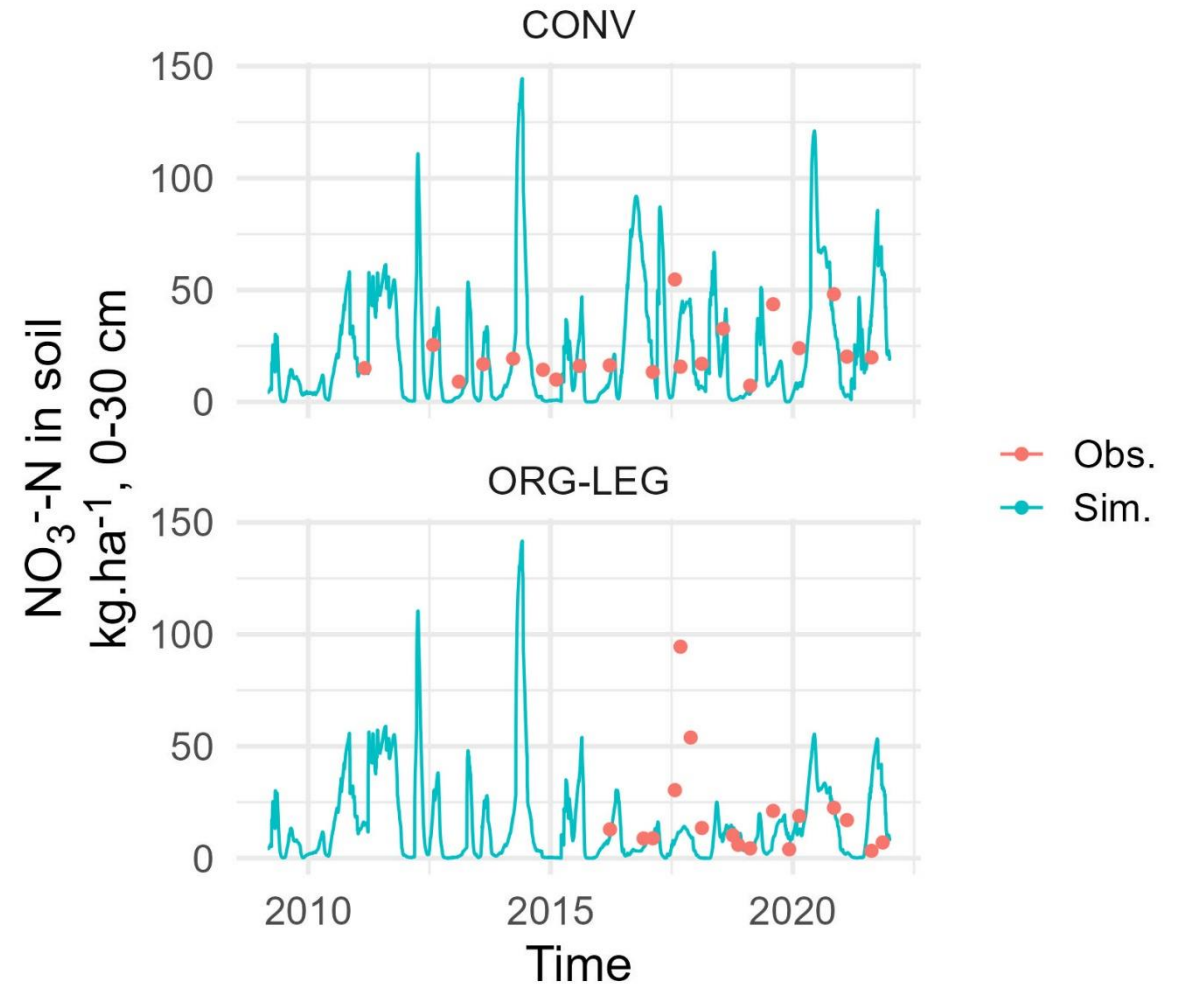
Comparison of three data sources for the estimation of the topsoil water content of the CONV treatment

➤ Results – Simulation of N₂O drivers

NH₄⁺ and NO₃⁻



Ammonium-nitrogen in soil through time for the CONV treatment

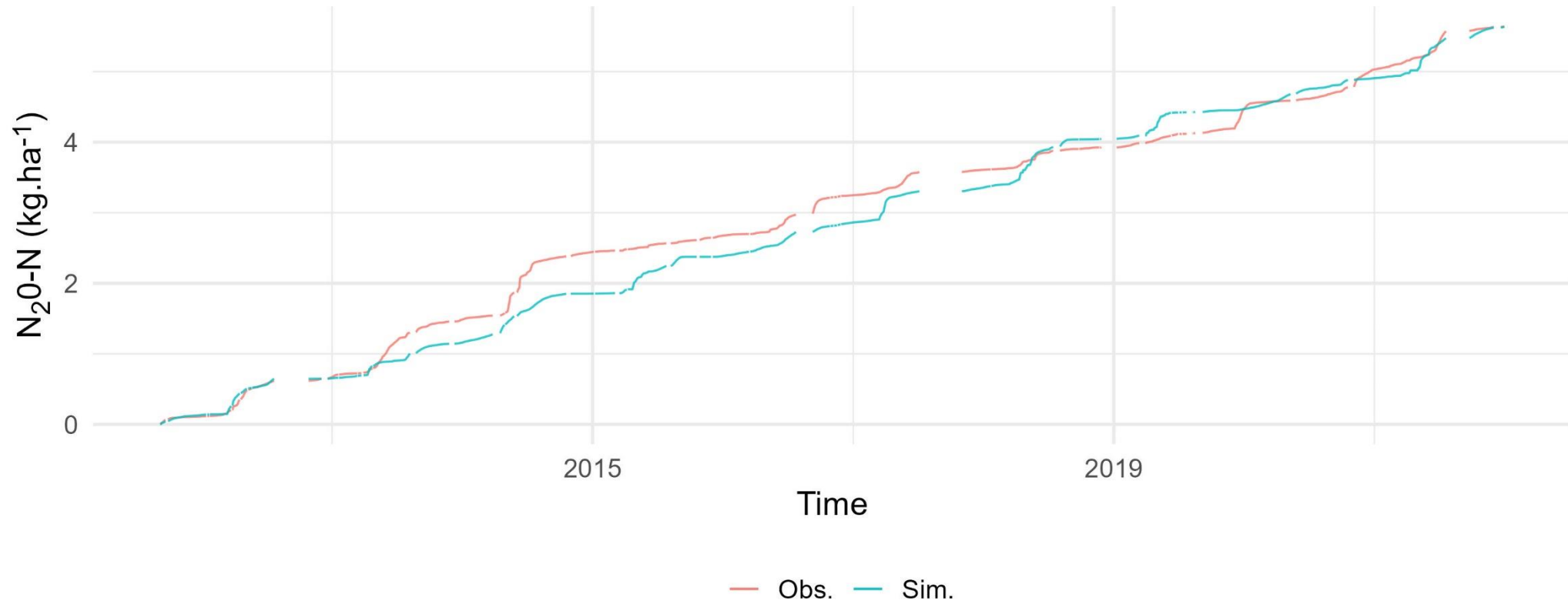


Nitrate-nitrogen in soil through time for the CONV and the ORG-LEG treatments



➤ Results – Adjusting the value of vpotdenit

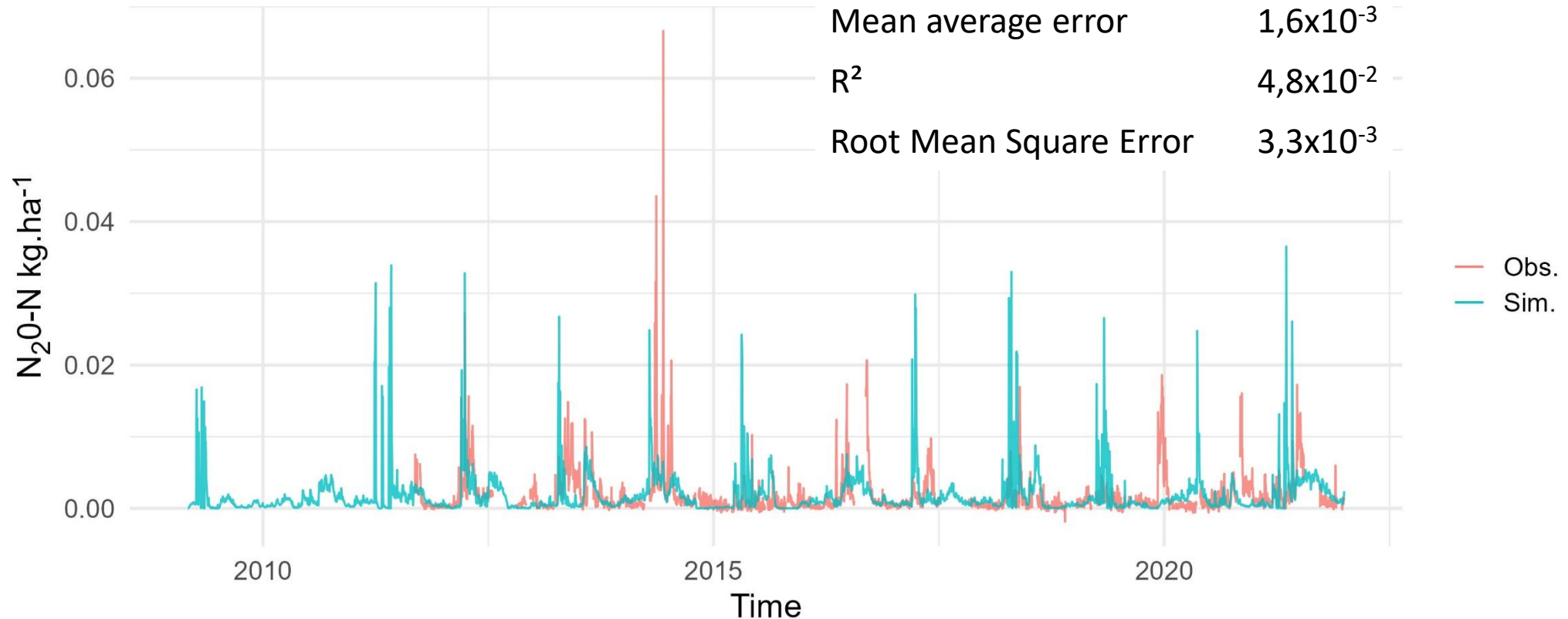
$v_{potdenit_s} = 0.07 \text{ kg}_N \cdot \text{ha}^{-1} \cdot \text{day}^{-1}$ over 0-20 cm (default is 2)



Cumulated N₂O-N emissions for the CONV treatment using $v_{potdenit} = 0,07$

➤ Results – Simulations of N₂O emissions

$v_{potdenit_s} = 0.07 \text{ kg}_N \cdot \text{ha}^{-1} \cdot \text{day}^{-1}$ over 0-20 cm (default is 2)

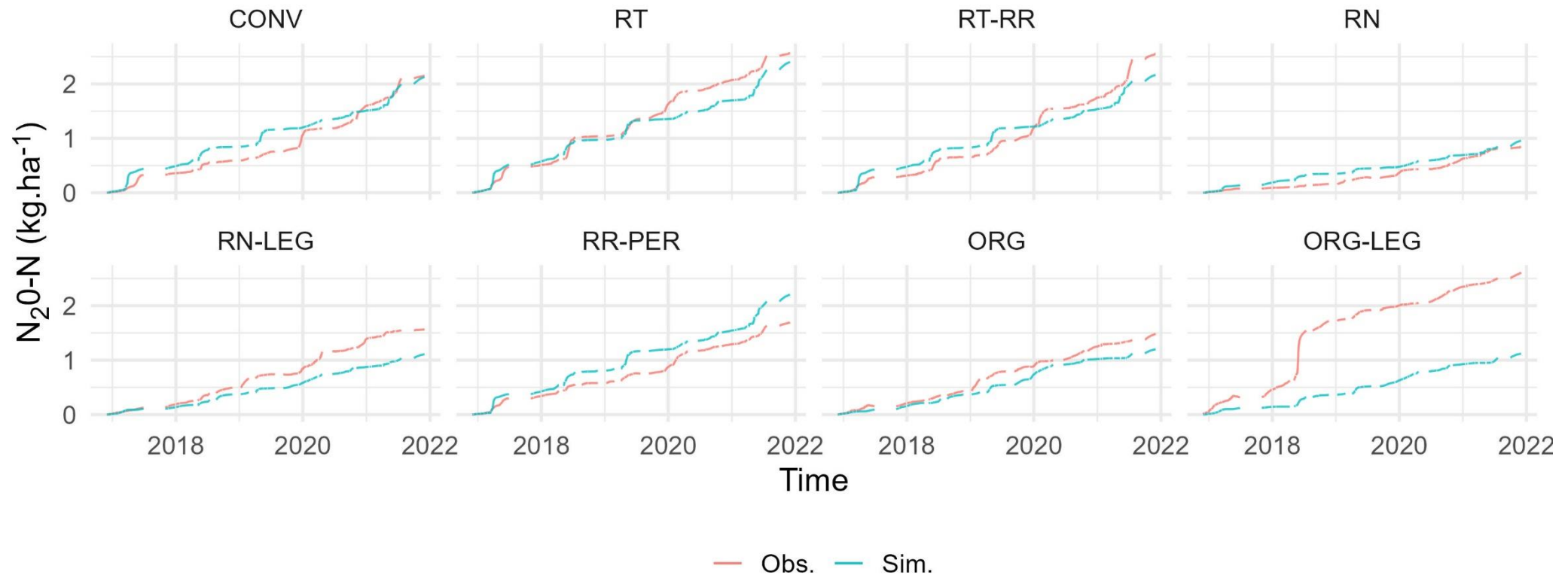


Observed and simulated N₂O-N emissions through time for the CONV treatment



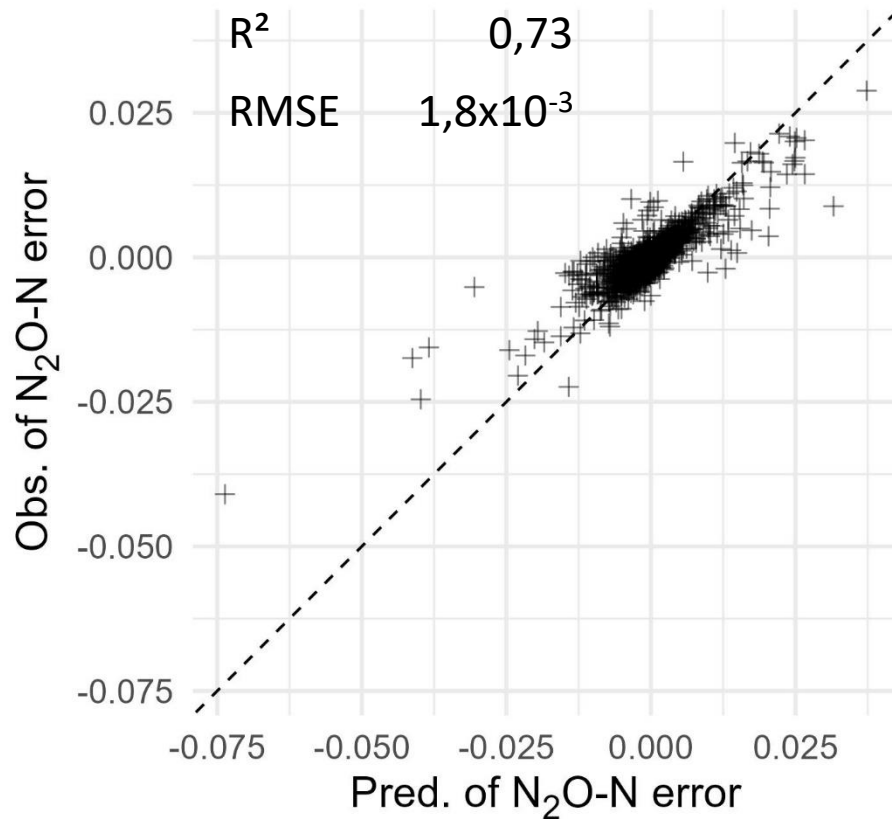
➤ Results – Simulations of N₂O emissions

$v_{potdenit_s} = 0.07 \text{ kg}_N \cdot \text{ha}^{-1} \cdot \text{day}^{-1}$ over 0-20 cm (default is 2)



Cumulated N₂O-N emissions for all treatments

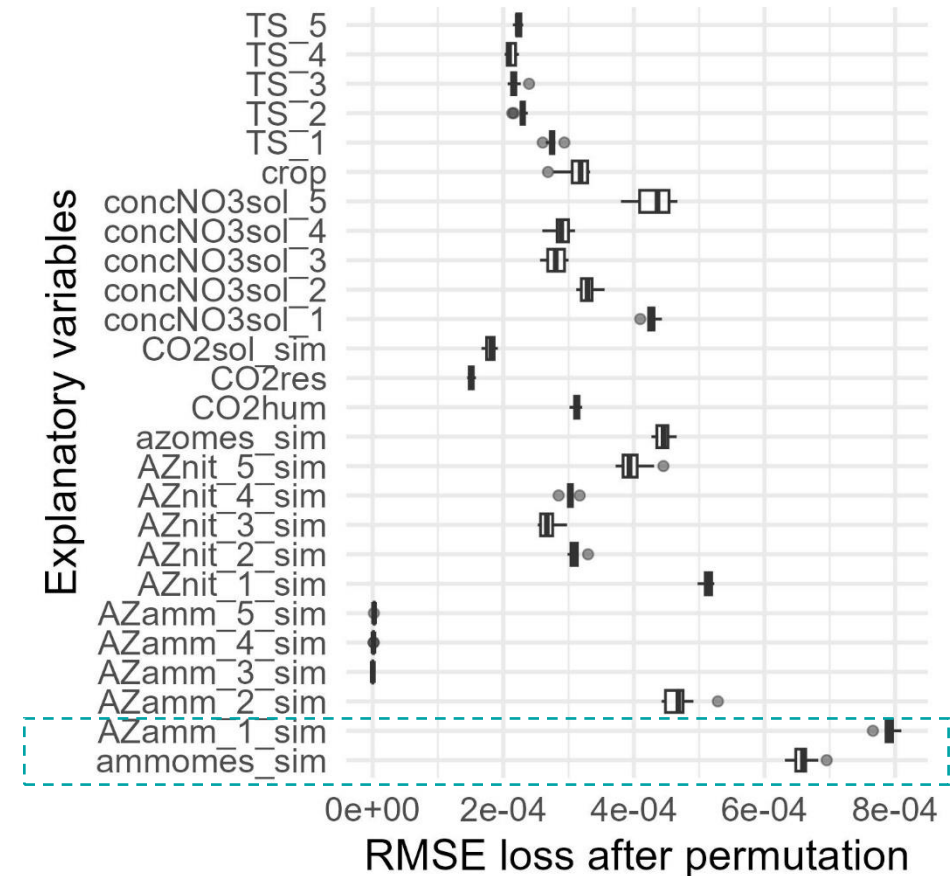
➤ Result – Predict STICS error on N₂O emissions



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

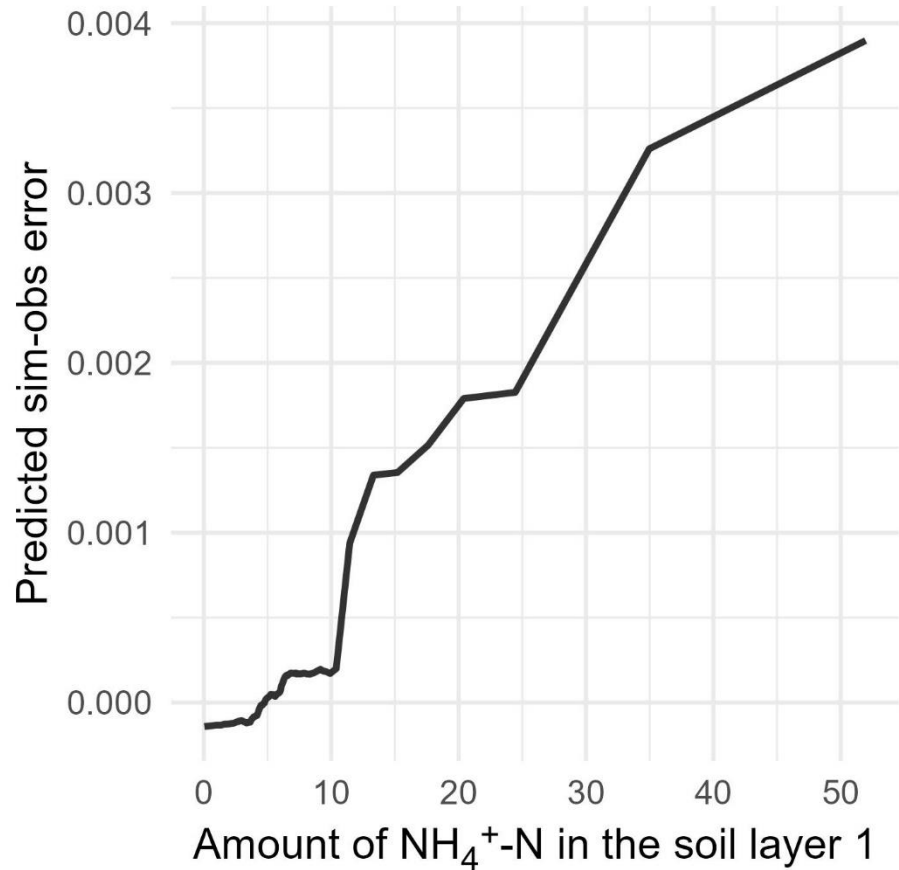
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2023-11-15 / Paul Belleville



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 N₂O emissions drivers
 - Soil temperature and soil moisture are considered as good enough
 - [NO₃⁻] is treatment-dependent
 - [NH₄⁺] is good for low concentration values but unknown for high concentration values.
- Simulation of N₂O
 - Despite bad R², 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 NH₄⁺ is the main variable contributing to the random forest

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➤ Thank you for your attention!

5 mins for questions