New crop fertilization strategies after introduction of anaerobic digesters in a territory and their consequences on carbon and nitrogen dynamics in soils: case study of the Versailles plain.

Camille Launay, Marianne Crépeau, Romain Girault, Florent Levavasseur, Sabine Houot

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ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

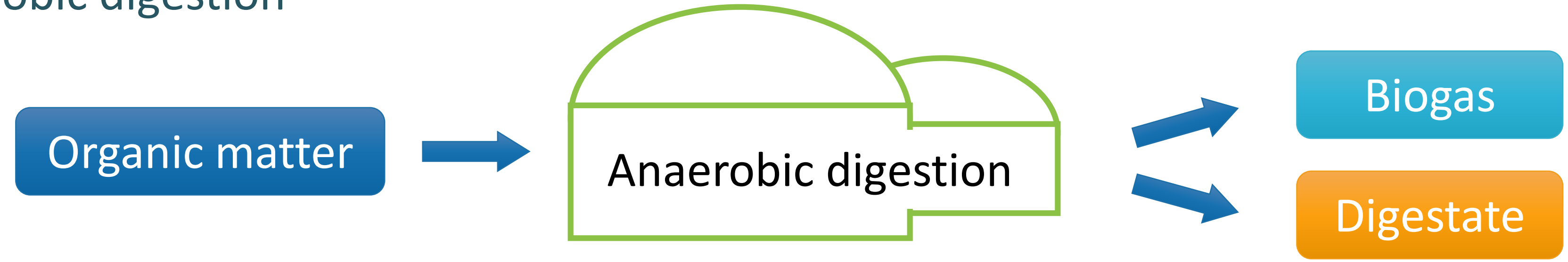
MéthaPolSol project (2016-2019)

Context

Anaerobic digestion

Context

Anaerobic digestion



Public policies promote anaerobic digestion as a means of mitigating climate change:

- Renewable energy production
- Substitution of synthetic nitrogen fertilizers by digestates
- Decrease in emissions from manure storage

Anaerobic digestion impacts cropping systems:

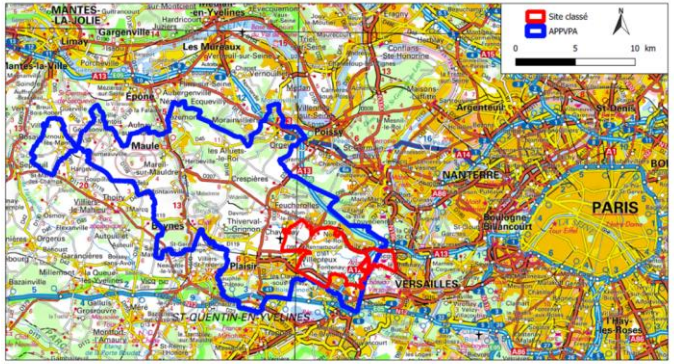
- Modification of fertilization strategy
- Mobilisation of crop residues
- Modification of crop successions to introduce cover crops for energy supply (CCESs)

⇒ Change in carbon and nitrogen dynamics

Context

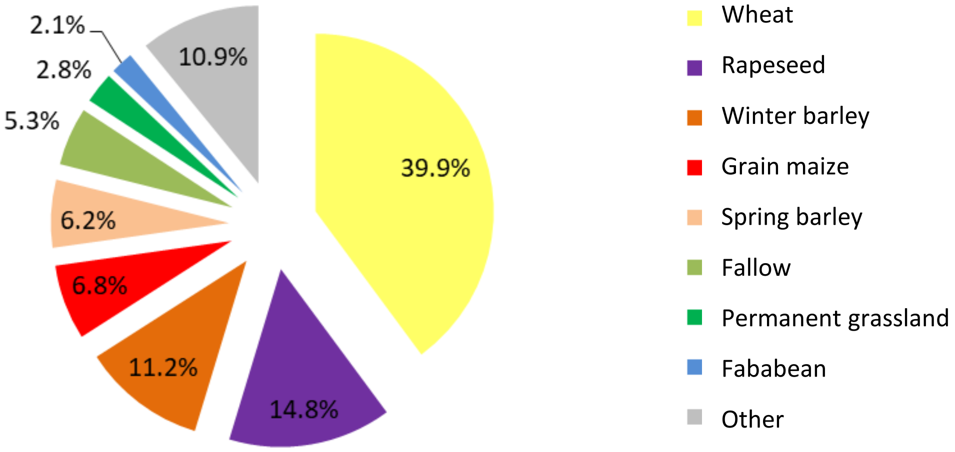
The Versailles plain

- 23 200 ha with 57 % of agricultural area
- Suburban area
- Agricultural practices of the territory have been well defined through surveys



Organic resources :

- Green waste compost
- Horse manure
- Bovine manure and slurry (from one big cattle farm)
- Sewage sludge
- Composted Pig slurry i.e. Humival
- Unmobilized food waste

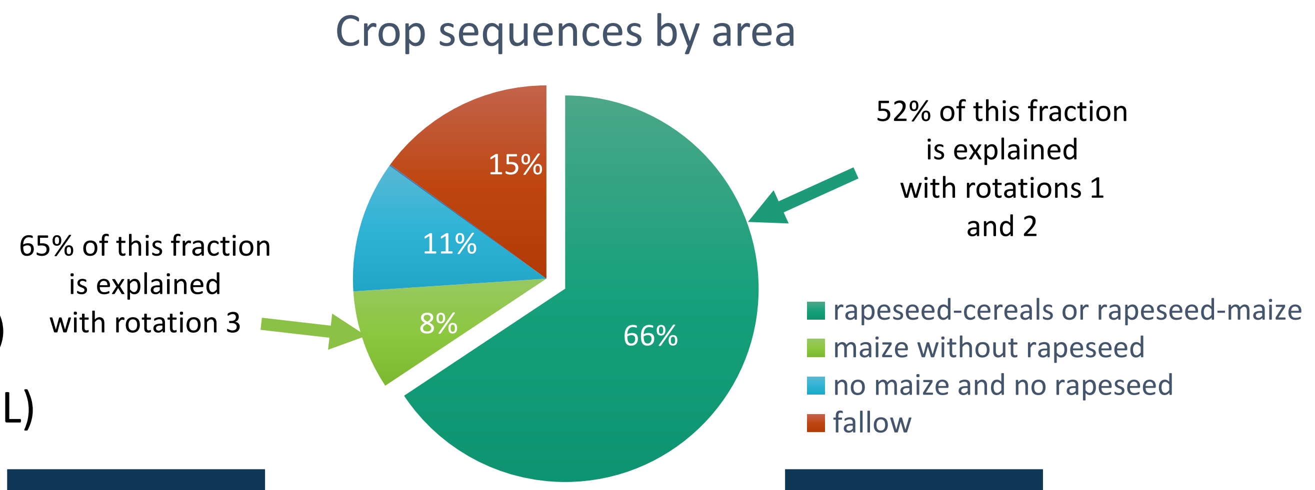


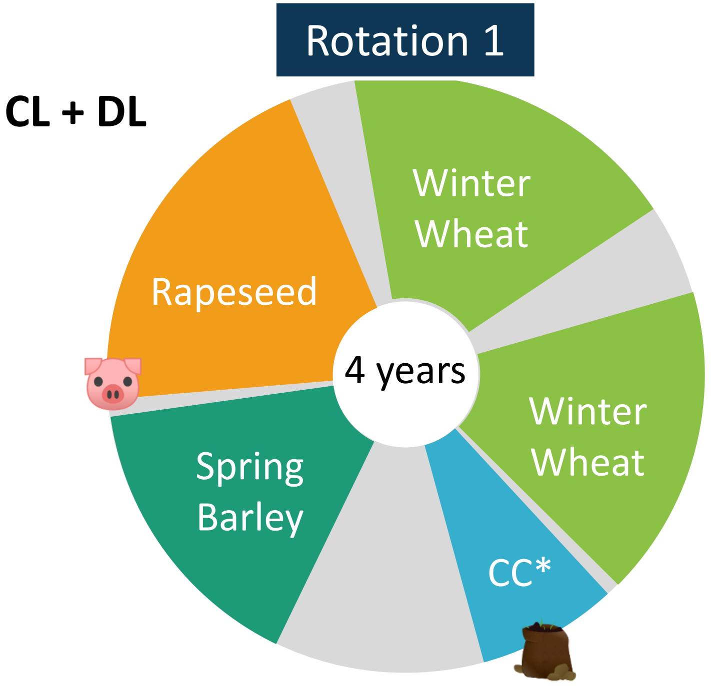
Average crop rotation in the territory 2015-2017 (source RPG 2015 to 2017).

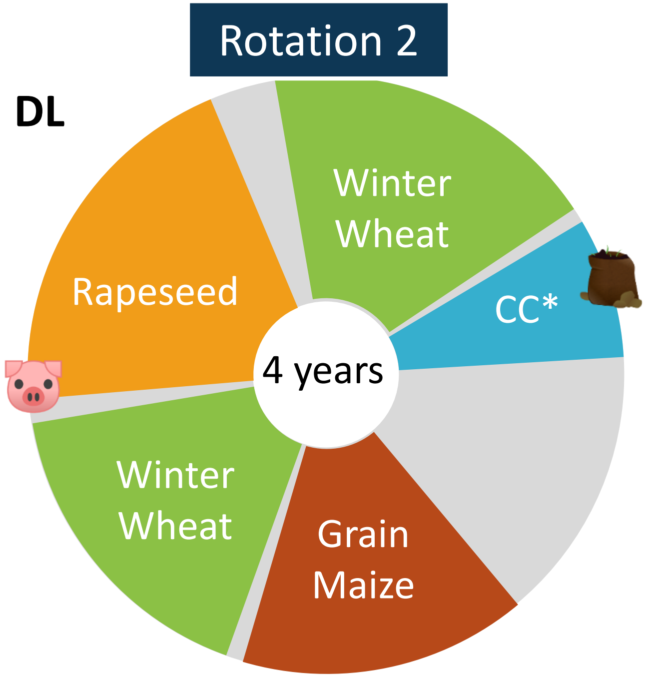
Context

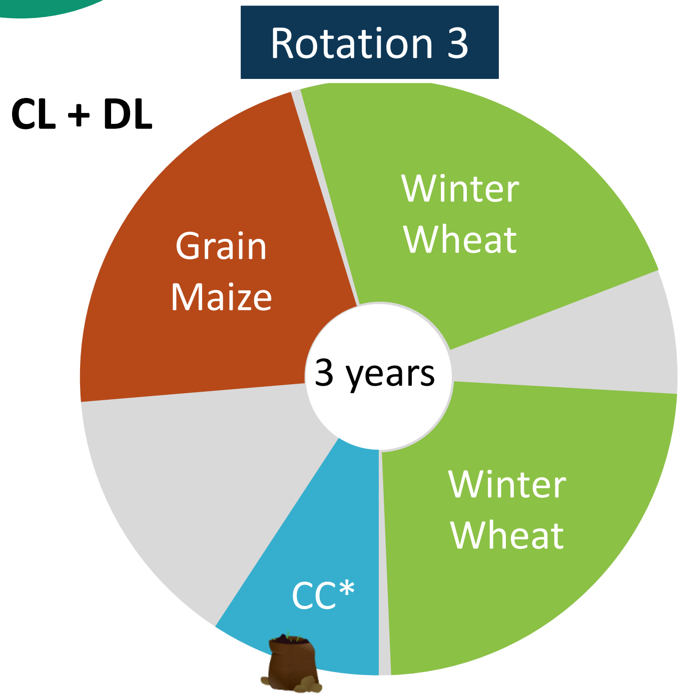
Crop sequences

- Two main soil types: clay-limestone (CL) and deep loamy soils (DL)
- Low SOC : 44,9 t C/ha (CL) and 43,5 t C/ha (DL)









*CC : Catch crop — Humival i.e. pig slurry compost — Green waste compost

Issue

Several projects of anaerobic digesters in the territory:

- Based on livestock that would use cattle and horse manure
- Based on livestock and cover crops
- Based on food wastes

Changes in cropping systems

What are the consequences on carbon (C) and nitrogen (N) flows at the plot scale of the development of these two types of anaerobic digesters on the territory?

N uptake

Leaching

NH_3 volatilization

Carbon storage

N_2O emissions

Method

Scenarios

EOMs* : exogenous organic matters

Scenario	Fertilization	Cover crop
Control	Mineral	Catch crop (mustard) incorporated
Current systems	Classic EOMs* (humival + green waste compost) + mineral	Catch crop (mustard) incorporated
Food waste anaerobic digesters projects	Food-based digestate with solid-liquid separation +mineral	Catch crop (mustard) incorporated
On-farm anaerobic digester project	Manure-based digestate with solid-liquid separation + mineral	Catch crop (mustard) incorporated
Mobilization of cover crops for anaerobic digestion	Manure and crop-based digestate with solid-liquid separation + mineral	CCES (maize, rye-grass or fababean) exported on summer and winter fallow

Method

Scenarios

x3 crop systems **x2 soil types** ganic matters

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Method

Simulations

Organic resources of the territory

↓

Anaerobic digestion model[1]

Digestate characteristics

- Water content *eaures*
- Carbon content *Crespc*
- Organic C/N *CsurNres*
- $N\text{-}NH_4$ content *Nminres*

↓

Model of C and N decomposition in soil

Kinetics of C and N mineralization in soils

- *kres, kbio*
- *yres, hres*
- *CNbio*

↓

Pedoclimatic conditions →

Cropping systems →

Model of C and N dynamics in the soil-plant-atmosphere system

↓

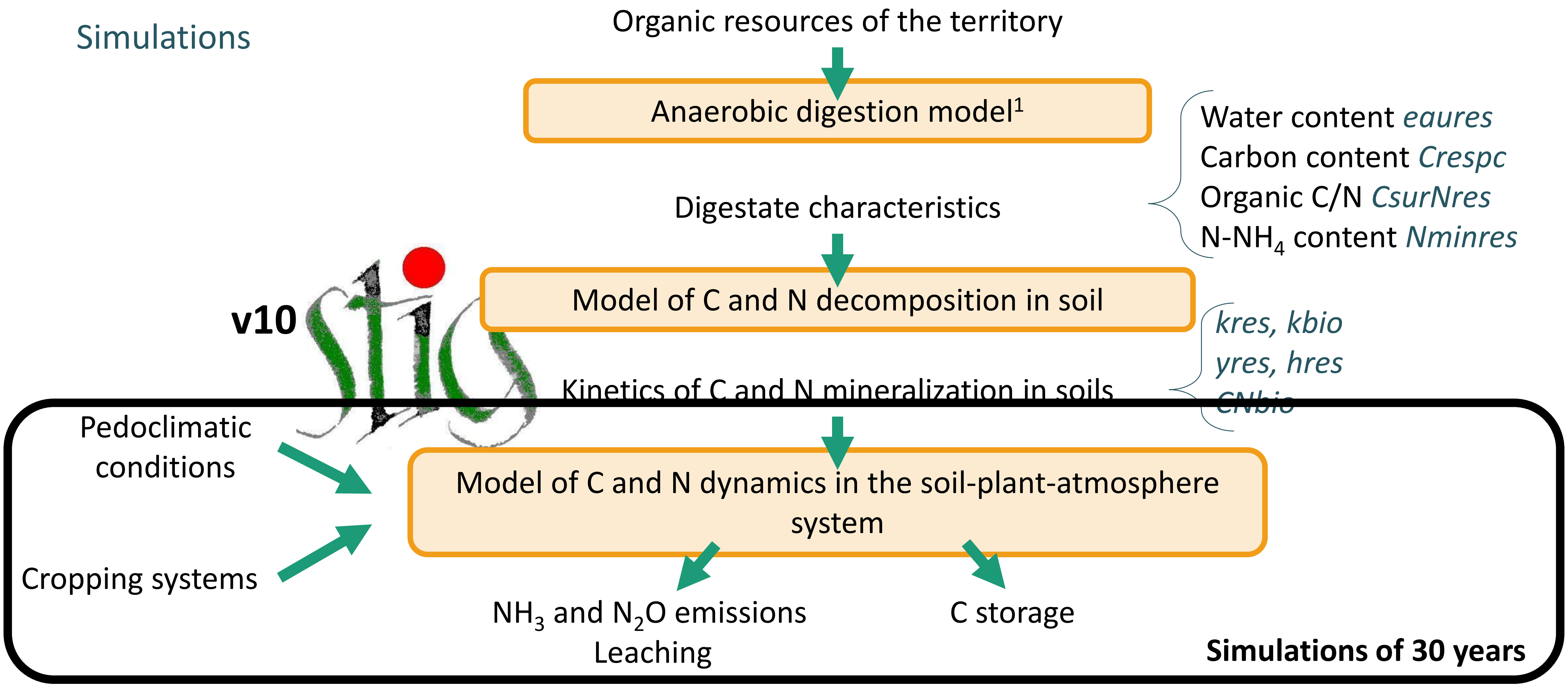
NH_3 and N_2O emissions
Leaching

C storage

[1] Bareha, Y. (2018). *Modélisation des processus de transformation de l'azote en digestion anaérobie : application à l'optimisation de la valorisation des digestats.* Retrieved from https://tel.archives-ouvertes.fr/tel-02115249/

Method

Simulations



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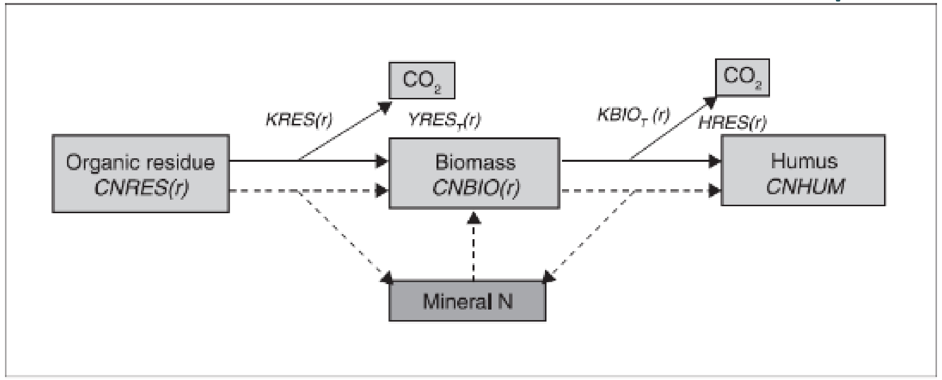
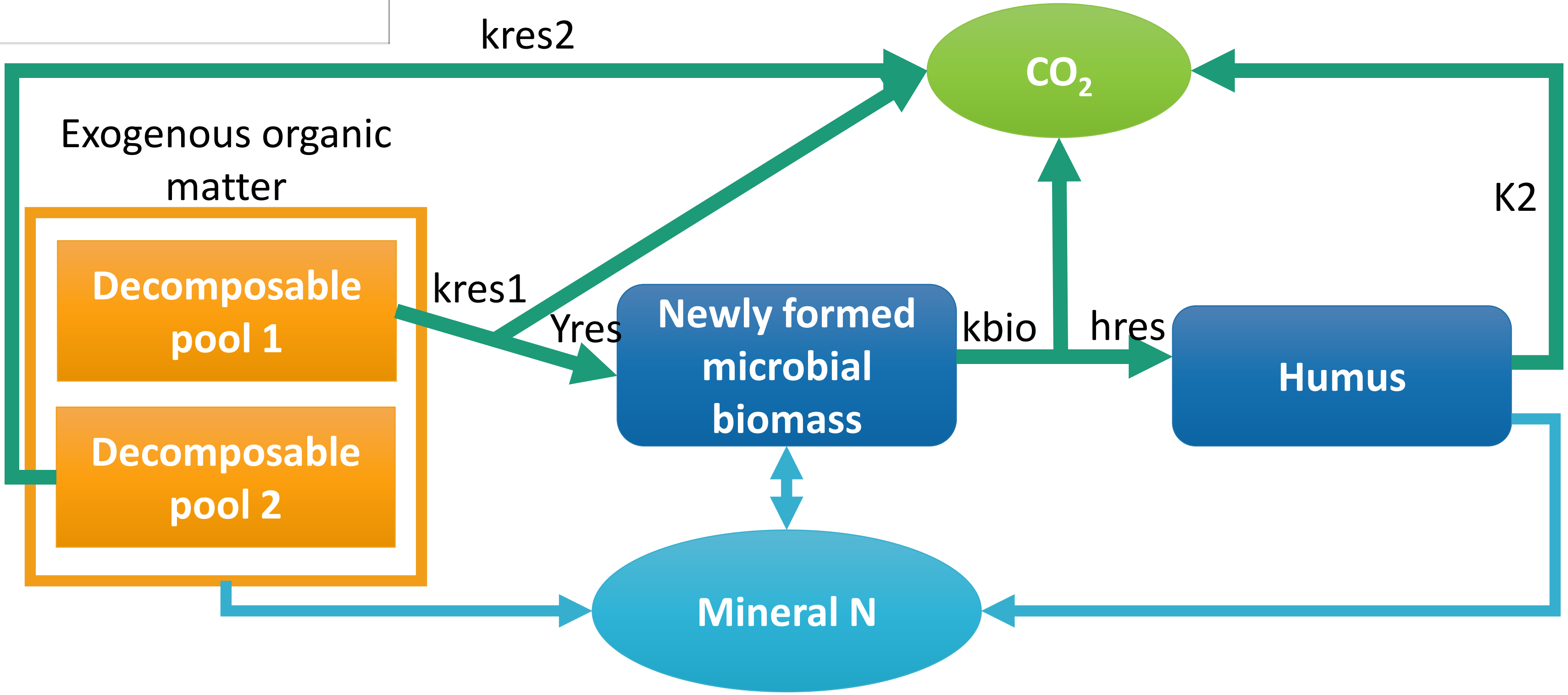
Method

New formalism for residues decomposition



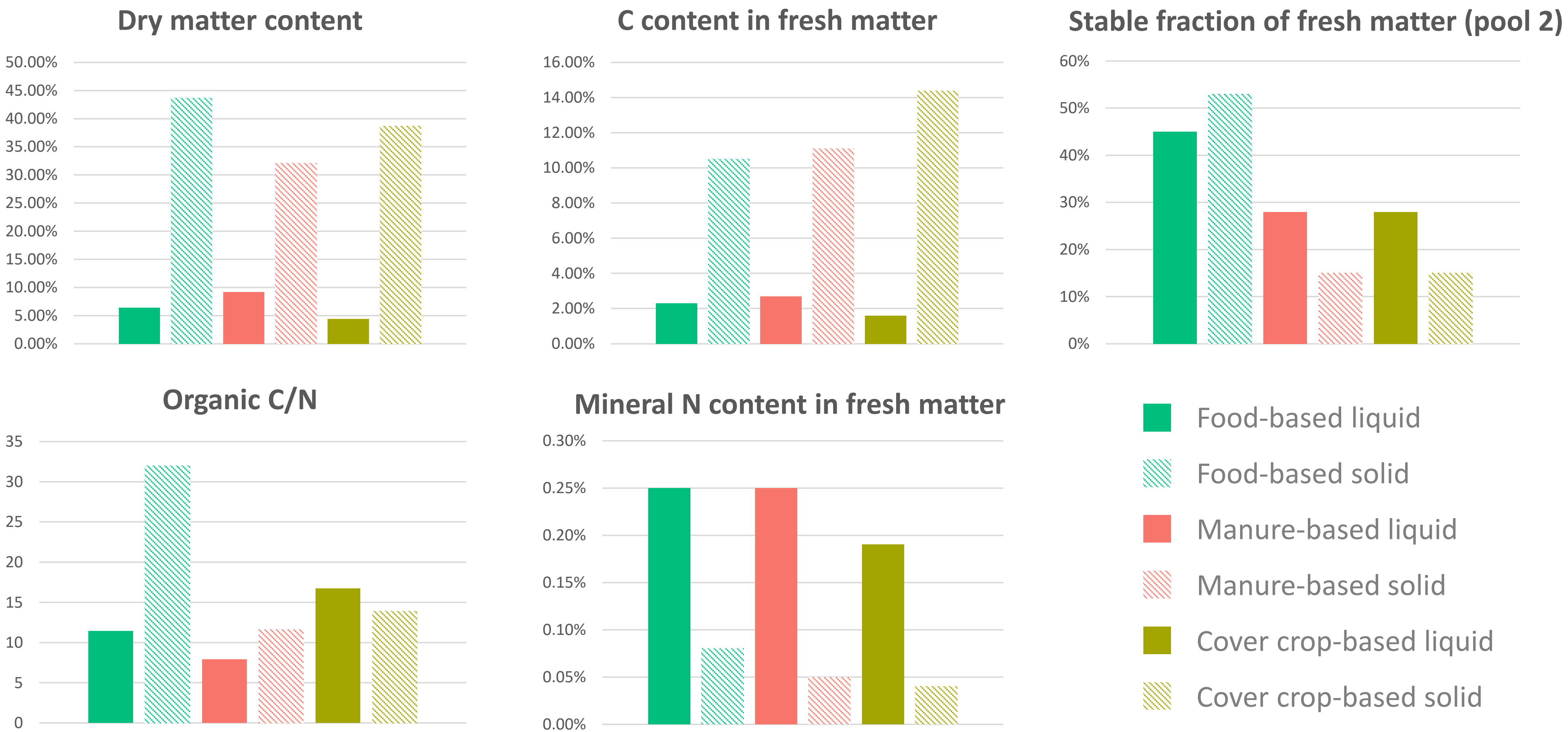
Brisson, N., Launay, M., Mary, B., & Beaudoin, N. (2009). *Conceptual basis, formalisations and parametrization of the STICS crop model* (Quae, Ed.). Versailles.

Levavasseur F. Mary B. Houot S., submitted. *Accuracy of the STICS model to simulate C storage and N dynamics after repeated application of organic amendments in a long-term experiment.* Submitted in Computers & Electronics in Agriculture



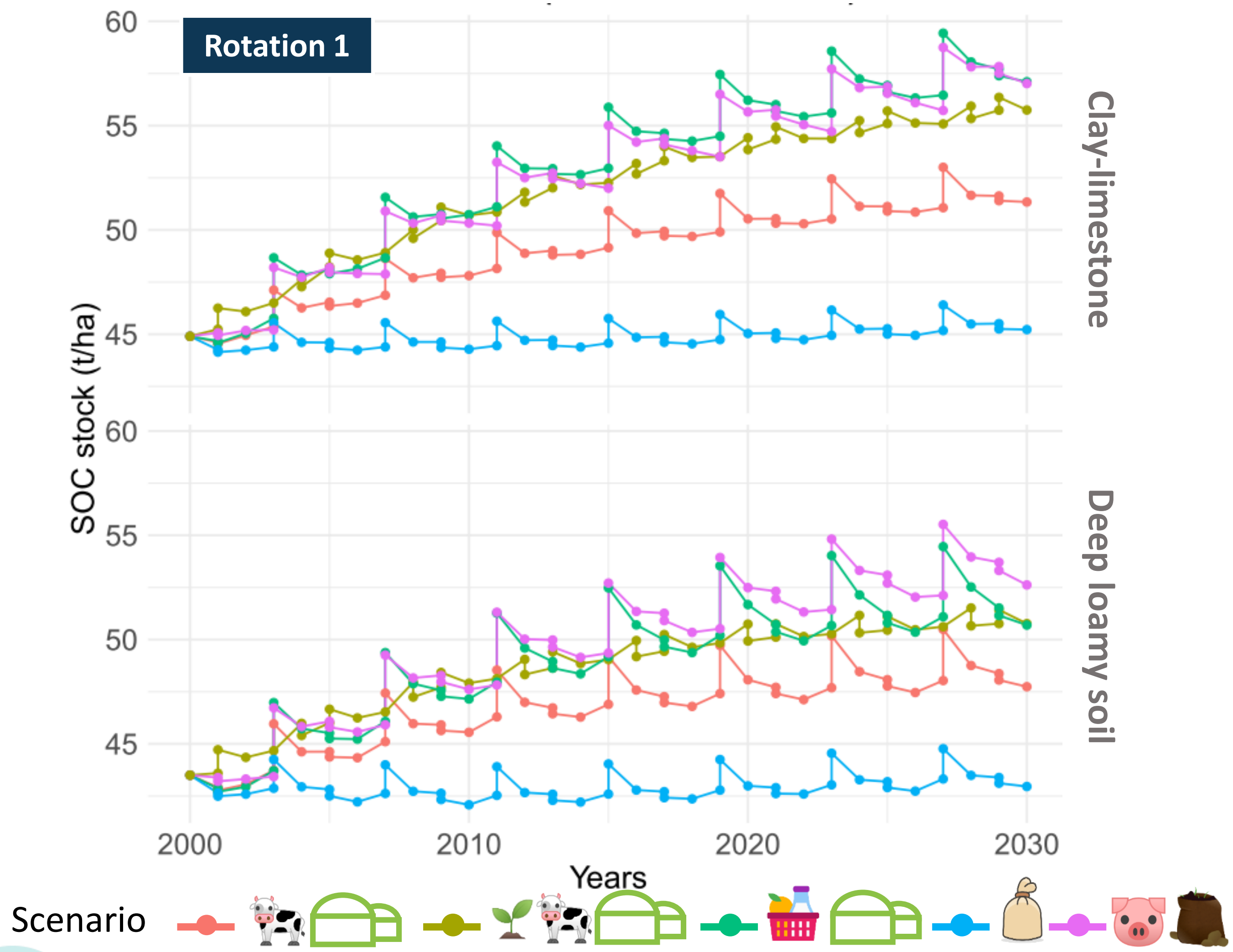
Method

Digestate characteristics



Results

Soil organic carbon (SOC) stocks



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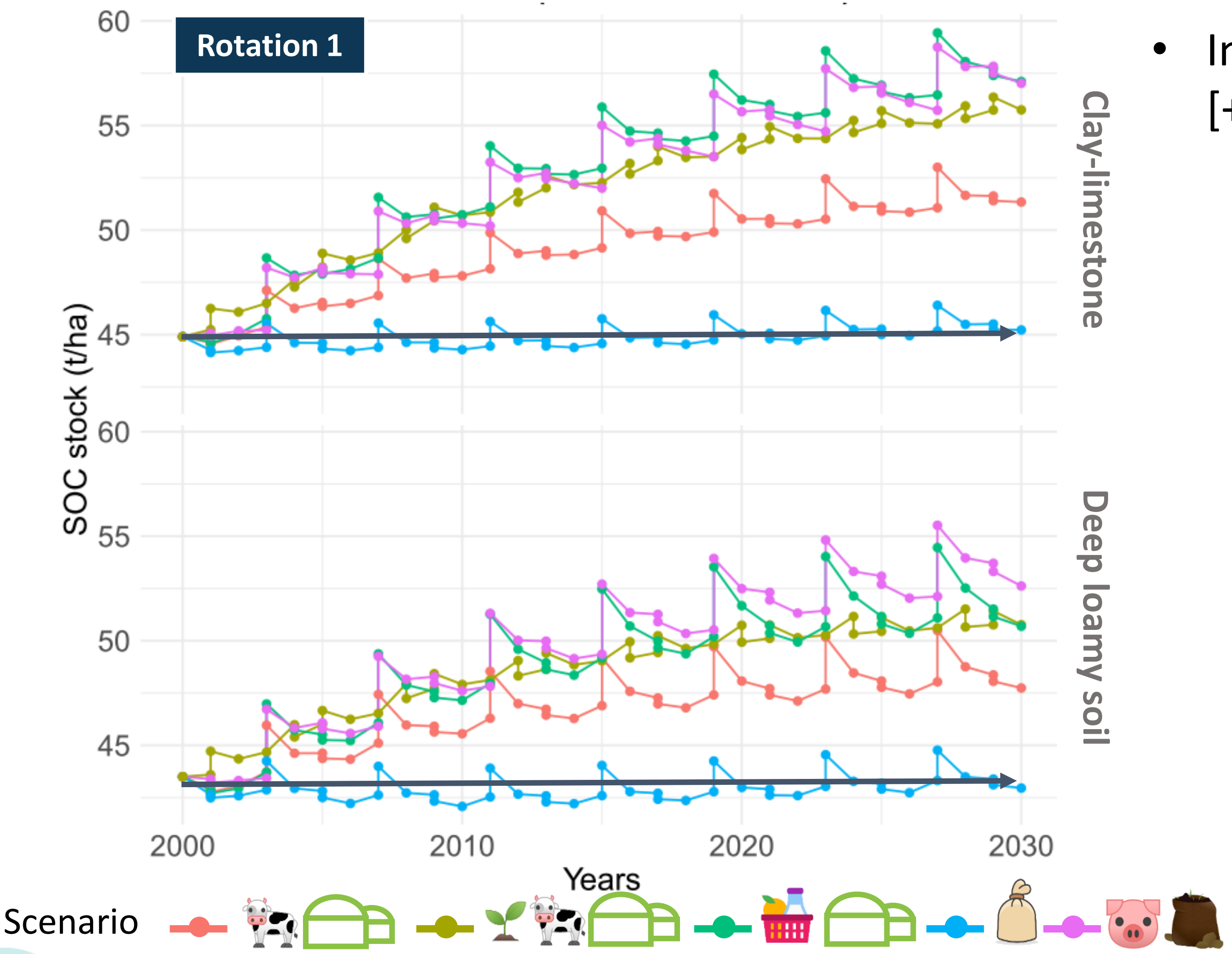


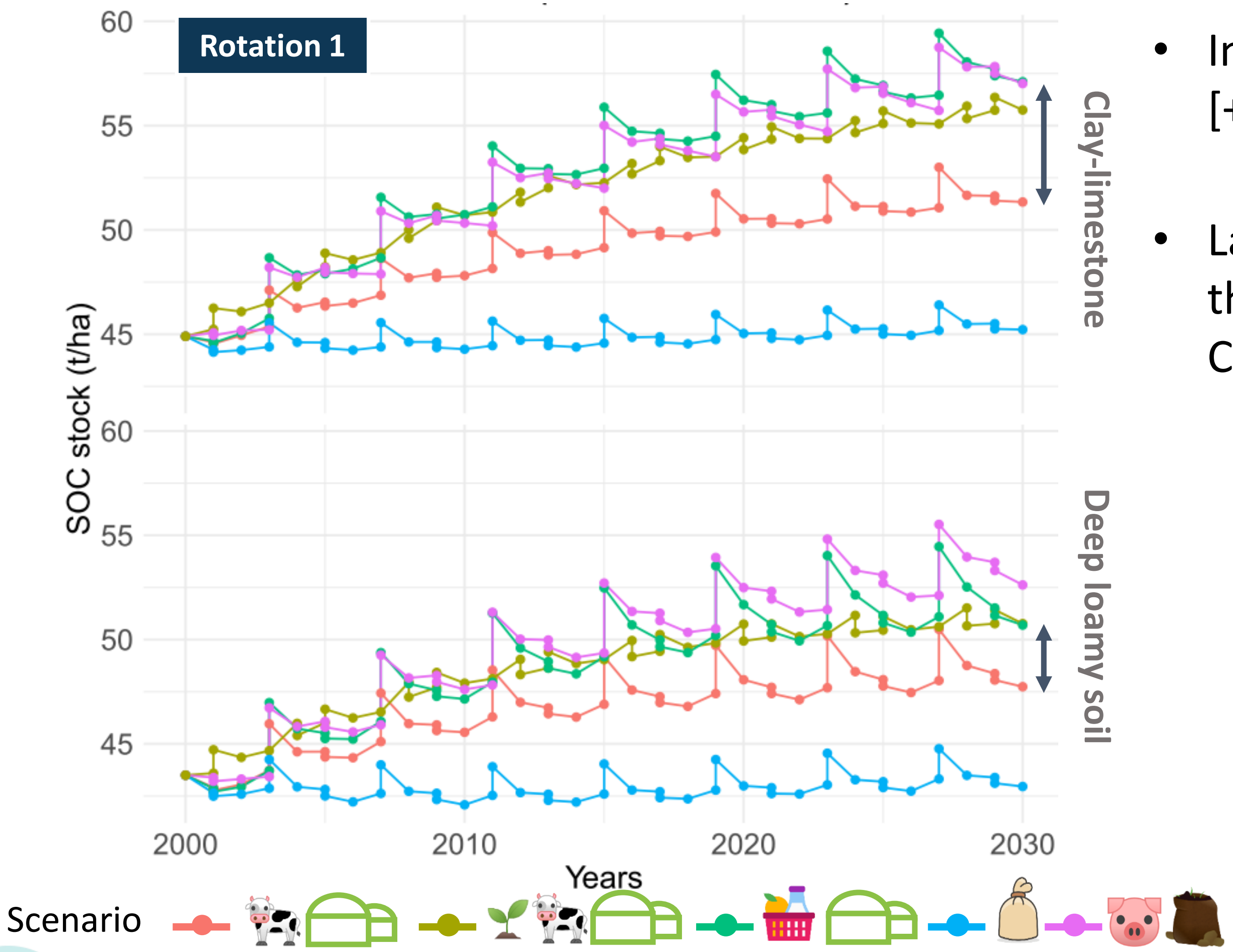
- Stable SOC stocks in mineral fertilizer scenario
- Increased SOC stocks in all EOMs scenarios [+0,1;+0,5] t C/ha/yr
  - Increased C inputs [+16;+41] %

C from EOMs : 20%

C from crop residues (aerial + roots) : 80%

Results

Soil organic carbon (SOC) stocks



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- Larger SOC increase with food-based digestate than with manure-based digestate [+0,1;+0,3] t C/ha/yr
  - Increased C inputs from digestate [+33;+57] %
  - More stable C

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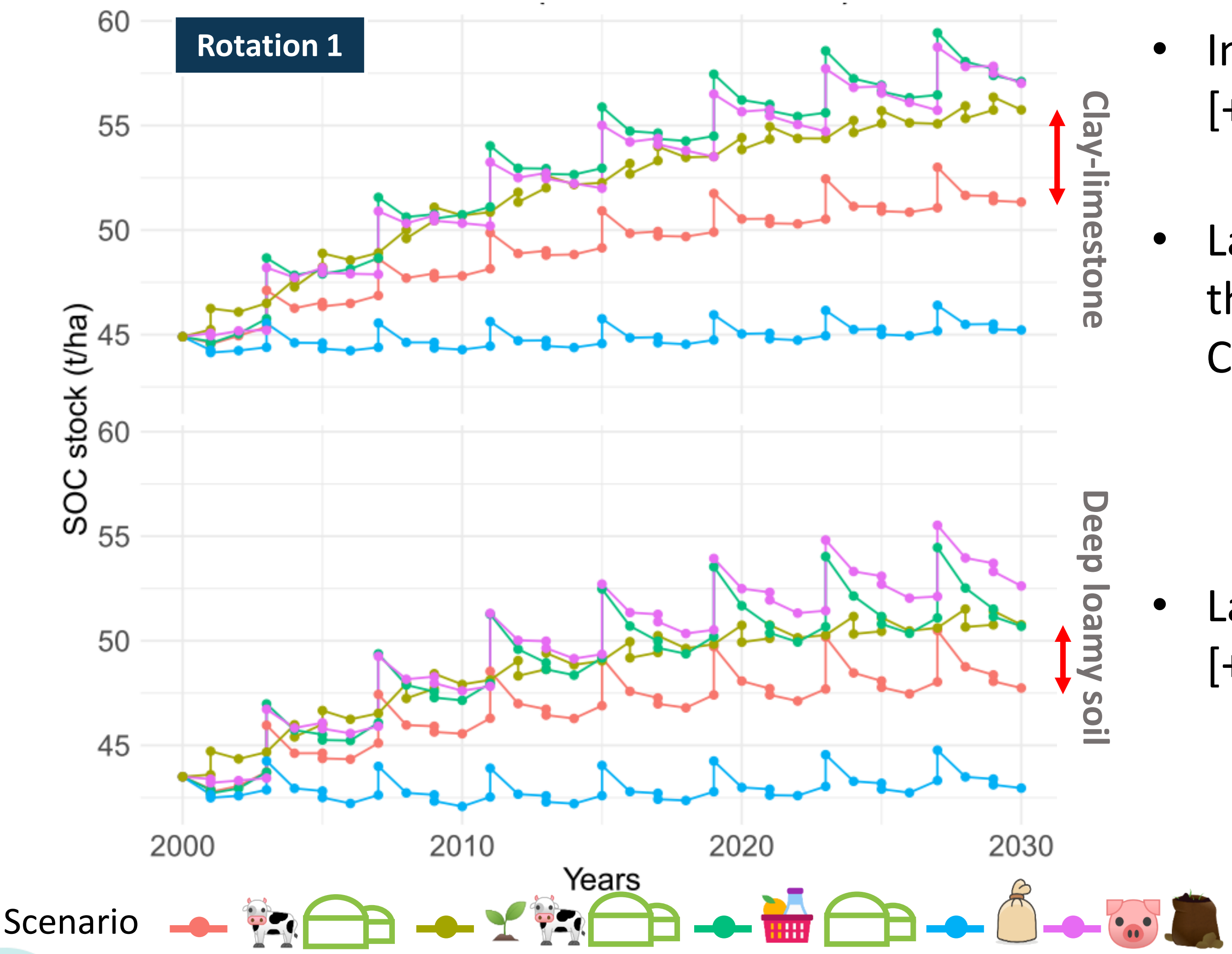

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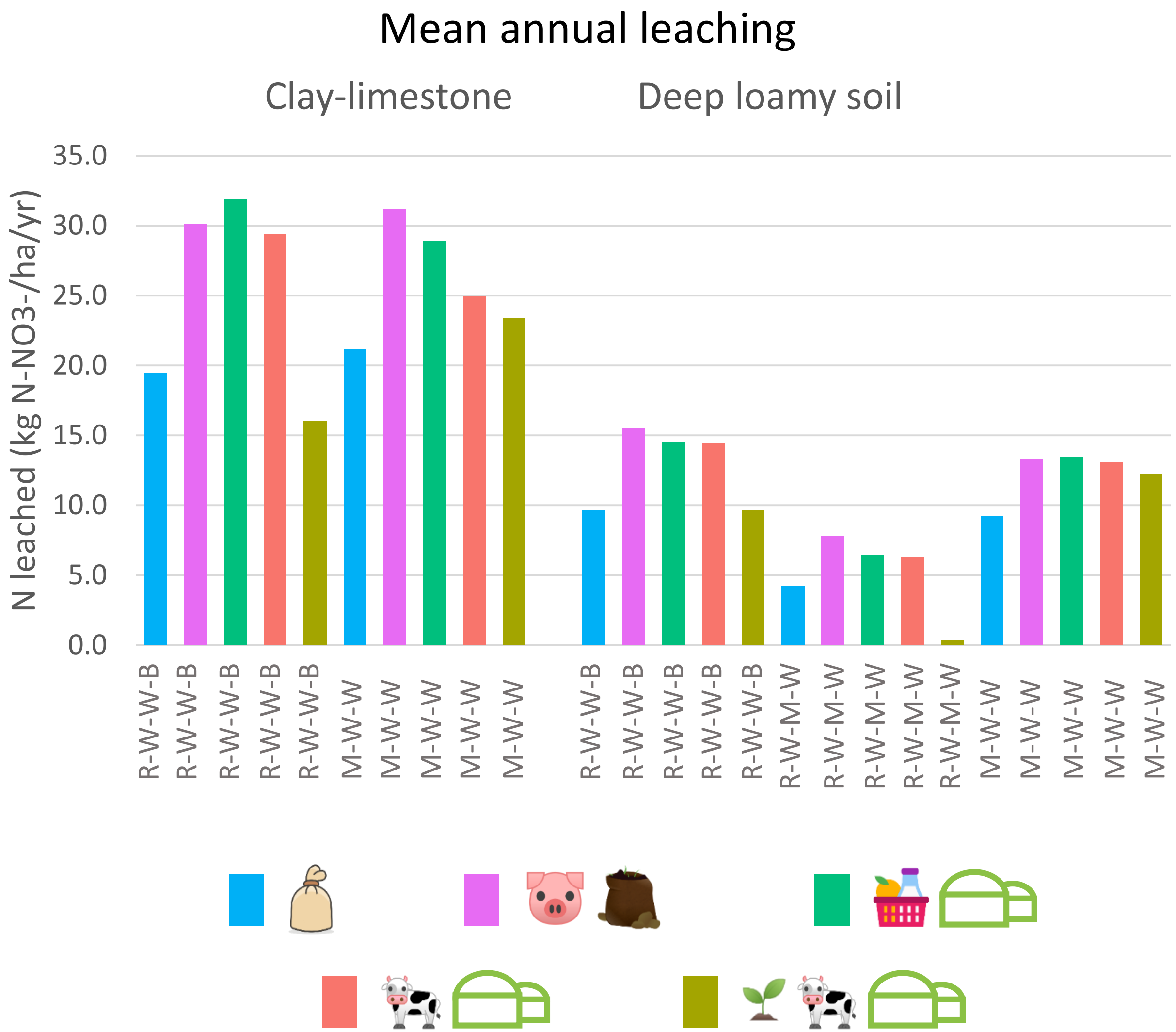
  - Increased C inputs from digestate [+33;+57] %
  - More stable C
- Larger SOC increase with introduction of CCES [+0,1;+0,2] t C/ha/yr
  - Increased C inputs from roots [+4;+27] % and digestate [+32;+46] %

Results

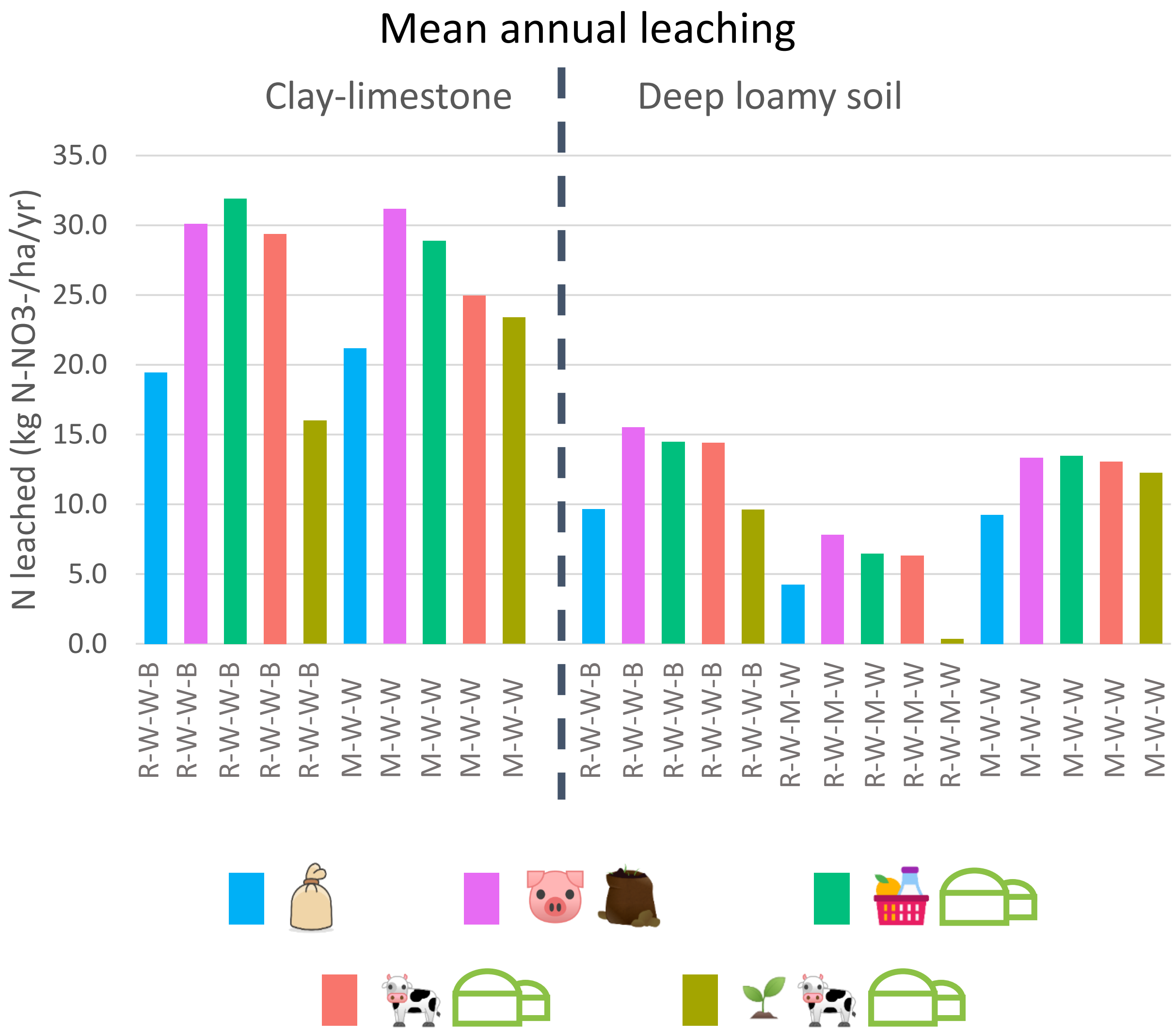
Leaching



Results

Leaching

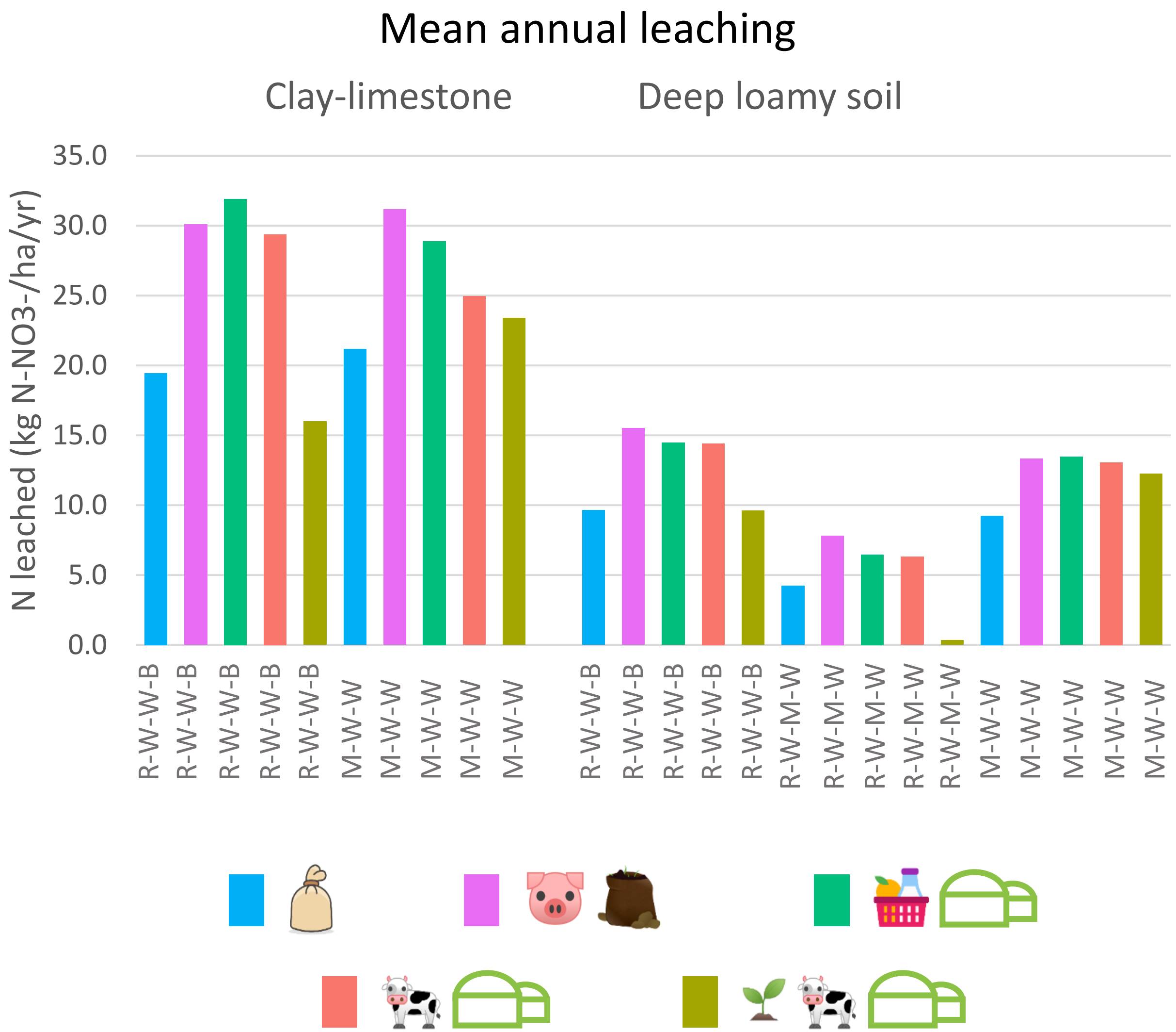
- More leaching under clay limestone than deep loamy soils because of soil depth and pebbles



Results

Leaching

- More leaching under clay limestone than deep loamy soils because of soil depth and pebbles
- Application of EOM tends to increase leaching [+19;+86]%
  - More total N inputs
  - N is continuously mineralized but soil cover isn't continuous



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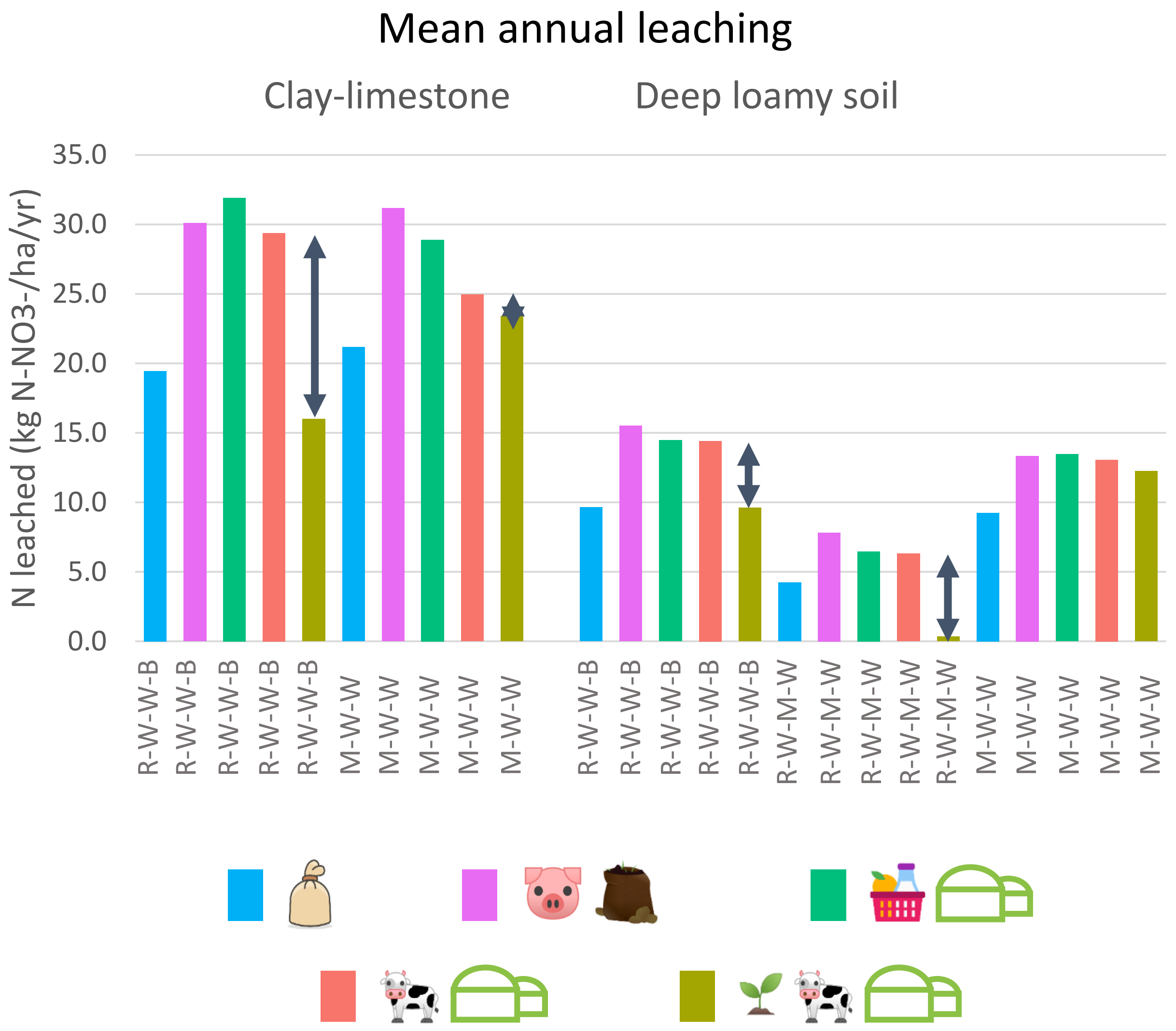
- CCES reduce leaching compared to reglementary catch crops [-6;-95]%
  - Summer cover reduces leaching during winter wheat
  - Longer winter cover



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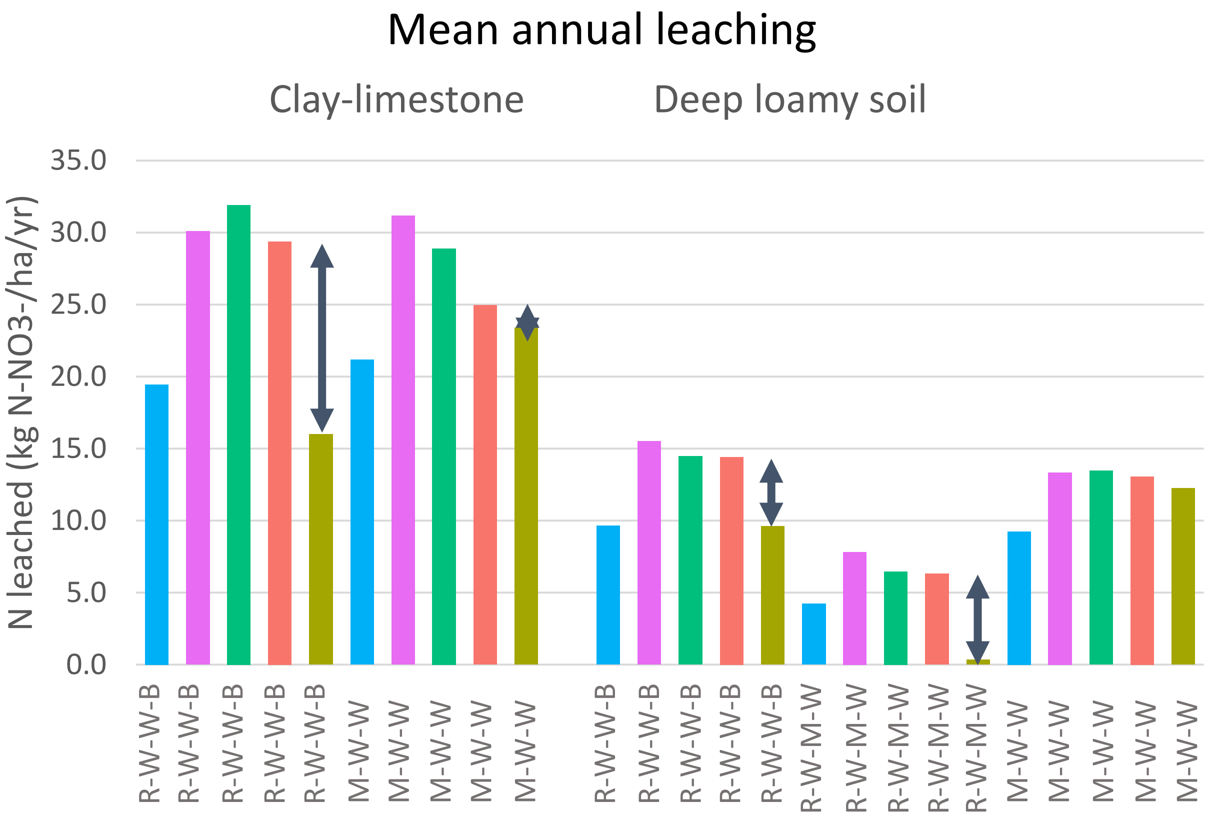
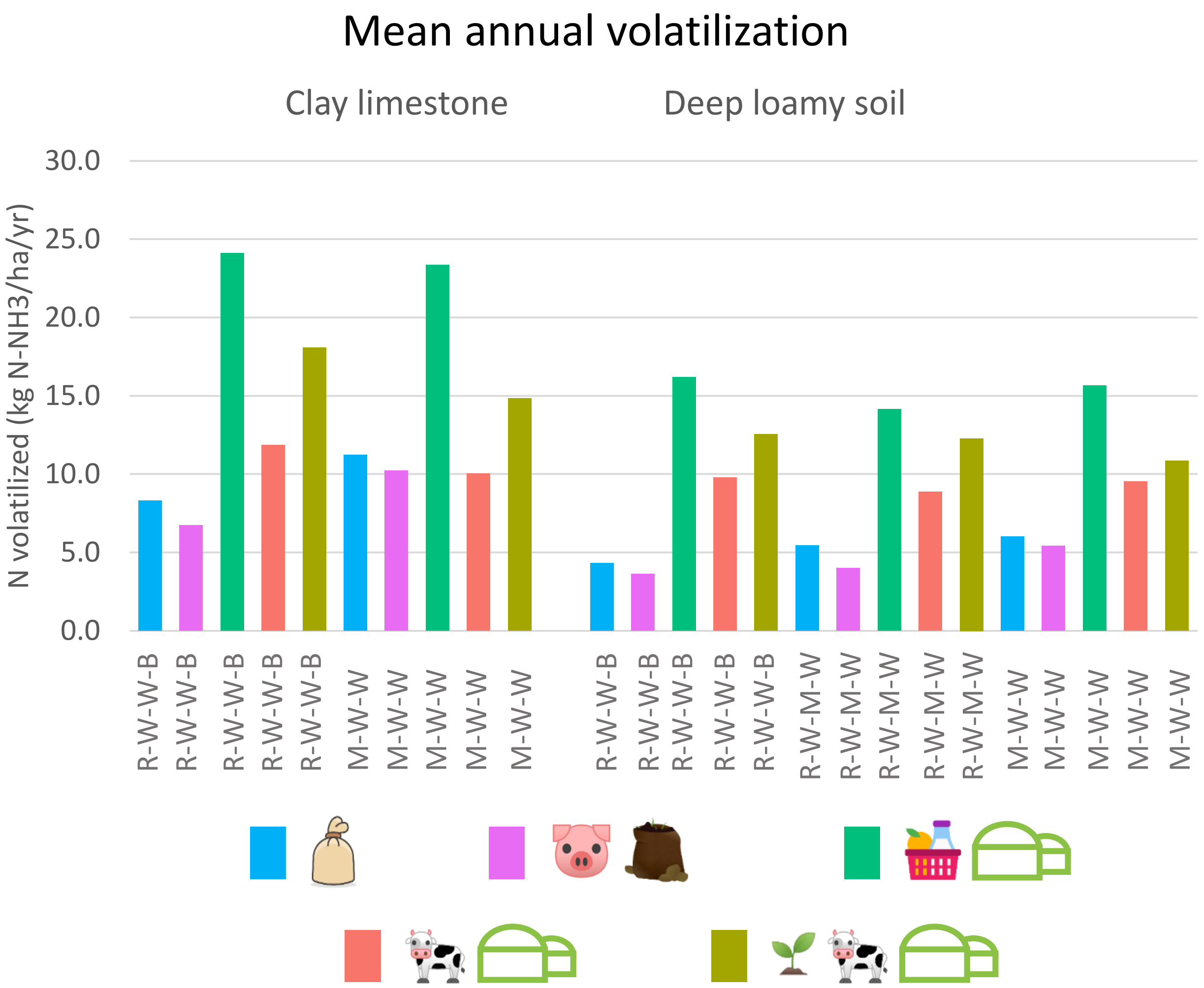


Leaching represents a loss up to **17%** of total N supply in digestate scenarios, CCES can reduce this percentage to **0,2%**

Results

Gaseous losses (N_2O and NH_3)



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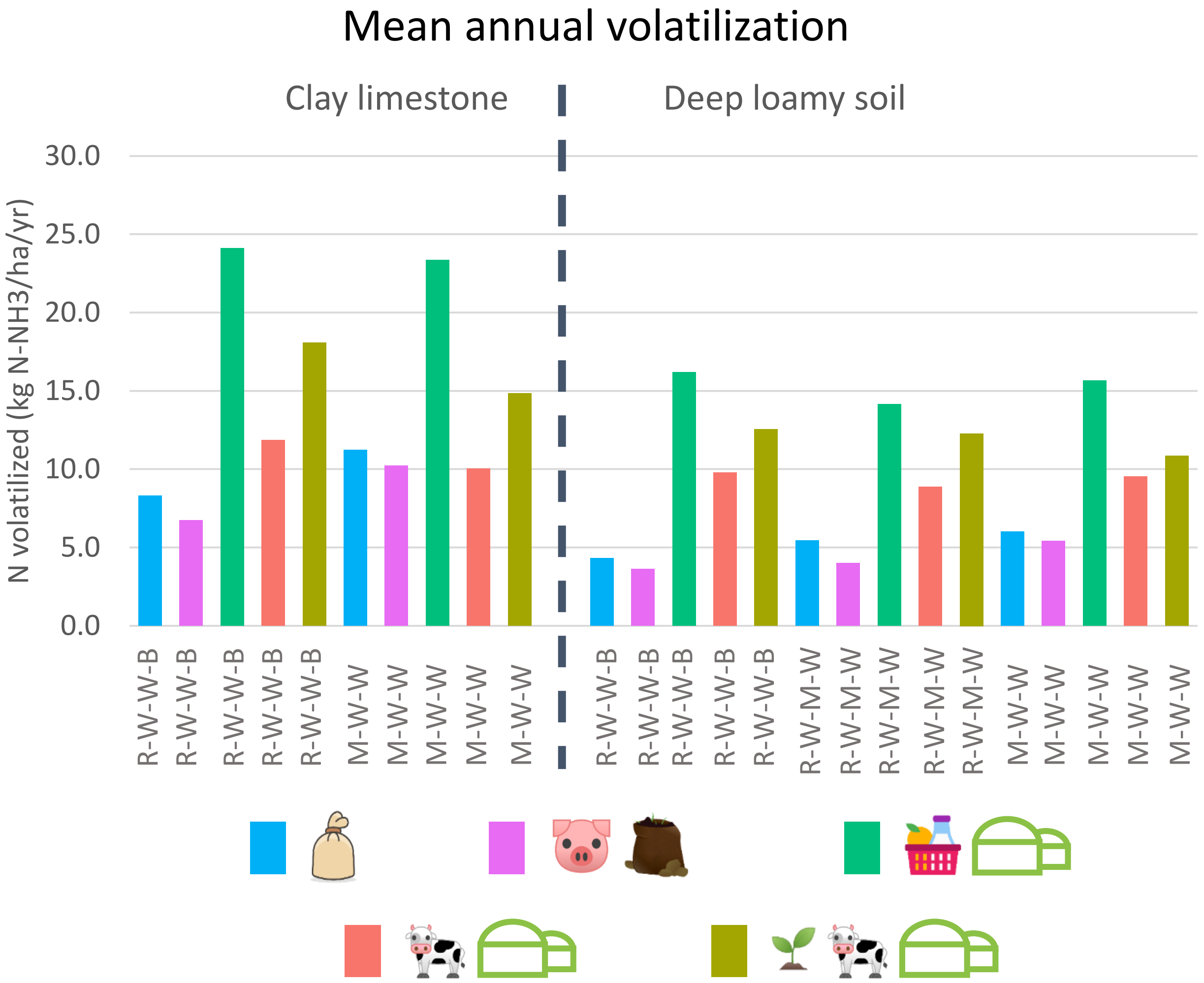

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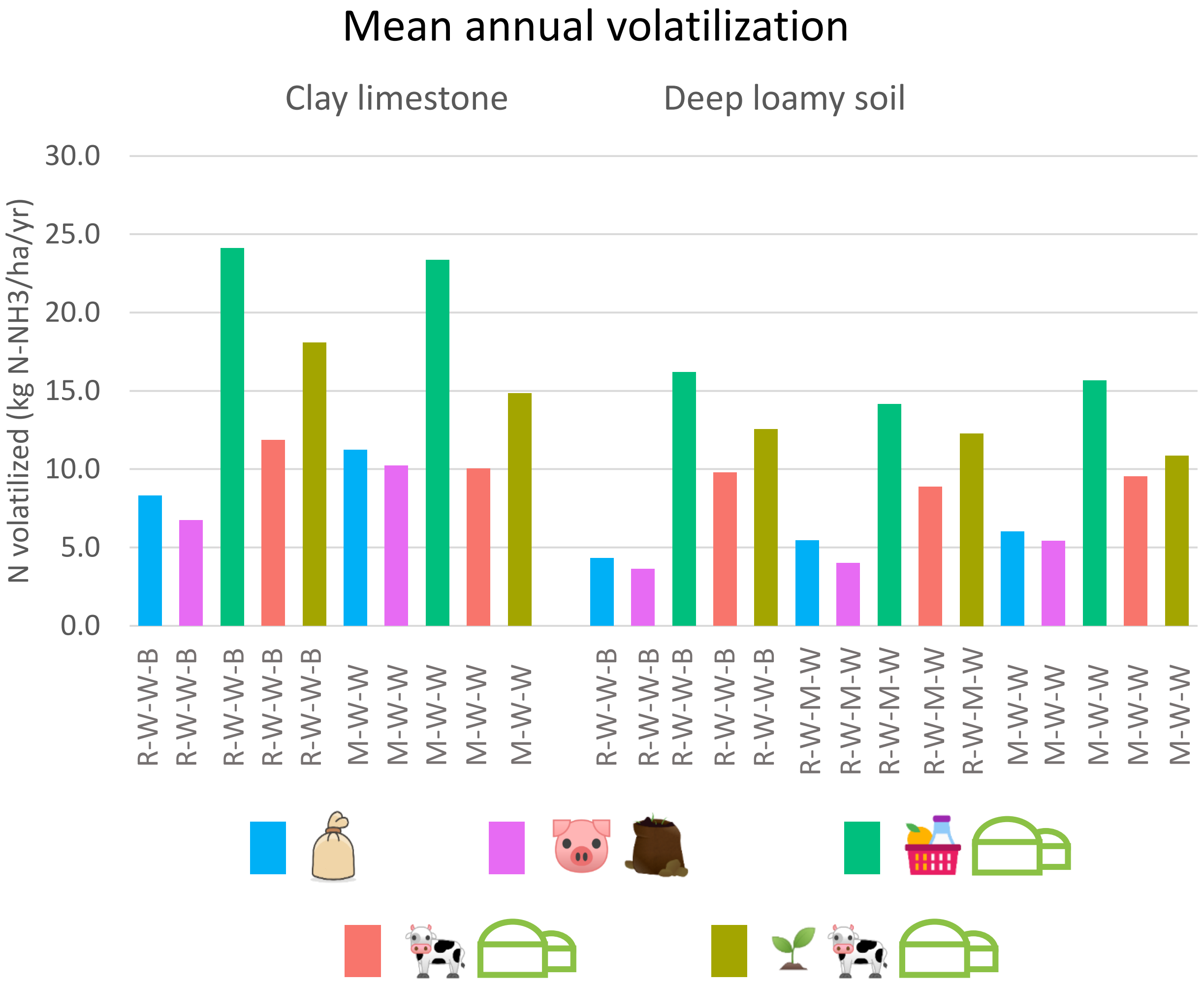

- Higher volatilization on clay limestone than deep loamy soils because of higher pH
- Digestate inputs increase volatilization compared to mineral control and actual EOMs use (x1 – x3,7)
  - 2x more N from organic matter inputs (93 -> 170 kg N/ha/an)

Results

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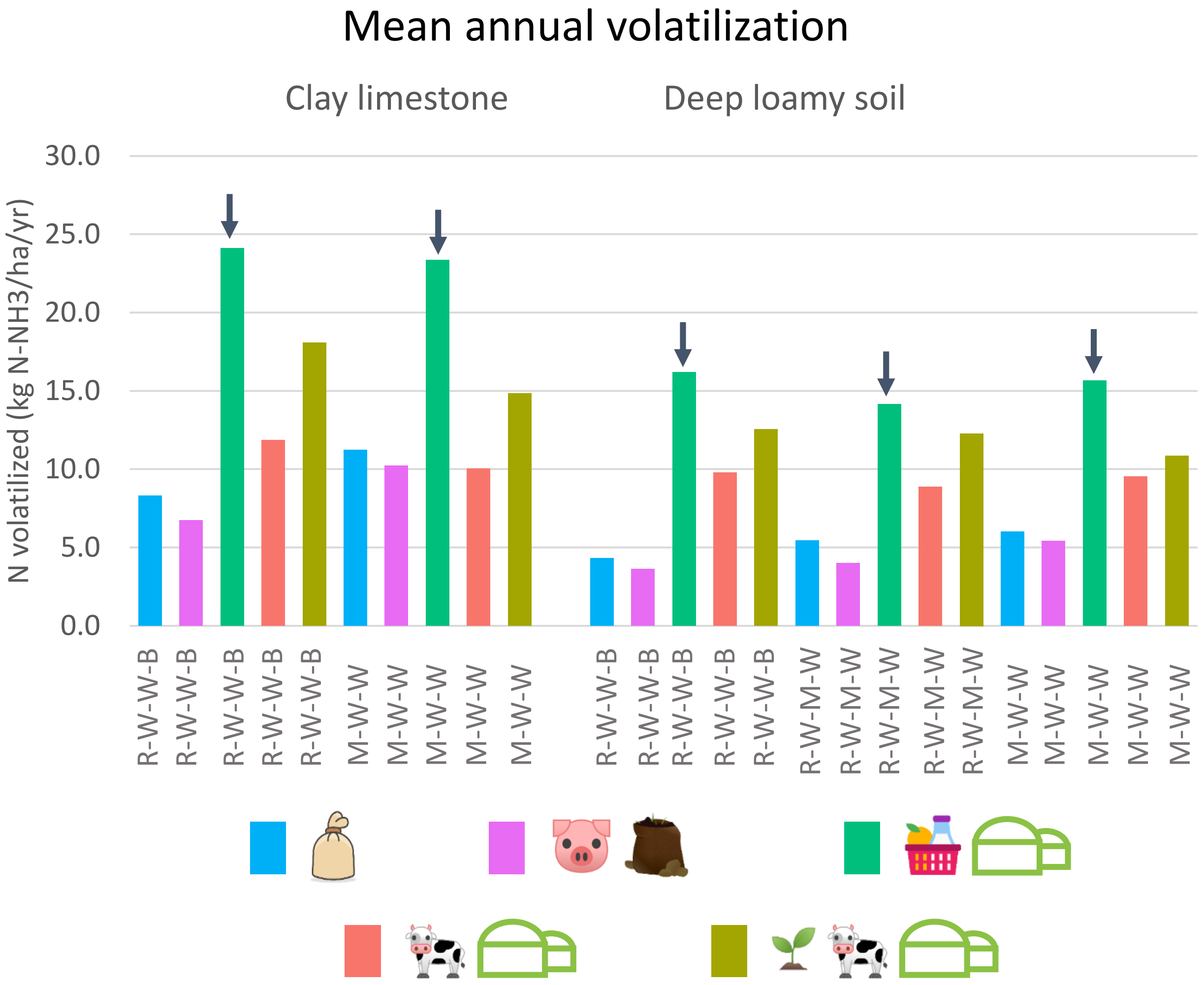

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- Among digestate scenarios, the food-based digestate loses the most of NH_3
    - Combination of applied quantity, mineral N content, water content and incorporation

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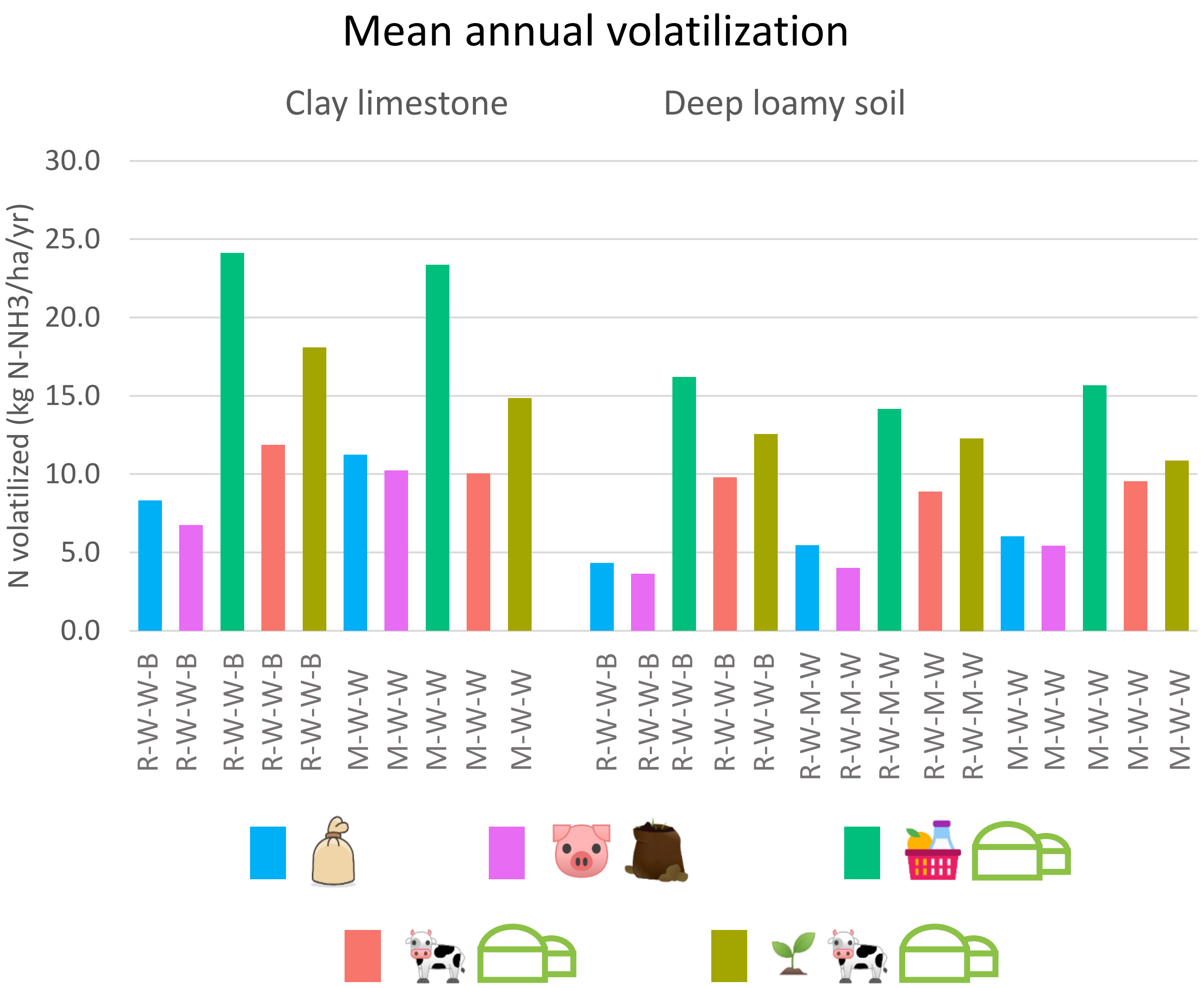

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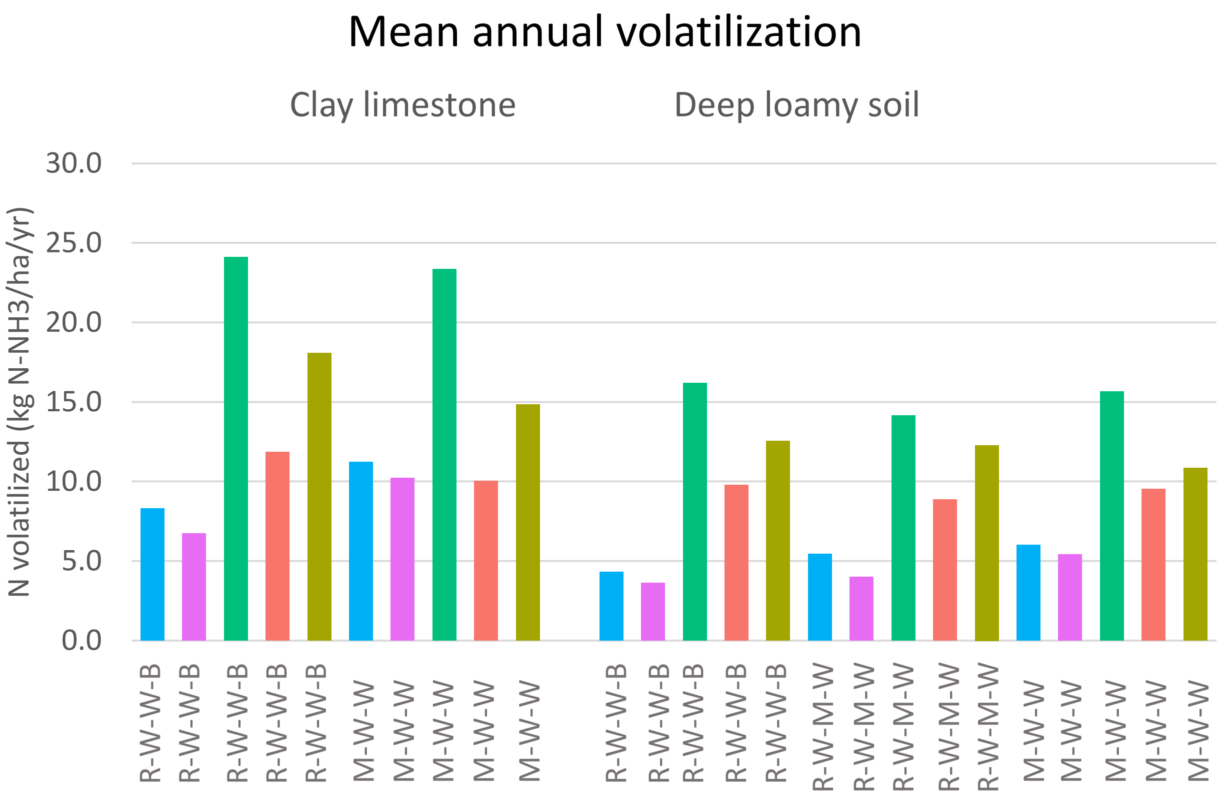
Ammonia volatilization represents a loss up to 20% of mineral N supply or **12%** of total N supply in digestate scenarios

Results

Gaseous losses (N_2O and NH_3)



N_2O emission represents a loss lower than **2%** of total N supply in digestate scenarios

- Higher volatilization on clay limestone than deep loamy soils because of higher pH
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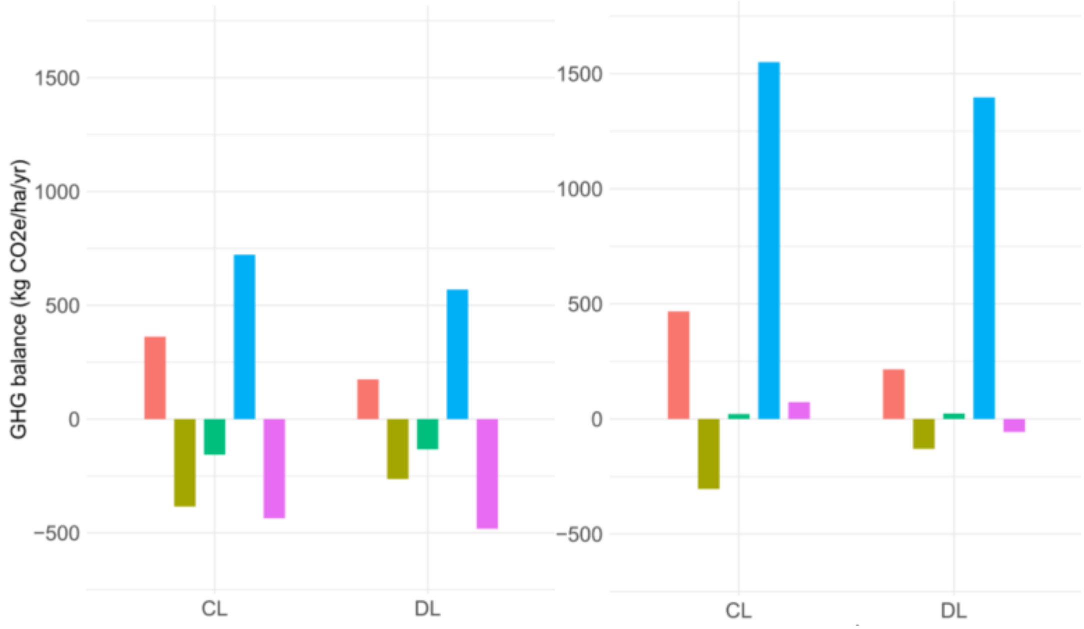
Ammonia volatilization represents a loss up to 20% of mineral N supply or **12%** of total N supply in digestate scenarios

Results

Greenhouse gas (GHG) balance

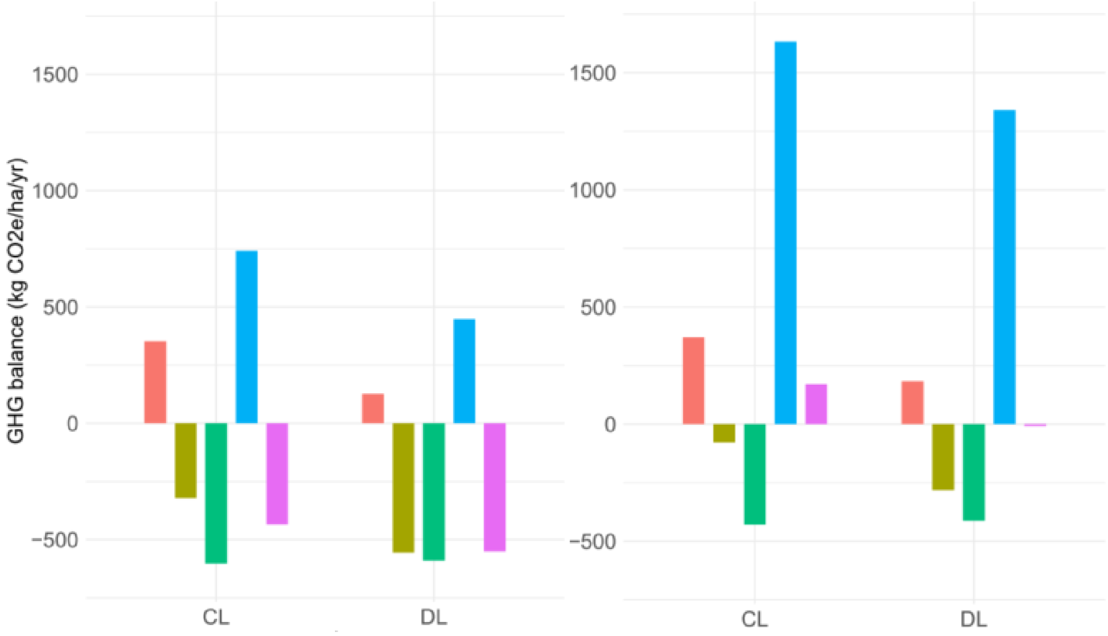
$$GHG_b = 296.\frac{44}{28}(direct\ N_2Oe + 0{,}01.N\ volatilized + 0{,}0075.N\ leached) - \frac{44}{12}\Delta SOC_{0-30} + 5{,}34.synthetic\ N$$ [1]



Without synthetic fertilizer production

Rotation 1

With synthetic fertilizer production



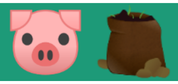
Without synthetic fertilizer production

Rotation 3

With synthetic fertilizer production

[1] Adapted from Autret, B., Beaudoin, N., Rakotovololona, L., Bertrand, M., Grandeau, G., Gréhan, E., … Mary, B. (2019). Can alternative cropping systems mitigate nitrogen losses and improve GHG balance? Results from a 19-yr experiment in Northern France. *Geoderma*, *342*(December 2018), 20–33. https://doi.org/10.1016/j.geoderma.2019.01.039

Conclusion

					
Leaching	+	+ +	+ +	+ +	+
Volatilization	+	+	+ + + +	+ +	+ + +
N_2O emissions	+	+ +	+ + +	+ + +	+ + +
C storage		+ + +	+ + +	+ +	+ + +
GHG balance	+ +	+ +	+ +	+	+ +
Synthetic N use	+ + + +	+ + +	+ +	+	+ +

- Leaching and volatilization are the biggest losses of N from digestates

Conclusion

Leaching	+	+ +	+ +	+ +	+
Volatilization	+	+	+ + + +	+ +	+ + +
N_2O emissions	+	+ +	+ + +	+ + +	+ + +
C storage		+ + +	+ + +	+ +	+ + +
GHG balance	+ +	+ +	+ +	+	+ +
Synthetic N use	+ + + +	+ + +	+ +	+	+ +

- Leaching and volatilization are the biggest losses of N from digestates
- Insertion of CCES reduces the negative impact of digestates on water quality (leaching) without compromising C storage.

Conclusion

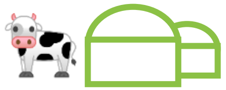
Leaching	+	+ +	+ +	+ +	+
Volatilization	+	+	+ + + +	+ +	+ + +
N_2O emissions	+	+ +	+ + +	+ + +	+ + (+)
C storage		+ + +	+ + +	+ +	+ + +
GHG balance	+ +	+ +	+ +	+	+ +
Synthetic N use	+ + + +	+ + +	+ +	+	+ +

- Leaching and volatilization are the biggest losses of N from digestates
- Insertion of CCES reduces the negative impact of digestates on water quality (leaching) without compromising C storage.
- Interaction crop rotation x soil x fertilization

Conclusion

Let’s go back to the territory scale

- Developing the use of CCES for anaerobic digestion induces a change in scale of production units because of the size of the potential resource :
    - ➢ 58 297 t FM harvestable

Scenario	Gaz production	Digestate production	Fertilized area	Synthetic fertilizer saved
	315 186 Nm^3/yr	7 875 t FM/yr liquid 772 t FM/yr solid	384 ha (20,5 m^3 FM/ha/yr) 77 ha (10 t FM/ha/yr)	58 752 kg N (153 kgN/ha/yr)
	3 979 429 Nm^3/yr	44 756 t FM/yr liquid 15 715 t FM/yr solid	961 ha (47 m^3 FM/ha/yr) 1526 ha (10 t FM/ha/yr)	123 008 kg N (128 kgN/ha/yr)

The end