

XIVth STICS seminar, 17-19 March 2026
organized by ULiege-GxABT & INRAE



Evaluation of STICS performance for predicting C and N mineralization kinetics and N₂O emissions from contrasted litter types on urban lawn soils

Hugues Clivot^{1,}, Tom Künnemann², Guillaume Humbert¹, Joël Léonard³,
Gonzague Alavoine¹, Patrice Cannavo², Gwenaëlle Lashermes¹*

¹Université de Reims Champagne-Ardenne, INRAE, FARE, UMR A 614, Reims, France

²Institut Agro, EPHOR, Angers, France

³BioEcoAgro Joint Research Unit, INRAE, Barenton-Bugny, France

* hugues.clivot@univ-reims.fr



Context



- **Urban green spaces (UGSs)** can play a key role in urban sustainability by providing services such as carbon (C) storage, biodiversity conservation and urban cooling
- Lawns represent a significant proportion of UGSs worldwide and can receive a **diversity of litter types** that can be exported instead of recycled into the soils

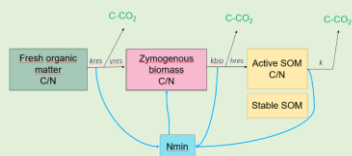


- Recycling this litter could improve **soil organic status and fertility**, but it may also present some potential risks of **N₂O emissions**

Context and objectives

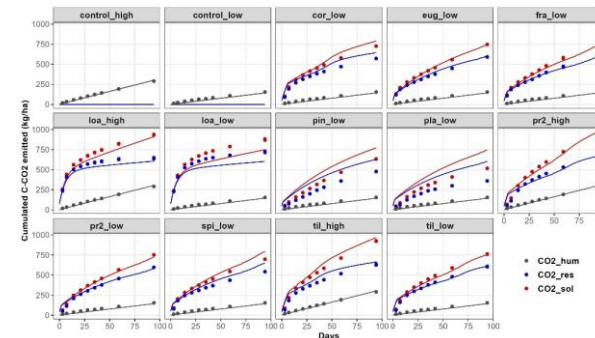
- N_2O emissions and Nitrogen (N) and C mineralization kinetics following litter restitution into the soil are known to vary with **litter biochemical characteristics**, notably **N and soluble contents** and **C:N ratio** of crop residues being relatively good predictors of:
 - N_2O emissions (Abalos *et al.*, 2022 ; Lashermes *et al.*, 2022)
 - N and C mineralization (Nicolardot *et al.*, 2001 ; Justes *et al.*, 2009)
- Less is known about UGSs, which harbour a great diversity of plants and soils under contrasted management practices

➤ **Objectives:** evaluating the genericity and robustness of STICS formalisms to simulate C and N mineralization kinetics and N_2O emissions of biochemically diverse litter types decomposing on lawn soils



Methods

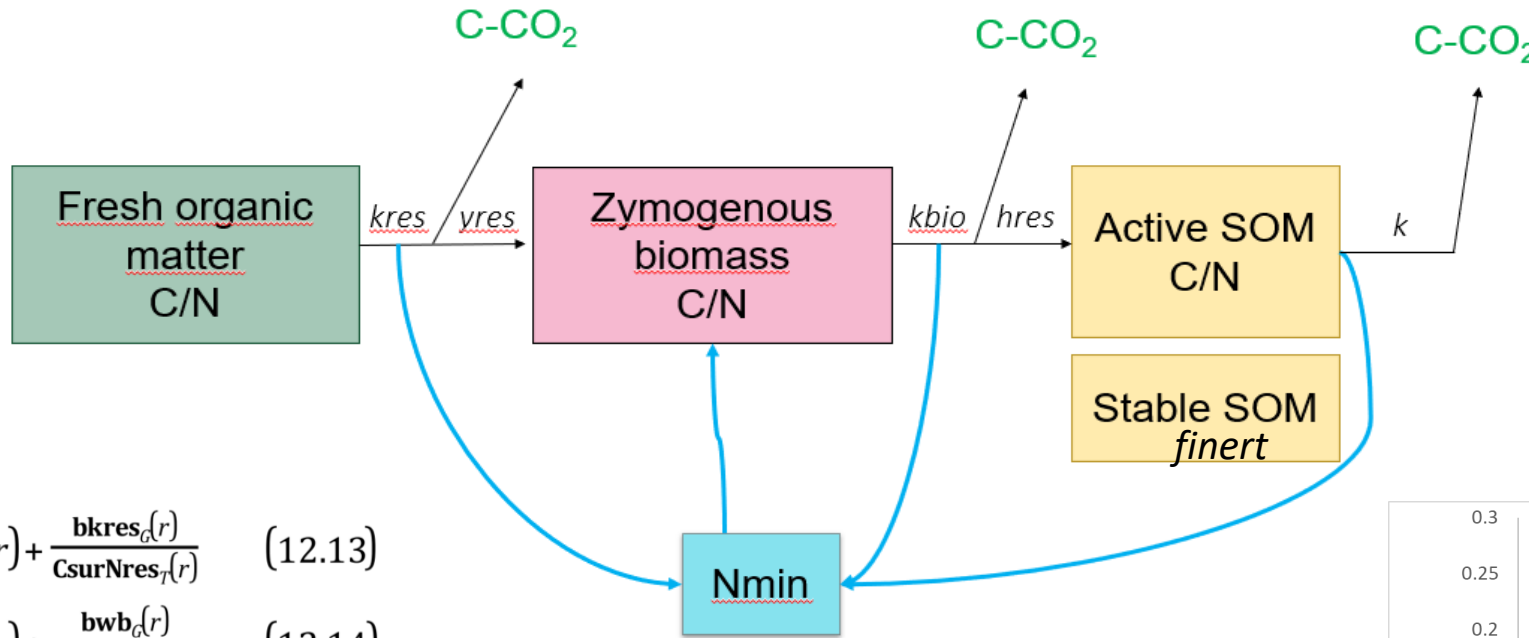
- **2 soil incubation experiments** under controlled conditions in the lab:
 - **9 different aerial litter types** from UGSs
 - **2 lawn soils** representative of 2 management practices
 - **Exp1.** CO₂ and soil N mineral dynamics for **litters mixed with the soils**
 - **Exp2.** CO₂, N₂O and N mineral in soil with **litters on the soil surface**
- Simulations with **STICS v10.5**
- **Evaluation** of simulations vs observed data
- Identification of **potential areas for improvement**



STICS residue and SOM submodel

Residue formalisms: Nicolardot *et al.* 2001, Justes *et al.* 2009

Submodel based on the C/N ratio of crop residues



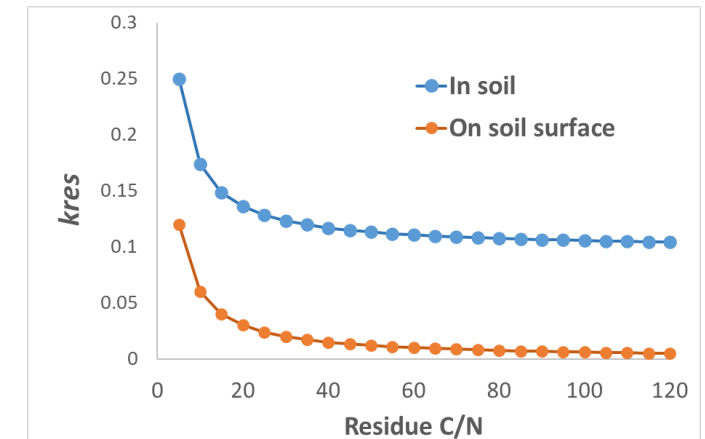
$$kres(r) = akres_G(r) + \frac{bkres_d(r)}{CsurNres_7(r)} \quad (12.13)$$

$$CNbio(r) = awb_G(r) + \frac{bwb_d(r)}{CsurNres_7(r)} \quad (12.14)$$

$$hres(r) = 1 - ahres_G(r) \cdot \frac{CsurNres_7(r)}{bhres_d(r) + CsurNres_7(r)} \quad (12.15)$$

$$\Delta Cres(z, t, r) = -kres(r) \cdot Cres(z, t, r) \cdot ftr(z, t) \cdot fh(z, t) \cdot fredkN(z, t) \quad (12.16)$$

Beaudoin *et al.* 2023. STICS soil-crop model: conceptual framework, equations and uses

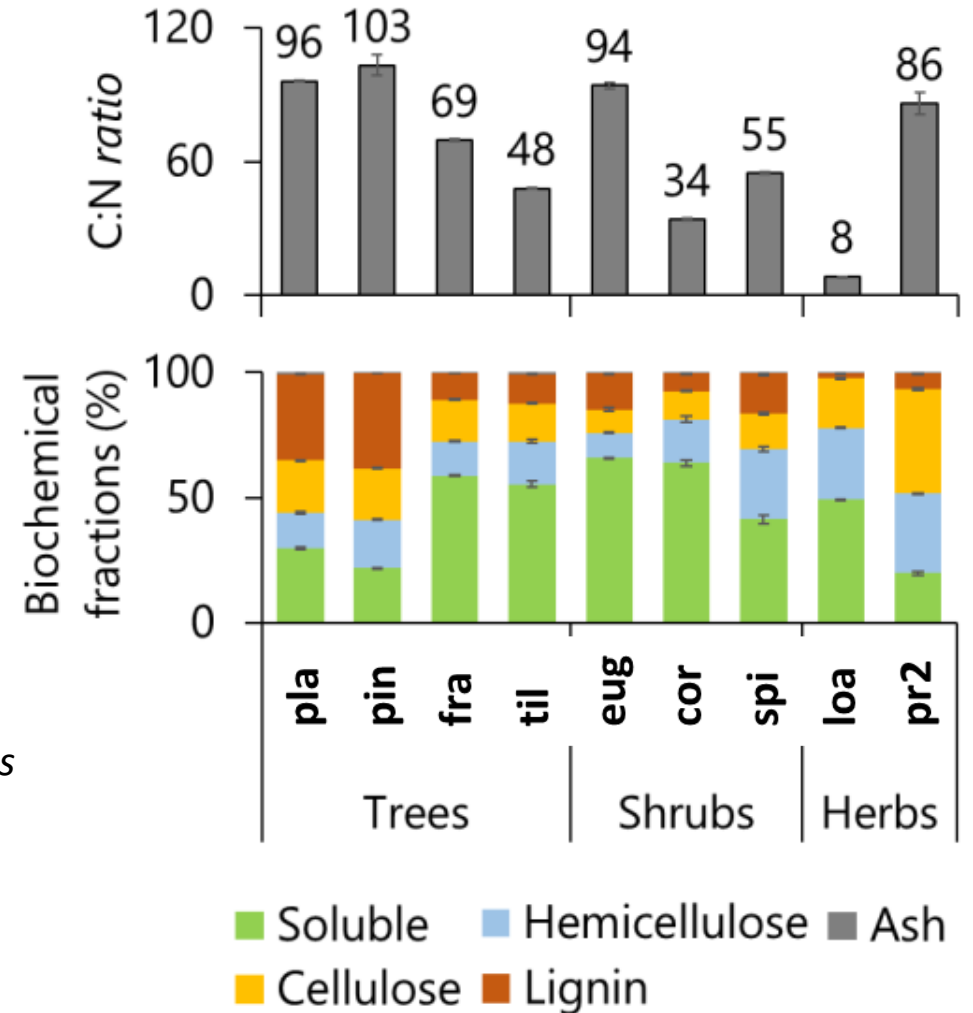


Litter biochemistry



pla: *Platanus × acerifolia*
pin: *Pinus radiata*
fra: *Fraxinus angustifolia*
til: *Tilia × europaea*
eug: *Euonymus grandifloras*
cor: *Cornus alba*
spi: *Spiraea vanhouttei*
loa: *Lolium arundinaceum*
pr2: *Meadow mix*

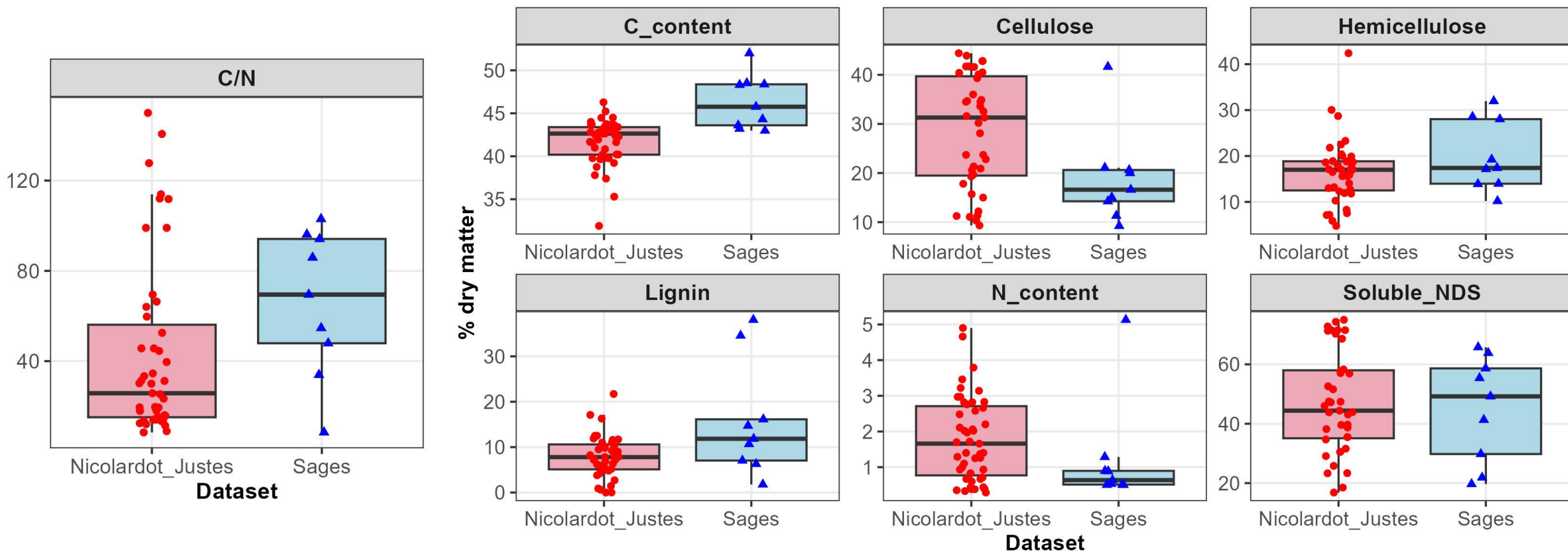
Contrasted biochemistry



Litter biochemistry

Comparison vs Nicolardot et al. 2001, Justes et al. 2009

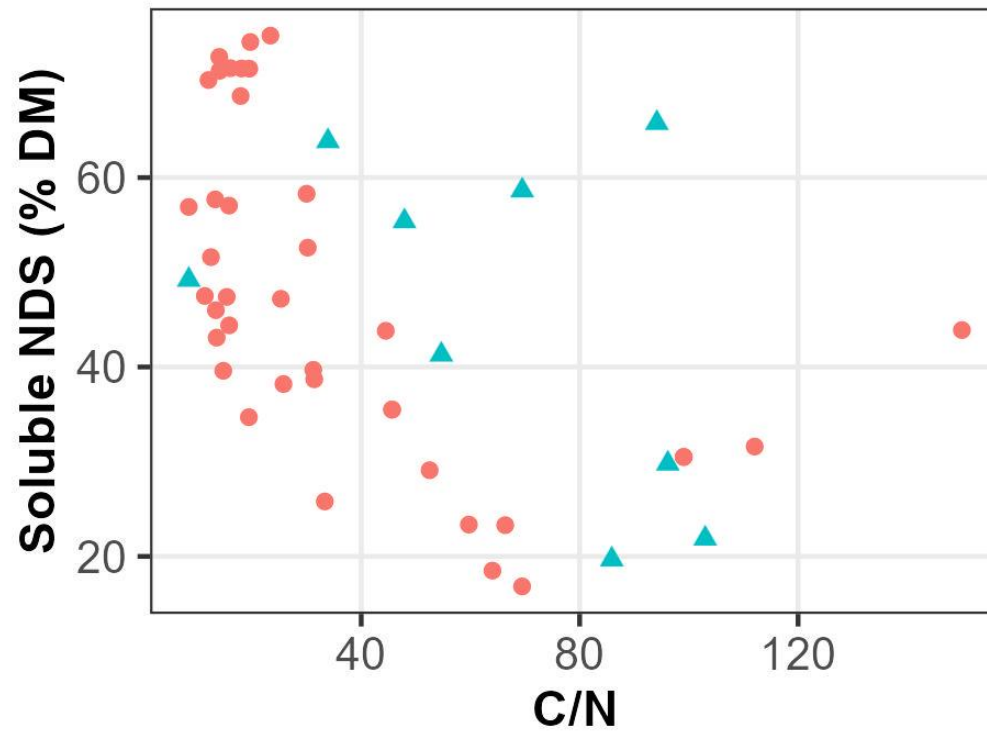
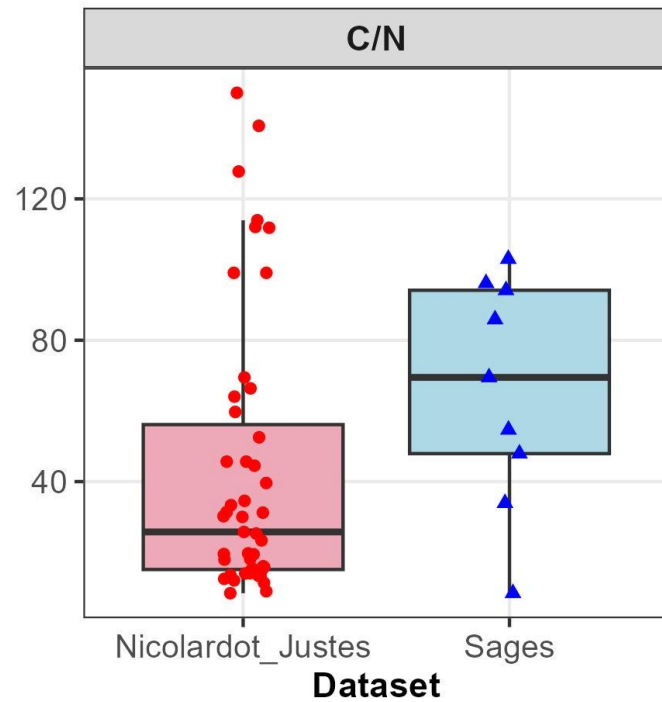
2 litters with high lignin content (pla & pin), 1 litter with high N content (loa)



Litter biochemistry

Comparison vs Nicolardot et al. 2001, Justes et al. 2009

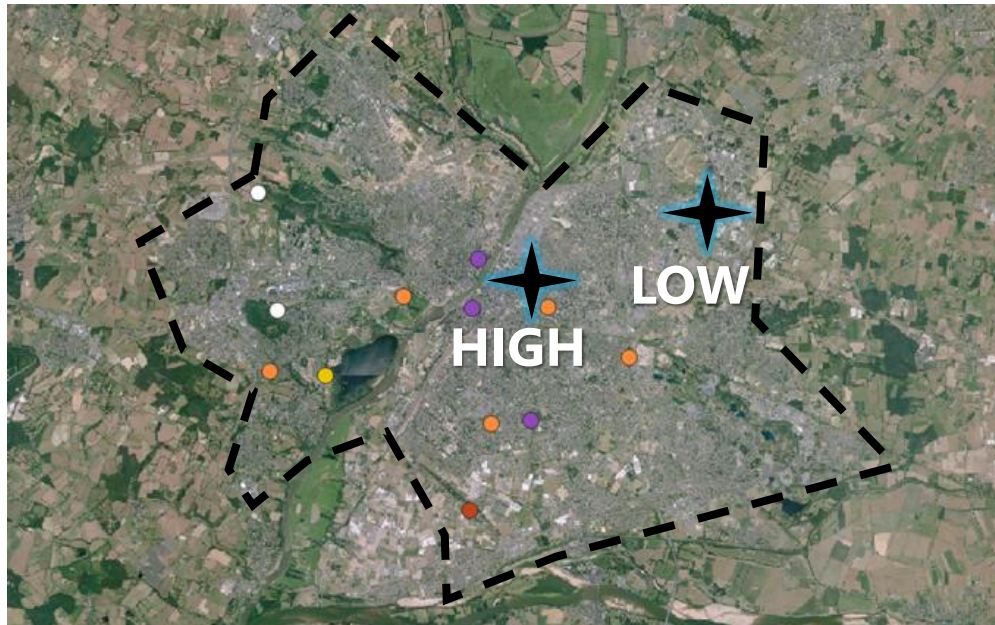
Some litters with high soluble content and low N content



- Nicolardot_Justes
- ▲ Sages

Soils

Collected in **Angers**, the “greenest” city of France (102 m² of UGS per inhabitant)



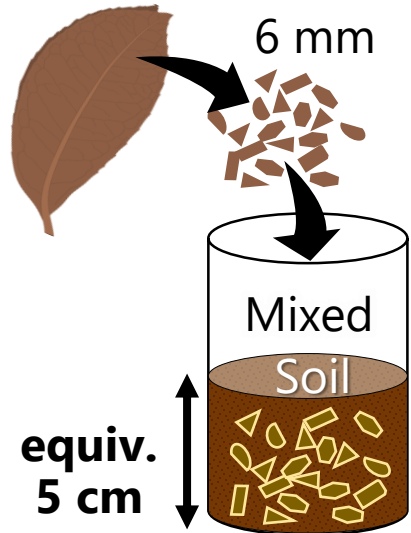
Representative of global UGS management practices (Ignatieva et al. 2020; Watson et al., 2020)



Org. C	1.8	5.9	%
Mic. Biom. C	0.35	1.60	g kg ⁻¹
Tot. N	0.2	0.5	%
C/N	10	12	
N-NO ₃ ⁻	9.0	20	mg kg ⁻¹
N-NH ₄ ⁺	0.2	0.2	mg kg ⁻¹
Olsen P	12	73	mg kg ⁻¹
pH	5.8	6.7	
Density	1.4	0.8	g cm ⁻³
Water retention	22	71	g H ₂ O g ⁻¹ at pF 2
Sandy loam		Sandy loam	

Microcosm

3 T DM ha⁻¹
of litter



Soil at *in situ* densities

Temperature : 15°C

Moisture at pF 2.9
~ 80% field capacity

94 days

Exp.1 : Incubation of 9 litters in soil "low" and a subset of 3 litters in soil "high"

CO₂ release

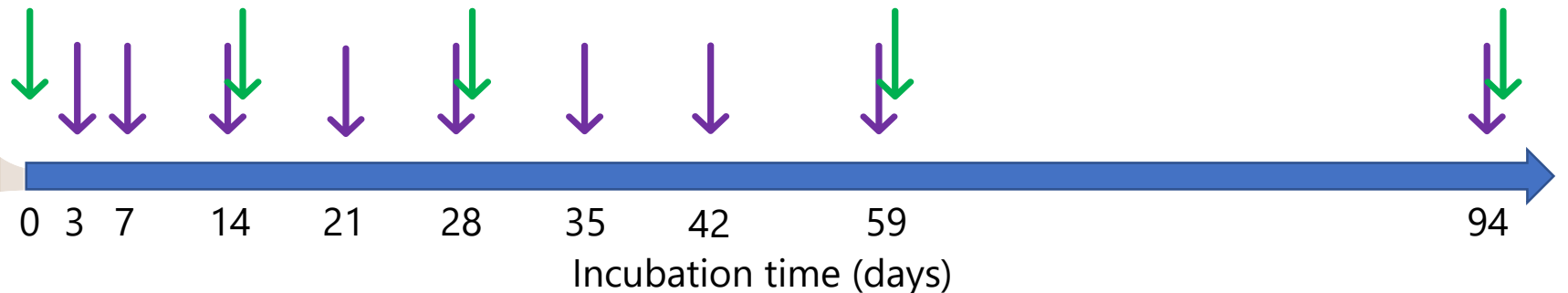
NaOH traps and continuous
flow colorimetry

9 measurements

Mineral N dynamic

NH₄⁺, NO₃⁻ extractions
with KCl

5 measurements

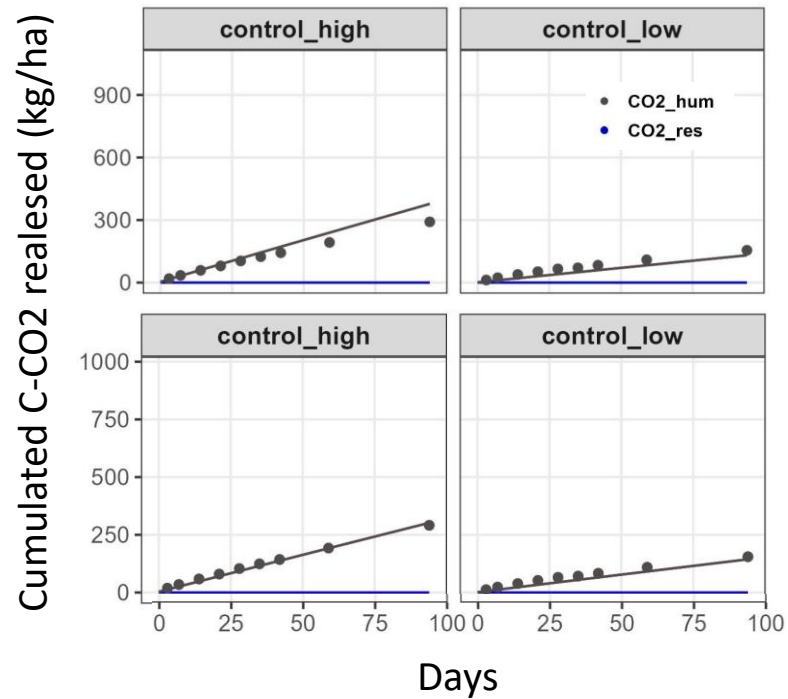


C & N mineralization kinetics (Exp 1)

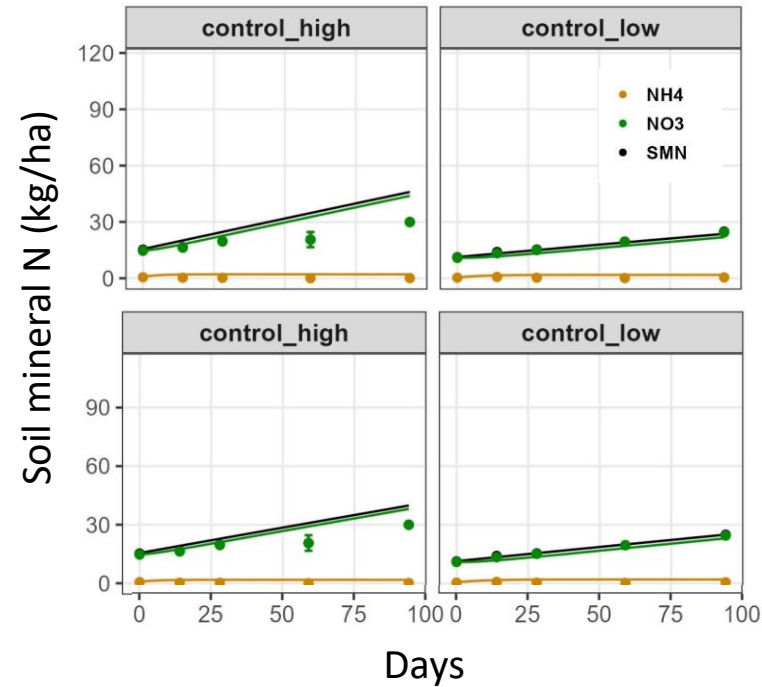
→ Control soils

Relatively good
default simulations of
SOM mineralization

C-CO₂ dynamics



Soil mineral N dynamics

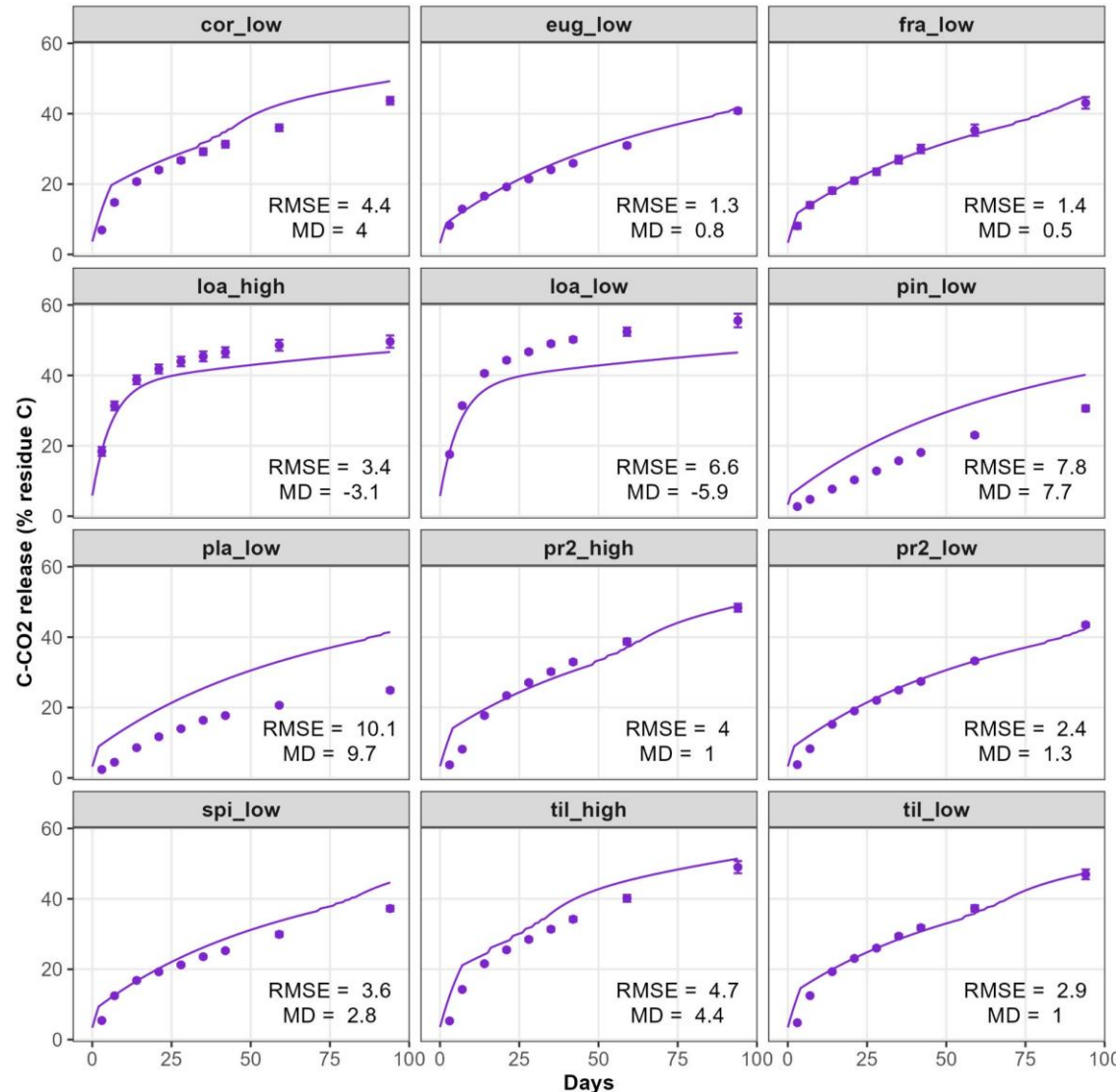


Default simulations
finert = 0.40

Simulations
finert optimized
(Coptimizer)
high = 0.52
low = 0.34

C mineralization kinetics (Exp 1)

Relatively good simulations of mineralized C on average 2 litters with overestimated decomposition (pin & pla) and 1 underestimated (loa)



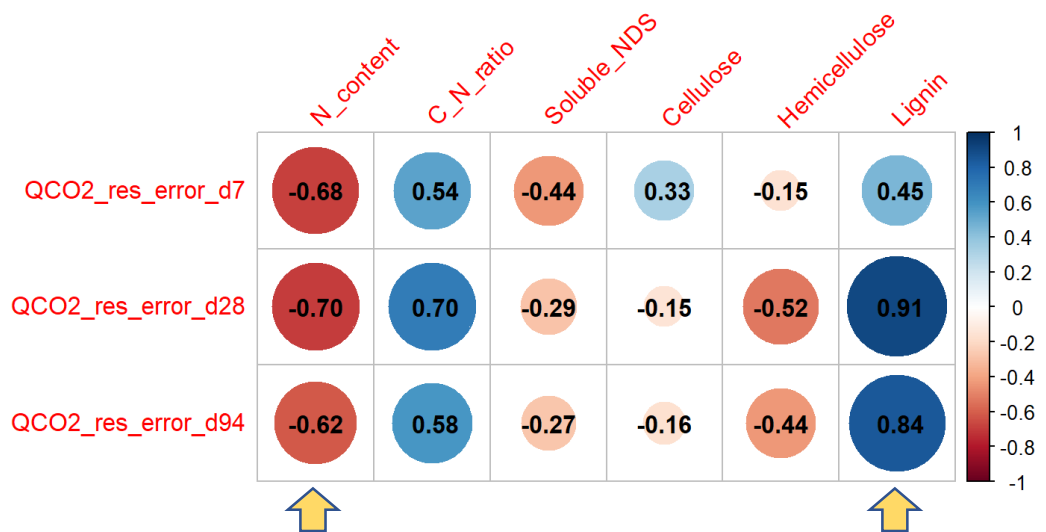
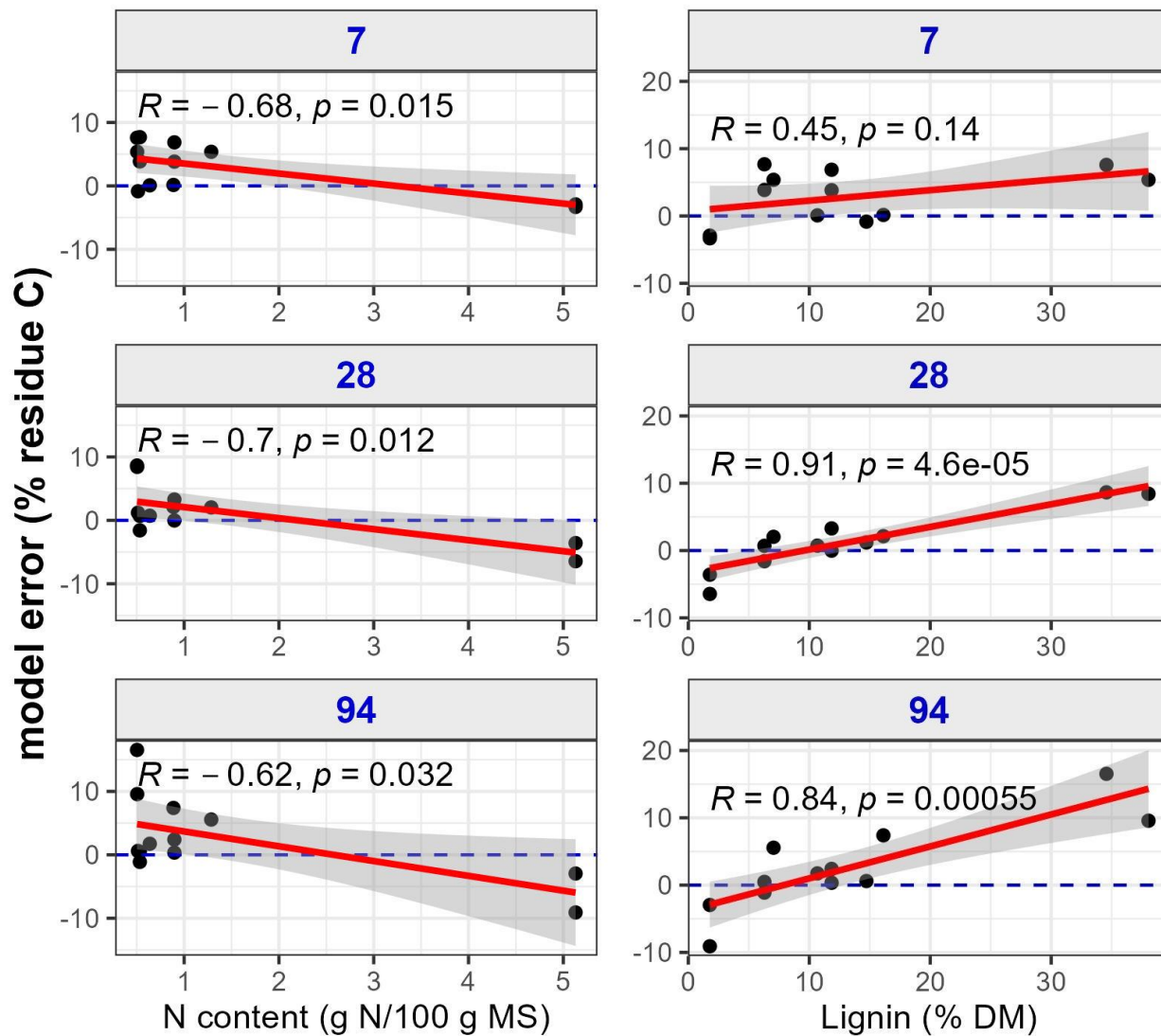
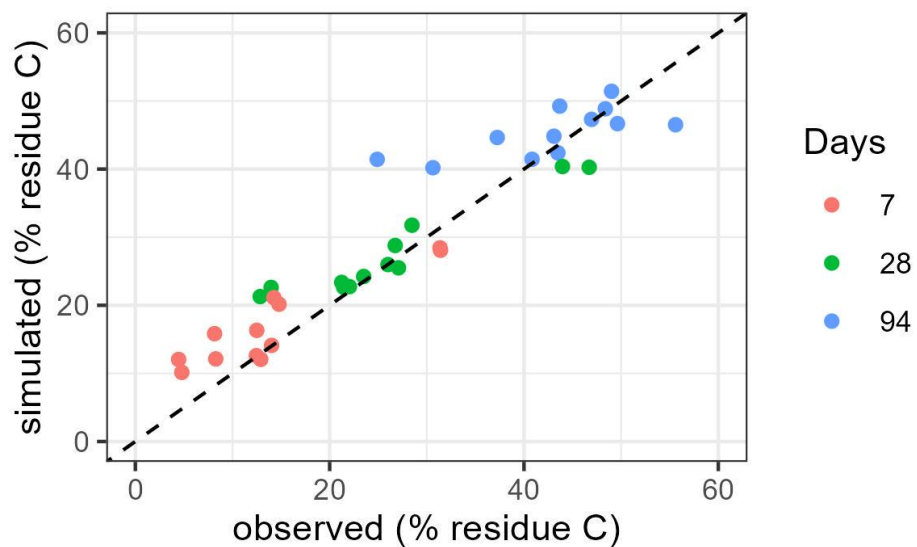
Apparent C-CO₂ dynamics (Soil+Litter – Control Soil)

RMSE = 4.4 & MD = 2.0 (sim-obs)
C release (% residue C)

vs RMSE = 5.9 and MD = 0.6
in Justes *et al.* 2009

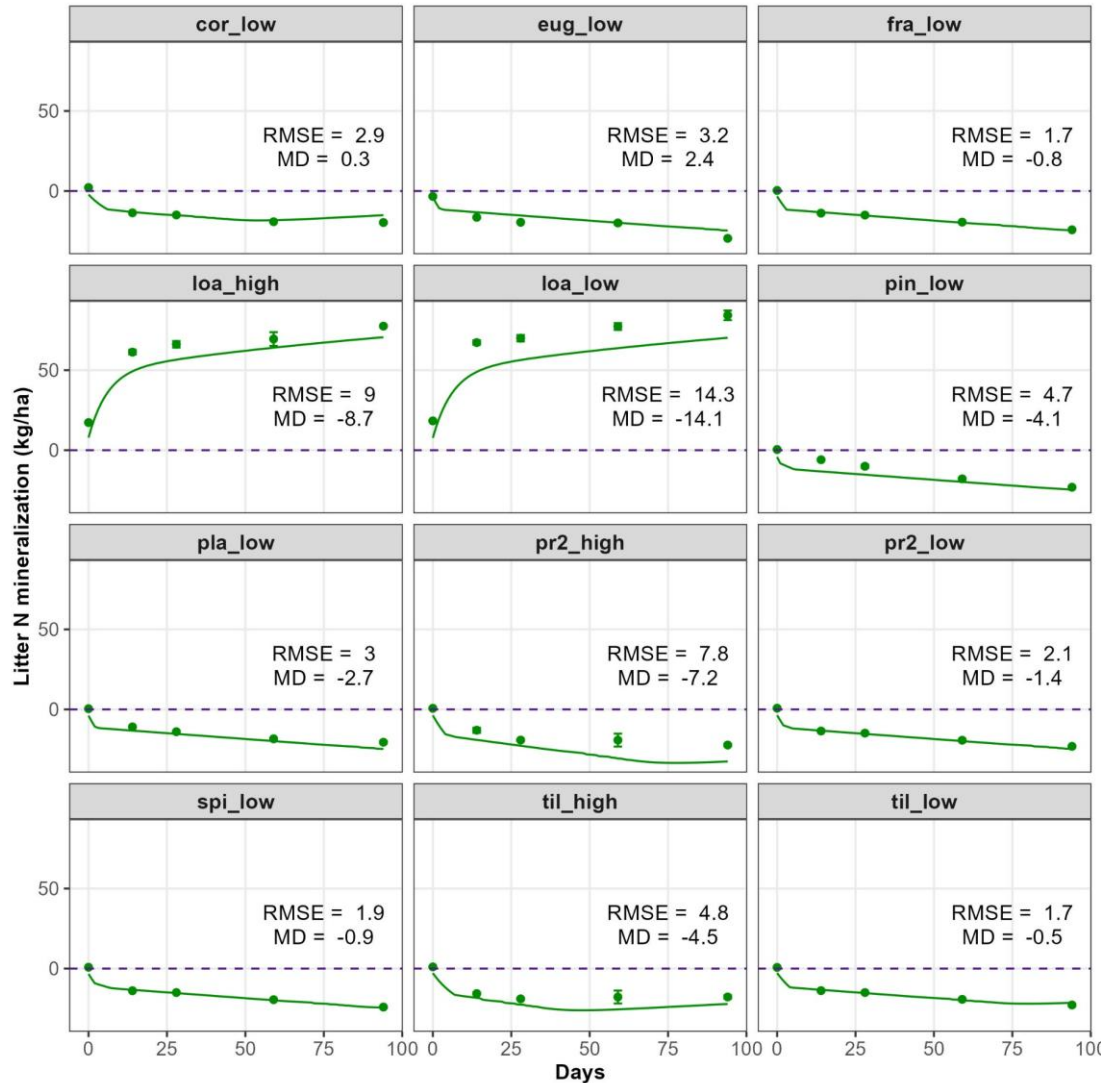
C mineralization kinetics (Exp 1)

Model error for C mineralization well correlated with litter lignin content



N mineralization kinetics (Exp 1)

Relatively good simulations of apparent N immobilization and net release



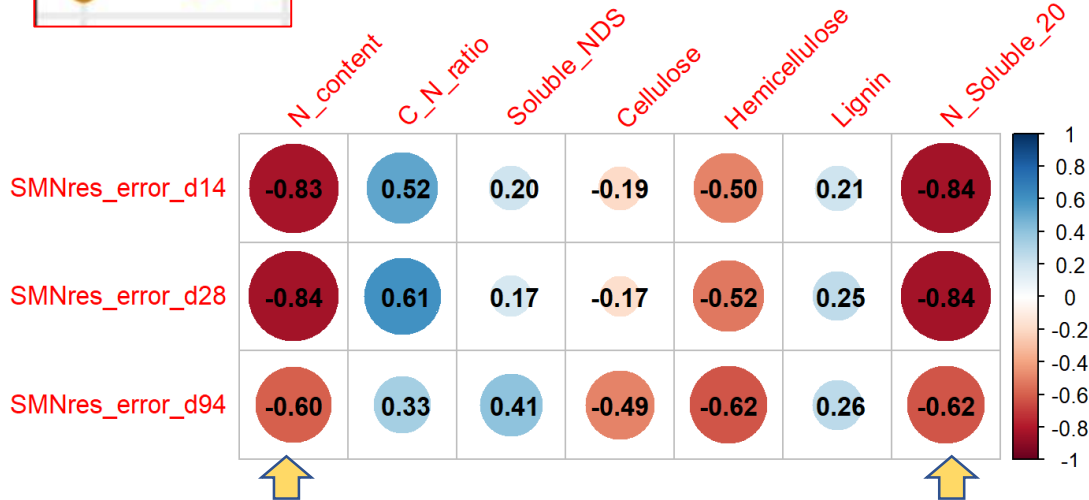
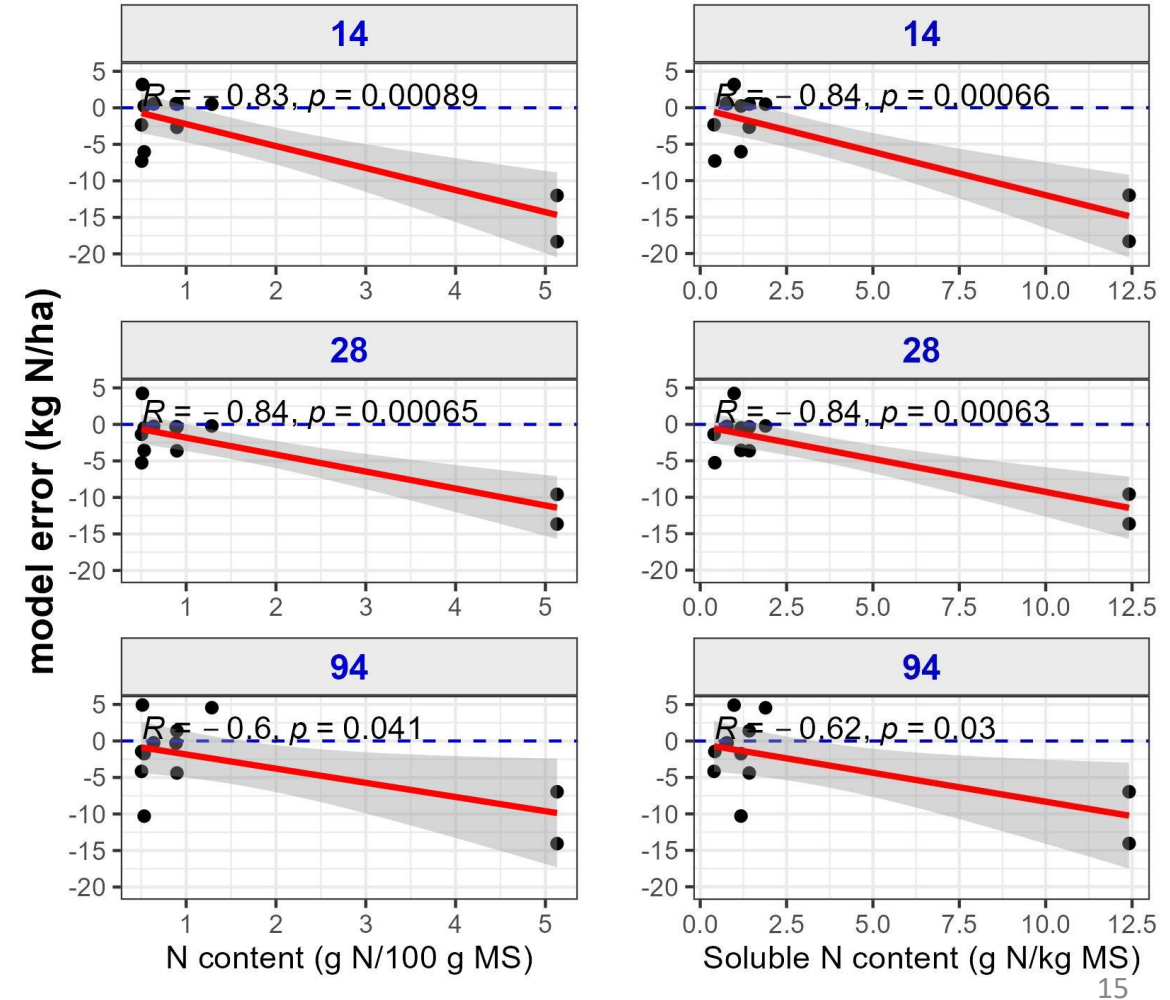
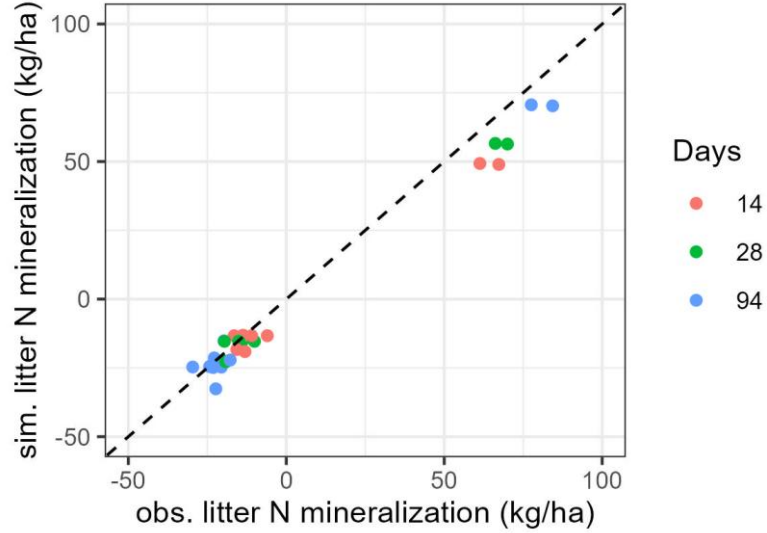
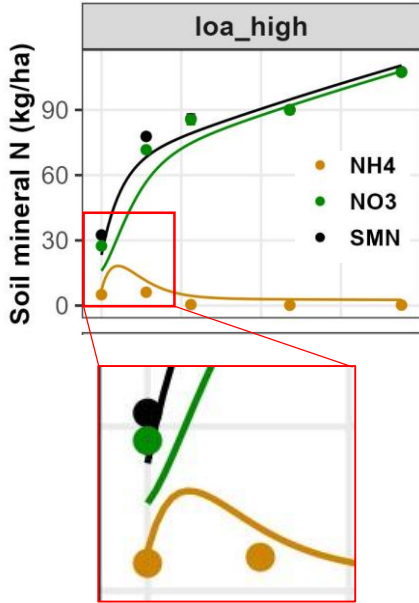
Apparent N mineralization
(Soil+Litter – Control Soil)

RMSE = 4.8 & MD = -3.5 (sim-obs)
(kg N/ha)
RMSE = 8.5 & MD = -6.6
(mg N/kg)

vs RMSE = 8.0 and MD = 2.0
(mg N/kg)
in Justes *et al.* 2009

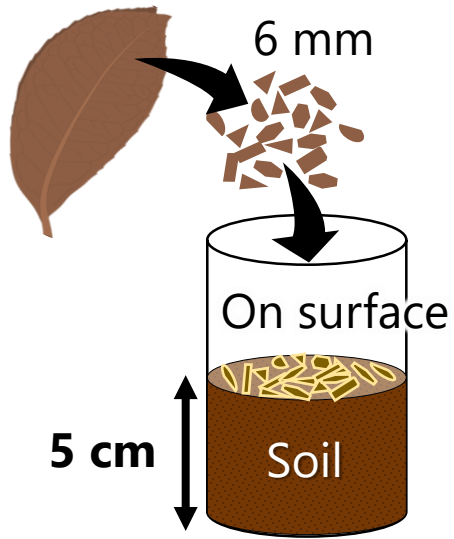
N mineralization kinetics (Exp 1)

Model error for N mineralization well correlated with N content (total and soluble, driven by loa), importance of initial mineral N and forms added with litter



Microcosm

3 T DM ha⁻¹
of litter



Soil at *in situ* densities

Temperature : 15°C

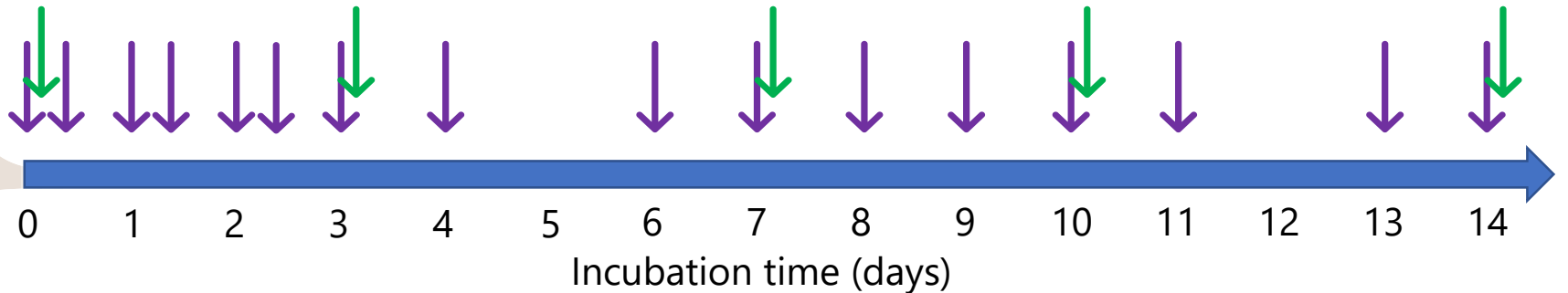
Moisture at pF 2
~ field capacity

14 days

Exp.2 : Incubation of 5 litters with 2 soils

Net CO₂ and N₂O and fluxes
IR analyzer
Frequent measurements

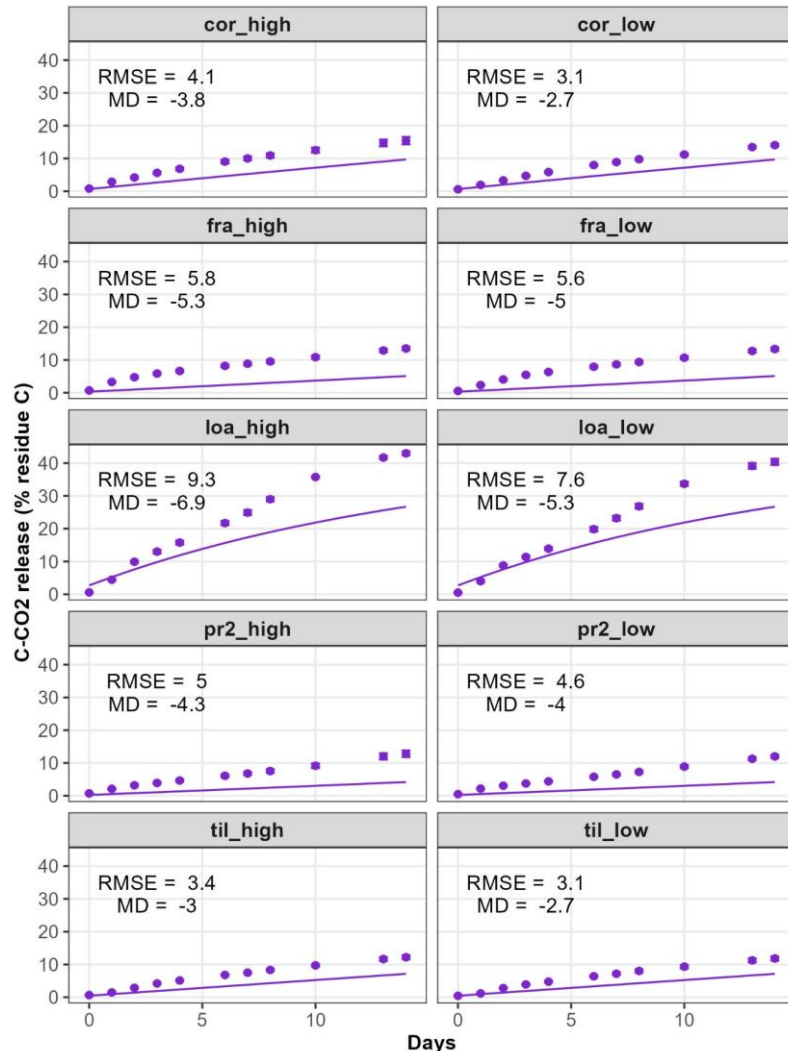
Mineral N dynamic
NH₄⁺, NO₃⁻ extractions
with KCl
5 measurements



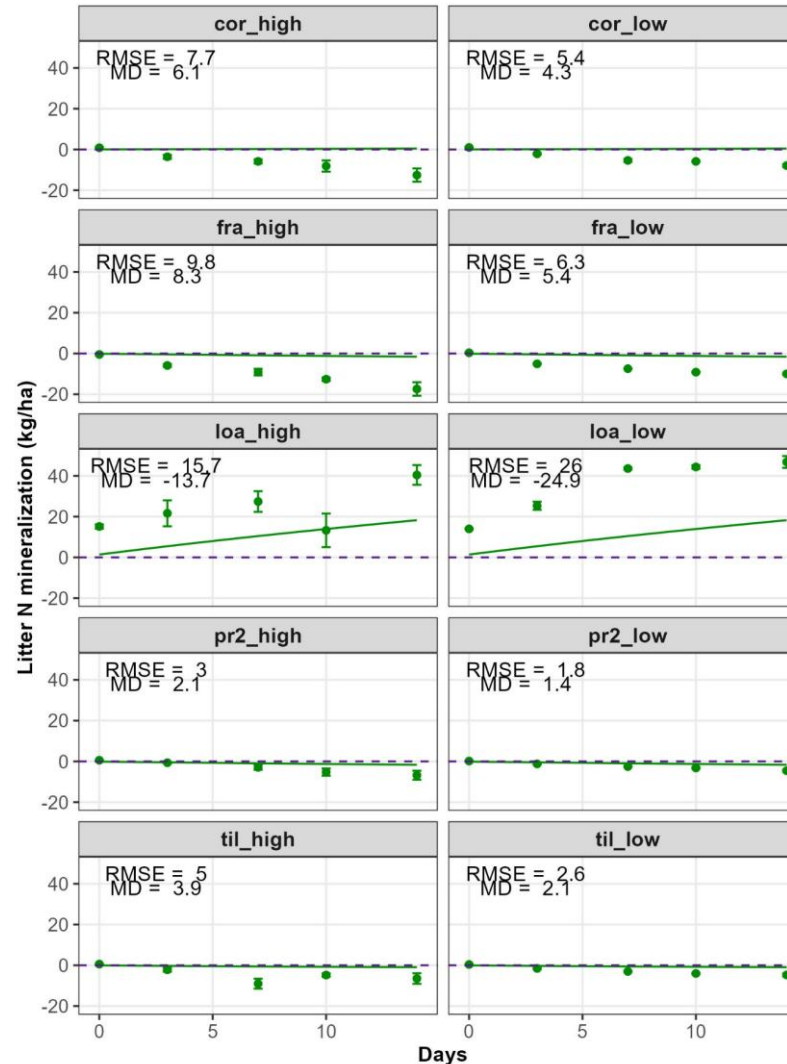
* WFPS = water filled pore space

C & N mineralization kinetics (Exp 2)

Apparent C-CO₂ dynamics



Apparent N mineralization



Underestimation of litter decomposition and associated N immobilization or N release (loa) on soil surface

Sim. settings with all mulch decomposable (qmulchdec) = 3 t DM/ha

Apparent C-CO₂ dynamics

RMSE = 5.2
MD = -4.3 (sim-obs)
 C release (% residue C)

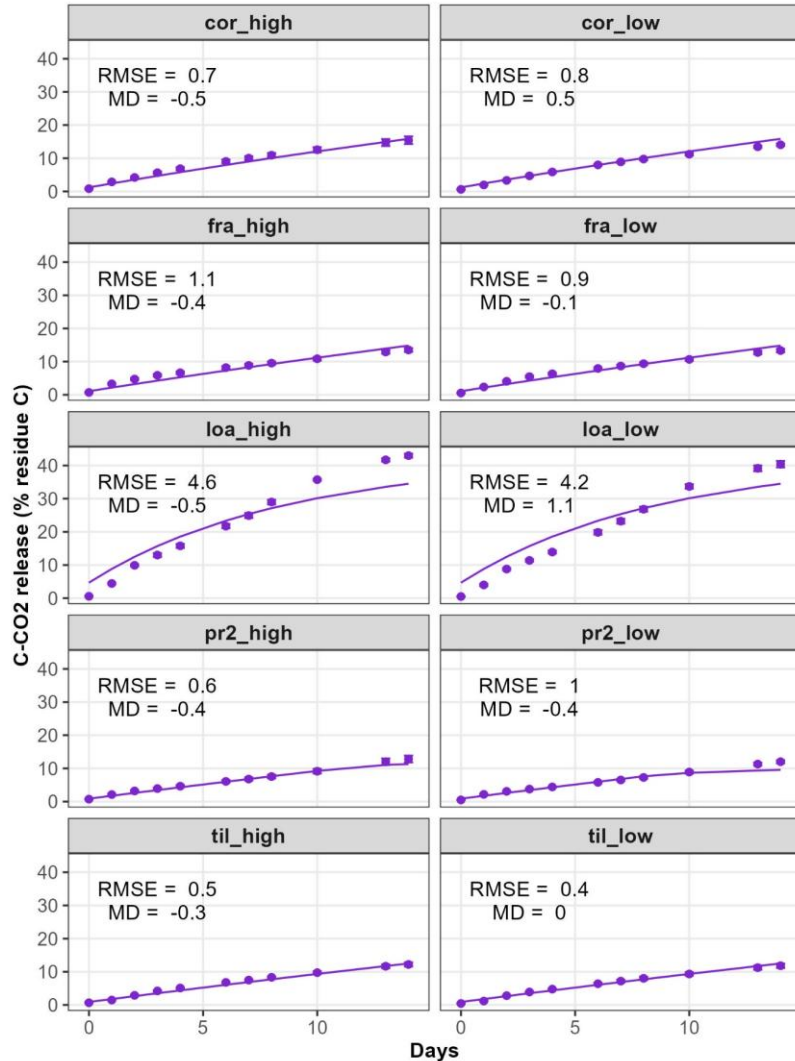
Apparent N mineralization

RMSE = 8.3
MD = -0.5 (sim-obs)
 (kg N/ha)

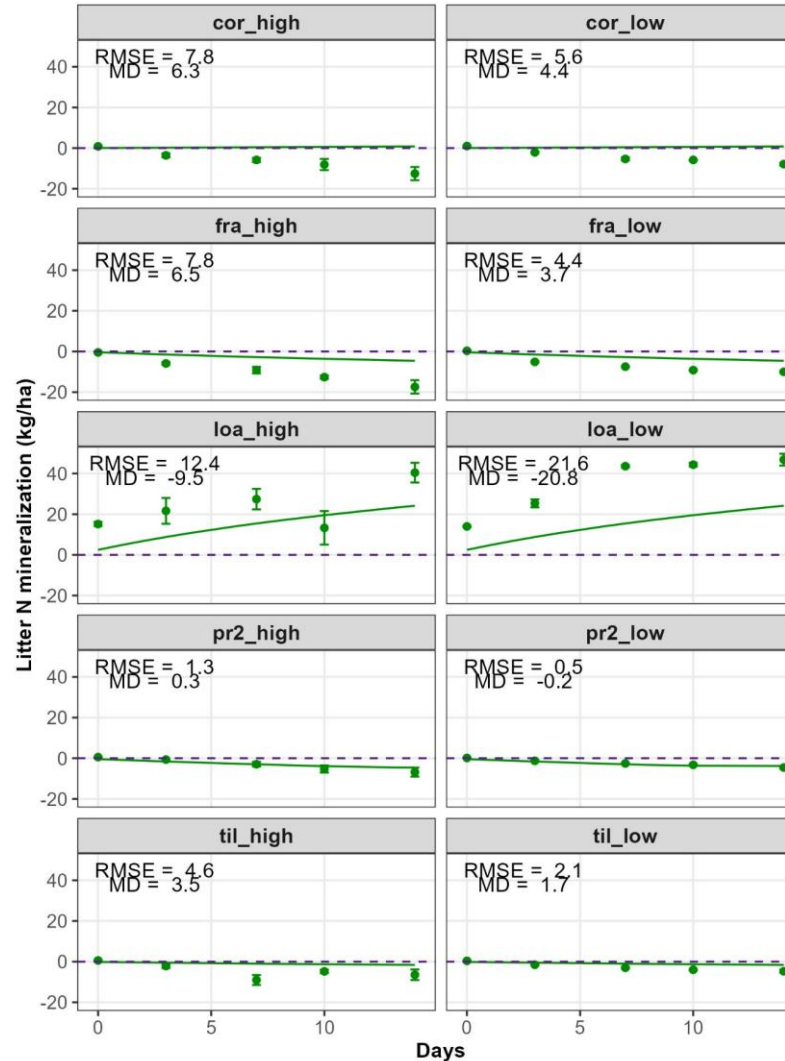
→ akres optimization

C & N mineralization kinetics (Exp 2)

Apparent C-CO₂ dynamics



Apparent N mineralization



akres optimization improves simulated decomposition but has limited effects on N immobilization

akres optimized values:
0.011 (til) – 0.052 (loa)
vs 0 (default)
→ kres x 1.7-3.3

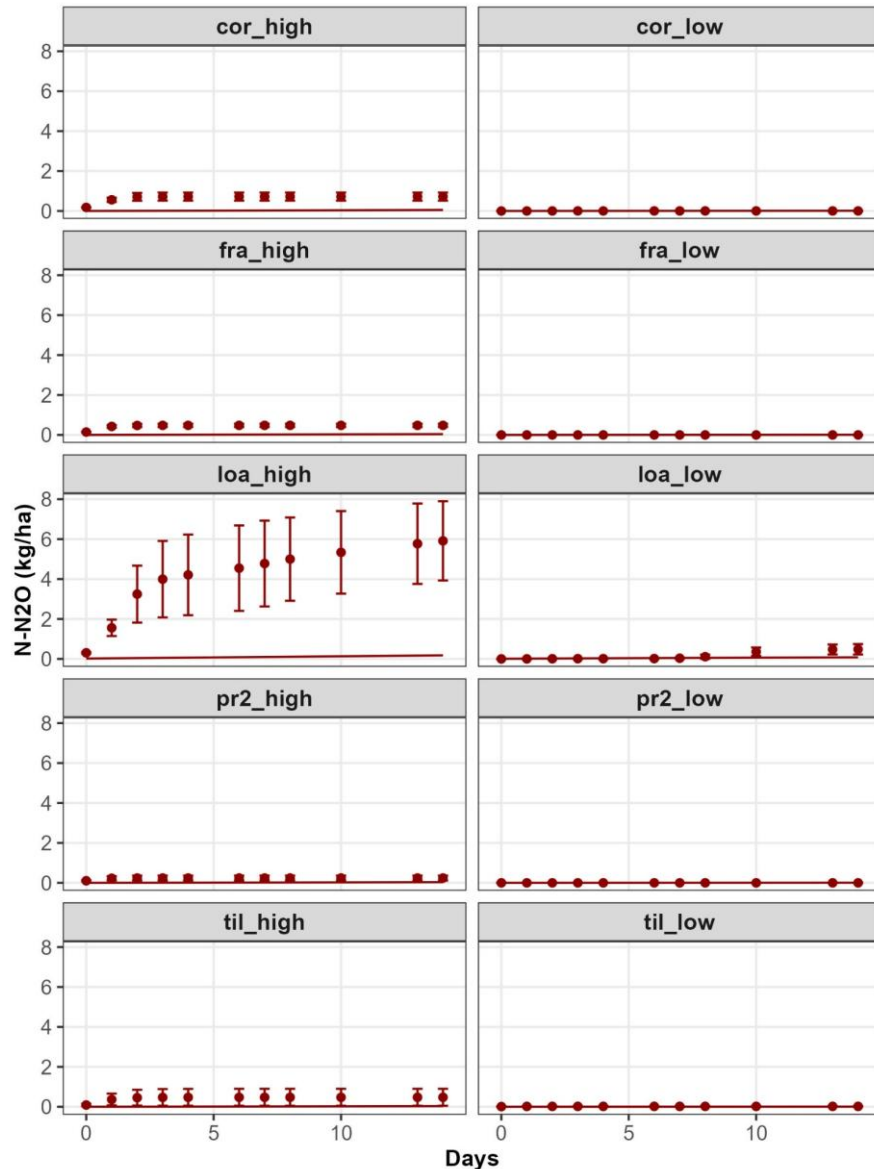
Apparent C-CO₂ dynamics

RMSE = 1.5
MD = -0.1 (sim-obs)
C release (% residue C)

Apparent N mineralization

RMSE = 6.8
MD = -0.4 (sim-obs)
(kg N/ha)

N₂O emissions (Exp 2)



The model is not able to simulate the only situation with high N₂O emissions (loa_high, EF ~ 4% N added)

Litters with high soluble and low N contents are not emitting N₂O

The soil with the lowest WFPS at pF 2 « low » (70%) is not emitting N₂O vs soil « high » (WFPS = 95%) for loa

* WFPS = water filled pore space

Litter	C/N	Soluble_NDS (%)
cor	33.9	63.8
fra	69.5	58.6
loa	8.4	49.2
pr2	85.9	19.7
til	47.9	55.4

Conclusion – Perspectives (1/2)

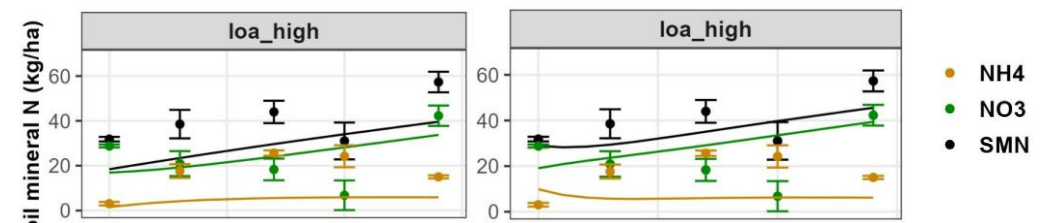
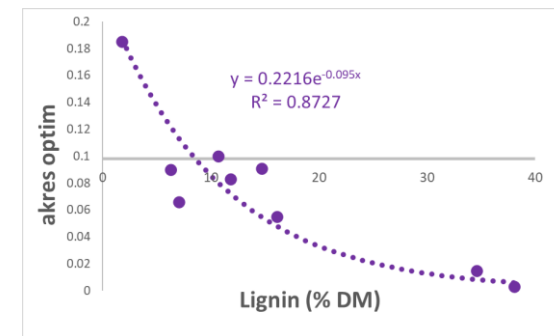
STICS ability to simulate **C and N mineralization** from original and contrasted **litter types mixed** with **lawn soils**

➤ relatively good simulations of SOM mineralization, mineralized C and N immobilization and net release of N from litter decomposing

➤ potential improvements:

➤ Considering **lignin content** to regulate litter decomposition rates

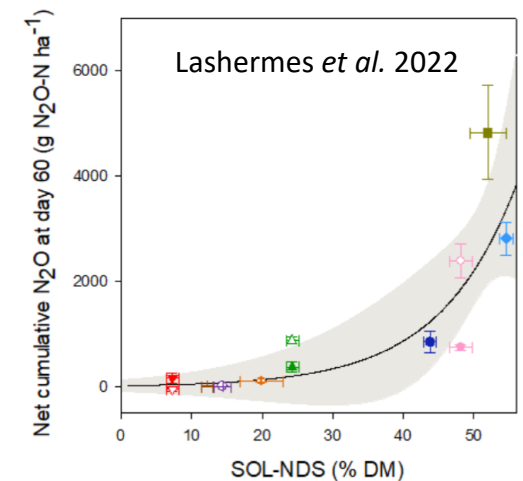
➤ Measuring **N min forms** (NH_4^+ / NO_3^-) added and allowing for their consideration for organic residues



Conclusion – Perspectives (2/2)

STICS ability to simulate **C and N dynamics** for **litter decomposing on the soil surface**

- underestimation of litter decomposition and N immobilization
- inability to simulate high N₂O emissions from soil + litter with high N and soluble contents
- potential ways of improvements:
 - Conducting a study on all available data (litter on soil surface/mulches) for a **better calibration** of decomposition parameters (and/or representation of accessible N ?)
 - Continuing to work on a refined version of **N₂O submodel** accounting for the effects of litter **soluble + N contents**



Next steps

ALAMOD project 2026-2028 (FairCarboN)



- Evaluating and improving the STICS simulation of plant litter decomposition (C and N, short and long term) with various data on plant litter decomposing under controlled and field conditions

COUPLAGES project 2026-2027 (Pari Scientifique INRAE)



- Improving the understanding and modeling formalisms of N₂O emissions following the return of crop residues to the soil

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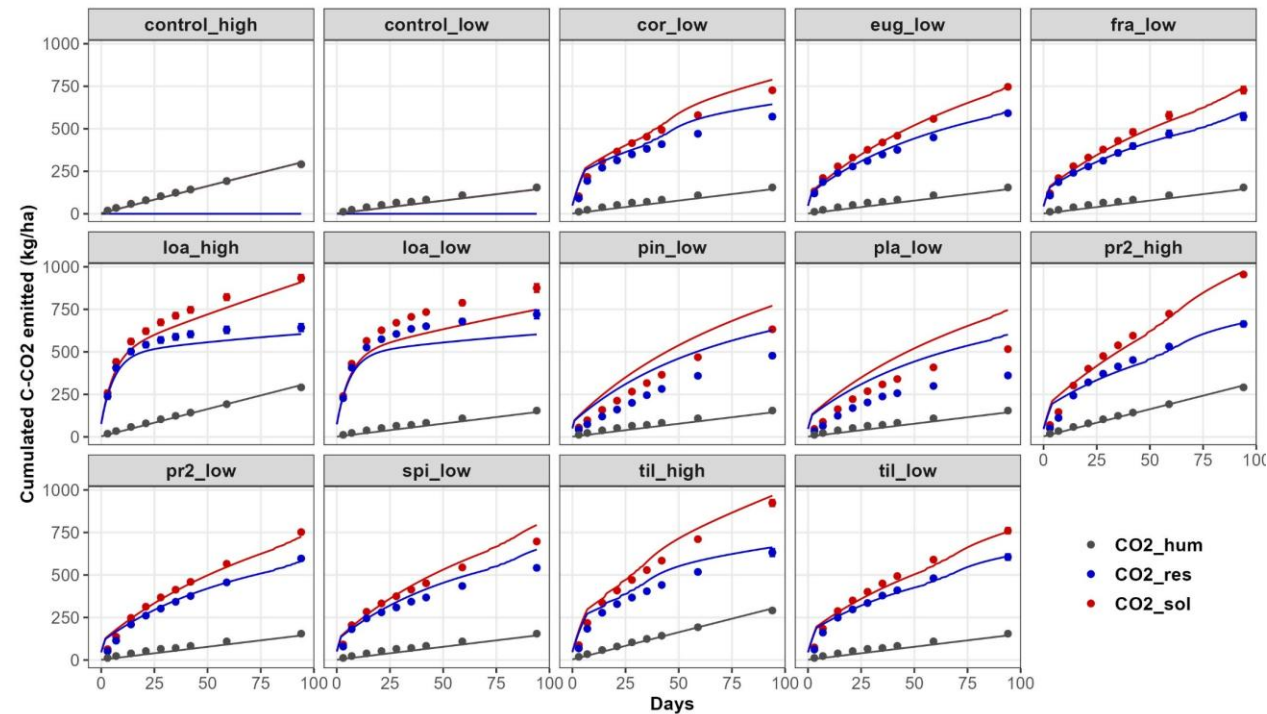
Supplementary materials

C & N mineralization kinetics (Exp 1)

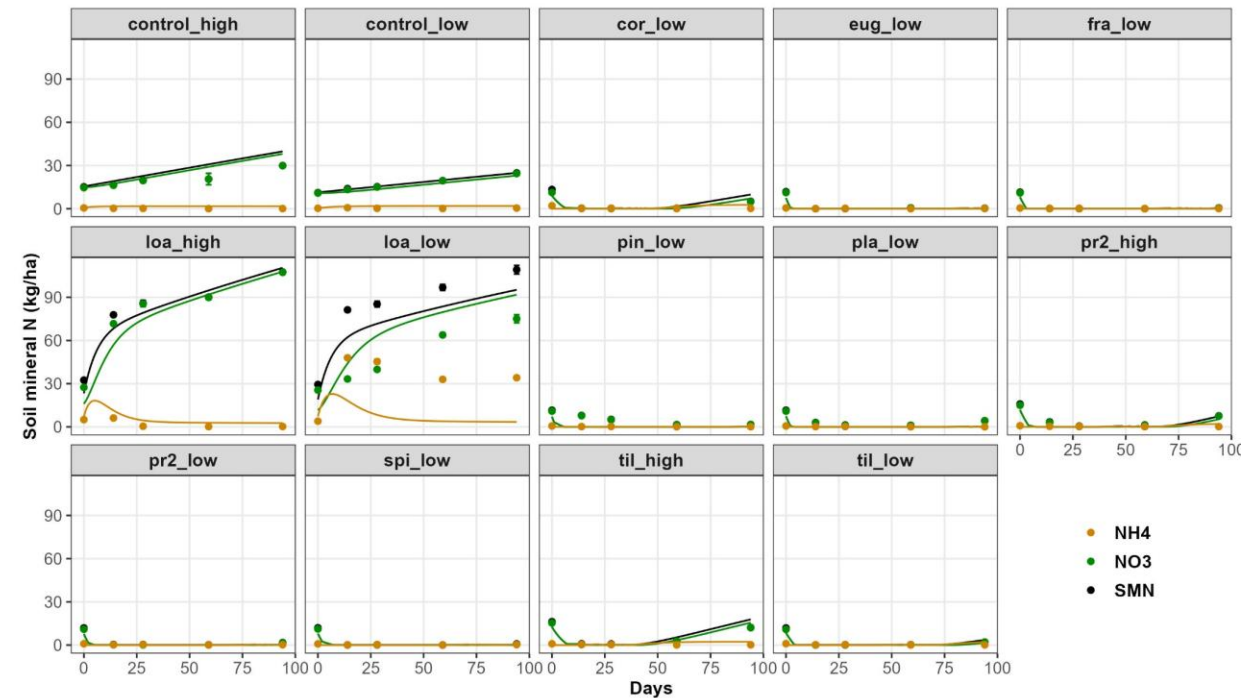
→ All treatments

Relatively good
simulations of N
immobilization and
net release

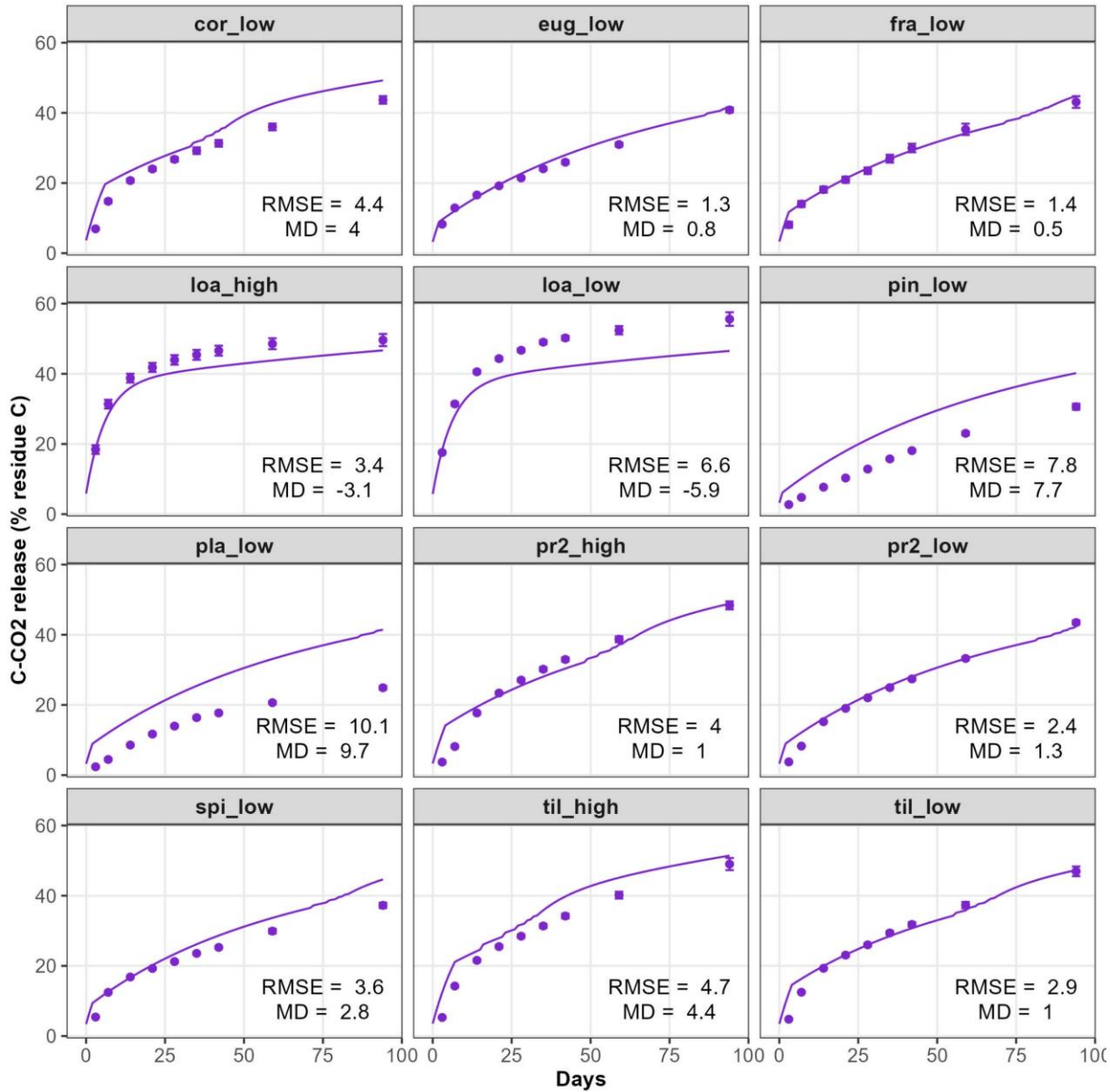
C-CO₂ dynamics



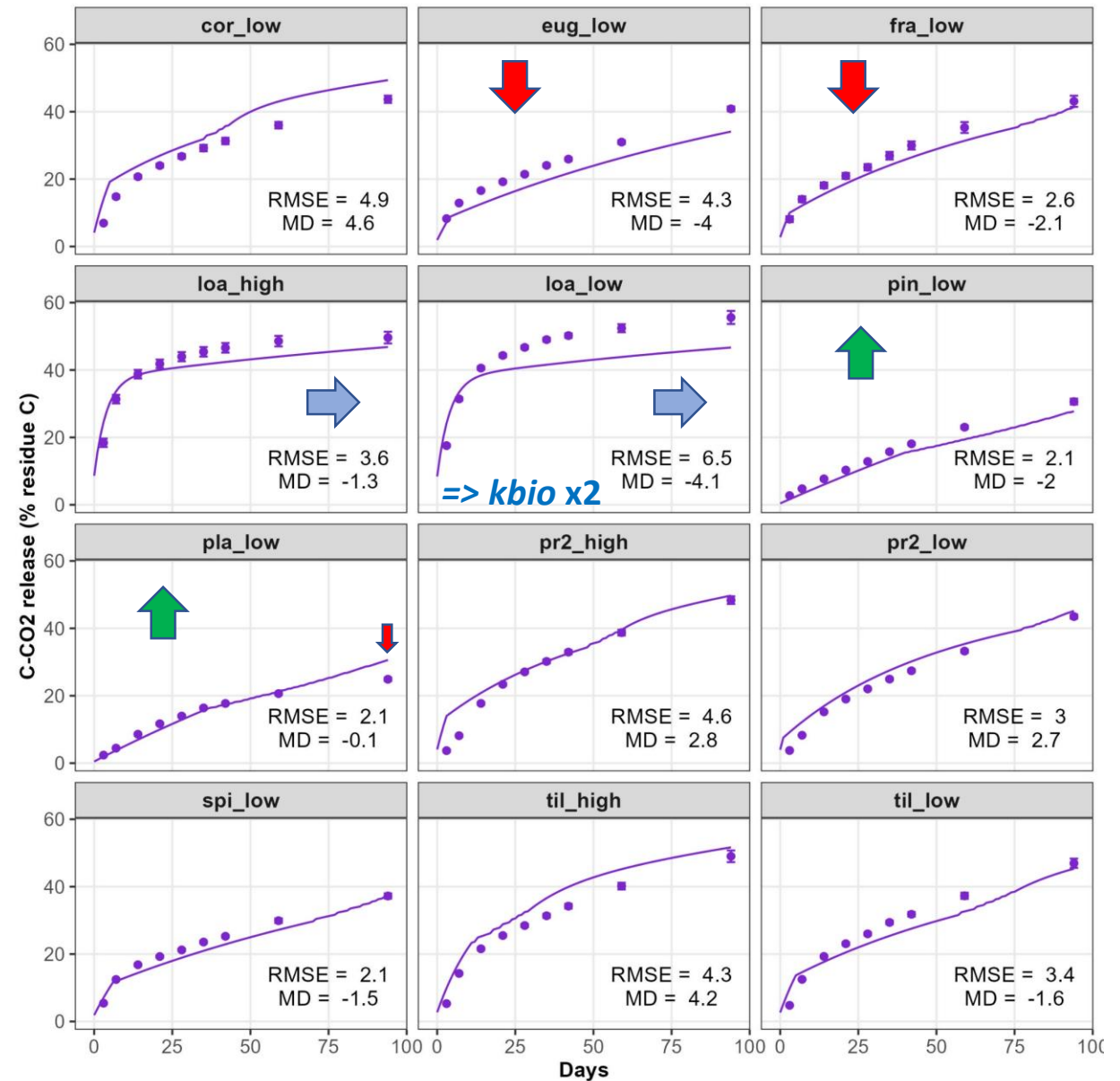
Soil mineral N dynamics



Default akres

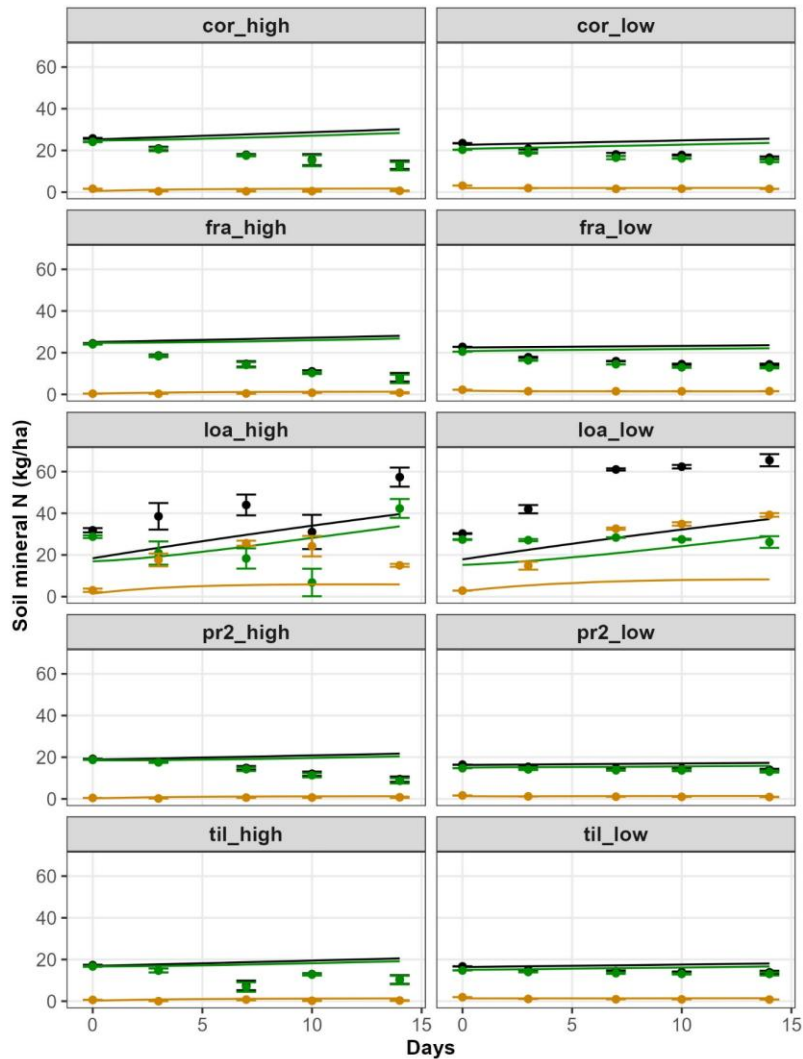


Akres = f(lignin)

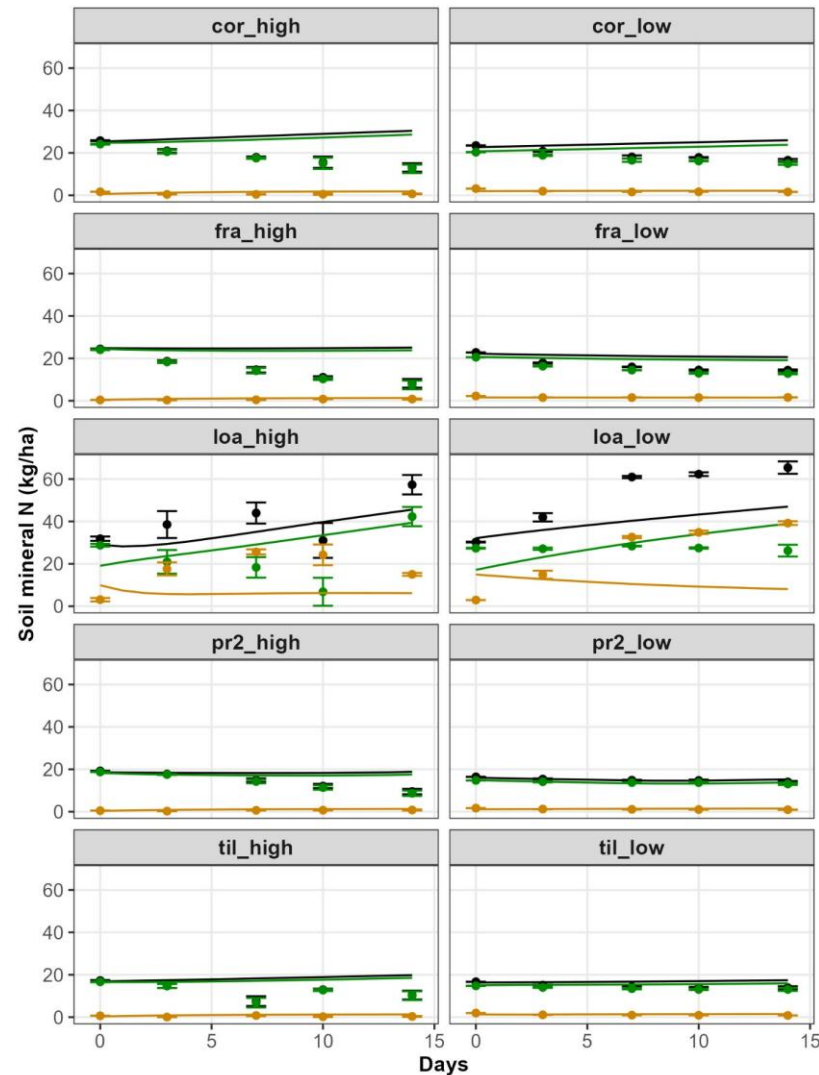


C & N mineralization kinetics (Exp 2)

Mineral N dynamics default



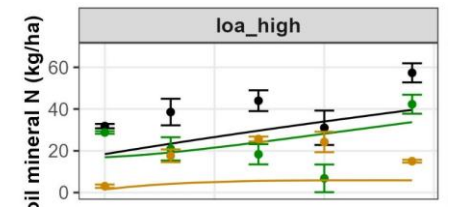
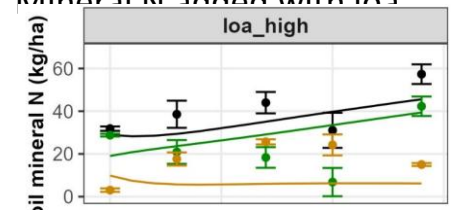
Mineral N dynamics



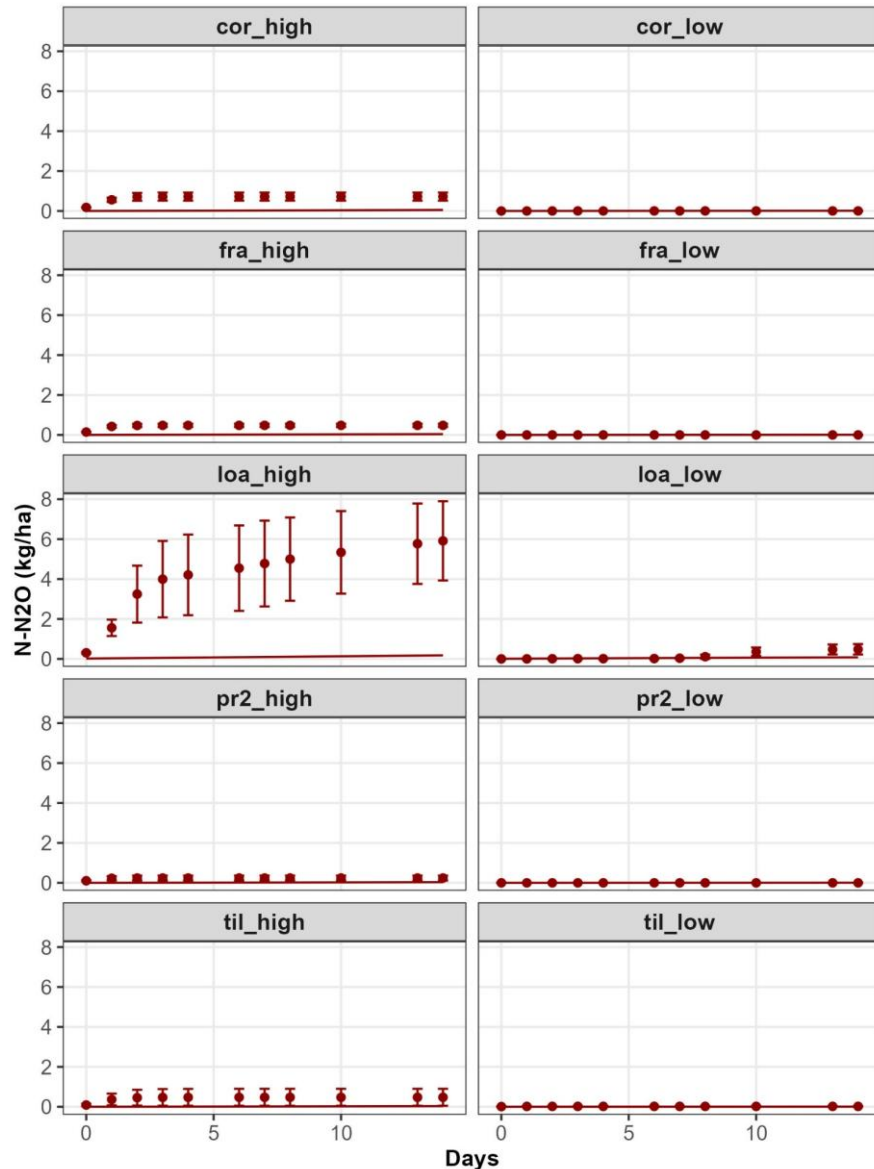
akres optimized values:
0.011 (til) – 0.052 (loa)
vs 0 (default)

+

Mineral N added with loa



N₂O emissions (Exp 2)



The model is not able to simulate the only situation with high N₂O emissions (loa_high, EF ~ 4% N added)

The soil with the lowest WFPS at pF 2 « low » (70%) is not emitting N₂O vs soil « high » (WFPS = 95%) for loa

Litters with high soluble and low N contents are not emitting N₂O

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til	47.9	55.4

Setting water content at pF 2.9 for soil « high » (WFPS = 71%) returns low emissions

