Changes in cropping systems associated with biogas plants in French cereal-growing areas

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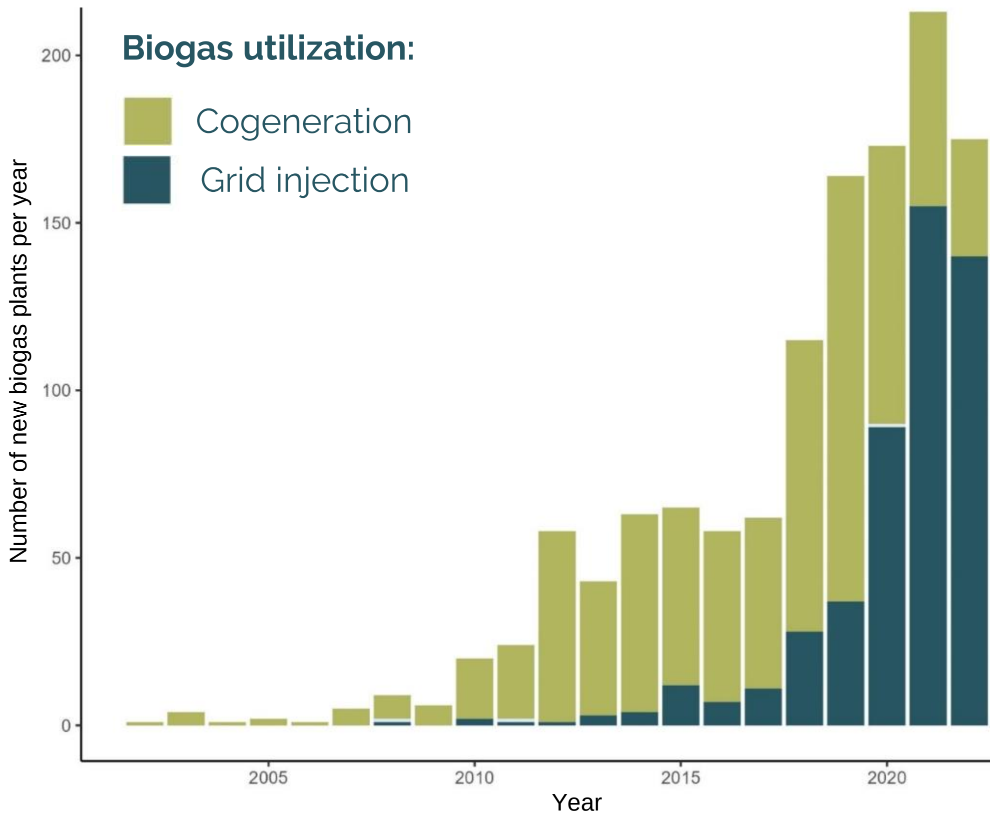
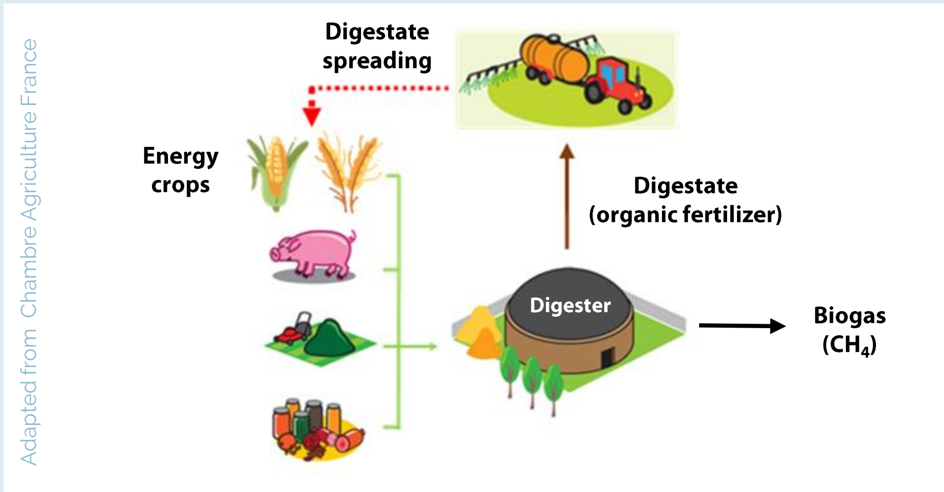
METAPROGRAMME CLIMAE

Context

> **Rapid growth of anaerobic digestion (AD) in Europe and more recently in France, with AD mainly relying on agricultural inputs**



Evolution of number of biogas plants per year between 2002 and 2022 in France
(Extracted from SINOE database, ADEME, 08/12/2023)



Principle of biogas production

Biogas production is promoted as it allows:

- Substitution of fossil energy with **renewable energy**
- Improvement of farmers' autonomy (financially and in terms of fertilizer)

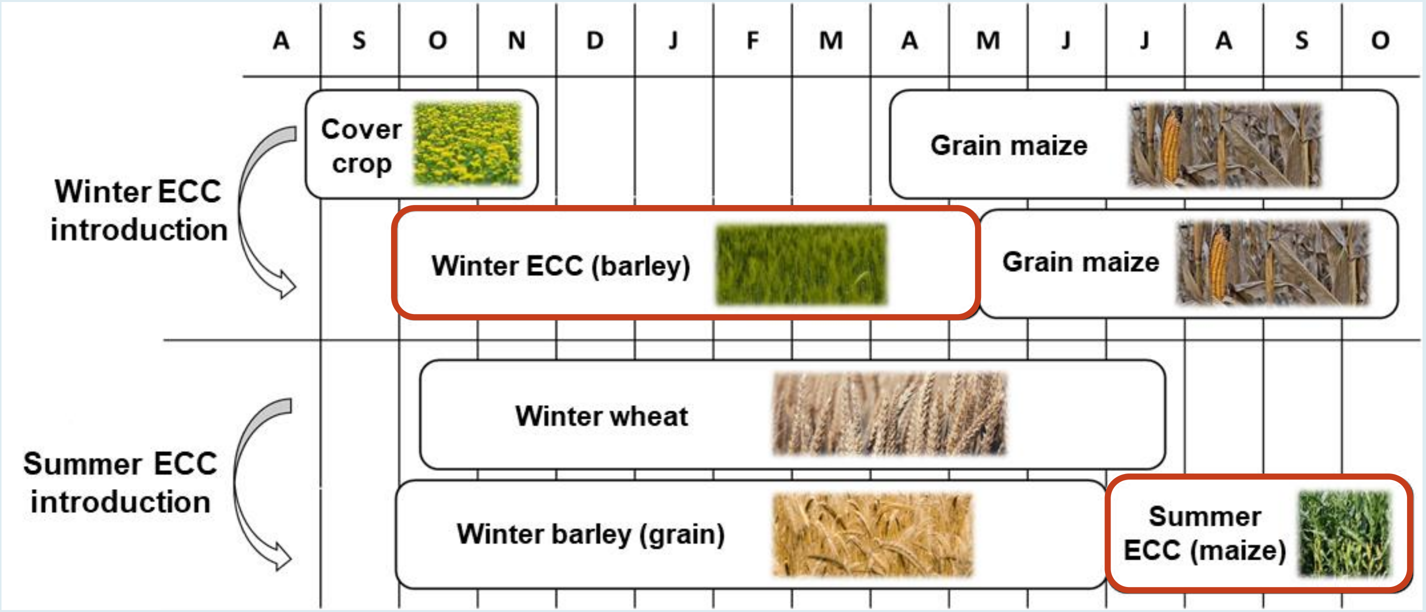
Context

> **Biogas production without manure, mainly based on energy cover crops** (ECC) **and agro-industrial waste has surged in France**

> **ECC are expected to become the main input for biogas plants in France and in Europe in the coming decades** *(Béline et al. 2023; Brémond et al., 2023)*

➔ ECC are grown **between two main crops** and have **limited impact on food production**, contrary to main crops produced for biogas

➔ **No limit to the amount of ECC that can be added to the digester in France**, contrary to main energy crops (15% of the annual feedstock gross tonnage in the digester)



Examples of crop rotations without and with ECC

Figure: F. Levavasseur

Context

> Growing ECC can have either positive or negative impacts on cropping systems:

Rye grown as ECC
Source : reference-agro.fr

➔ Positive:

- Reduction in GHG emissions with the use of digestate instead of chemical fertilizers (Bacenetti et al. 2016 ; Esnouf et al. 2021 ; Hijazi et al. 2016)
- Nitrogen leaching reduction (Heggenstaller et al. 2008, Malone et al. 2018)
- Soil carbon storage through roots and digestate spreading (Launay et al. 2022, Levavasseur et al. 2022)

➔ Negative:

- Potential yield loss on crop following winter ECC (Marsac et al. 2019)
- Soil compaction following silage and digestate spreading (Lantz and Börjesson, 2014)
- Potential increase in fertilizer, pesticide or water use at the farm scale (Launay et al., 2022)

Objective

➔ Despite the anticipated impacts of energy cover crops for biogas, cropping systems involving ECC remain understudied regarding farmers' practices

➔ AD environmental assessments* are based on theoretical practices, potentially disconnected from farm practices

Objective

Characterize the cropping system changes associated with AD in French cereal-growing areas

Source: Photolia

* (Bacenetti et al. 2016 ; Berger et al. 2022 ; Esnouf et al. 2021 ; Malet et al. 2023 ; Nilsson et al. 2024 ; Riau et al. 2021 ; Styles et al. 2015)

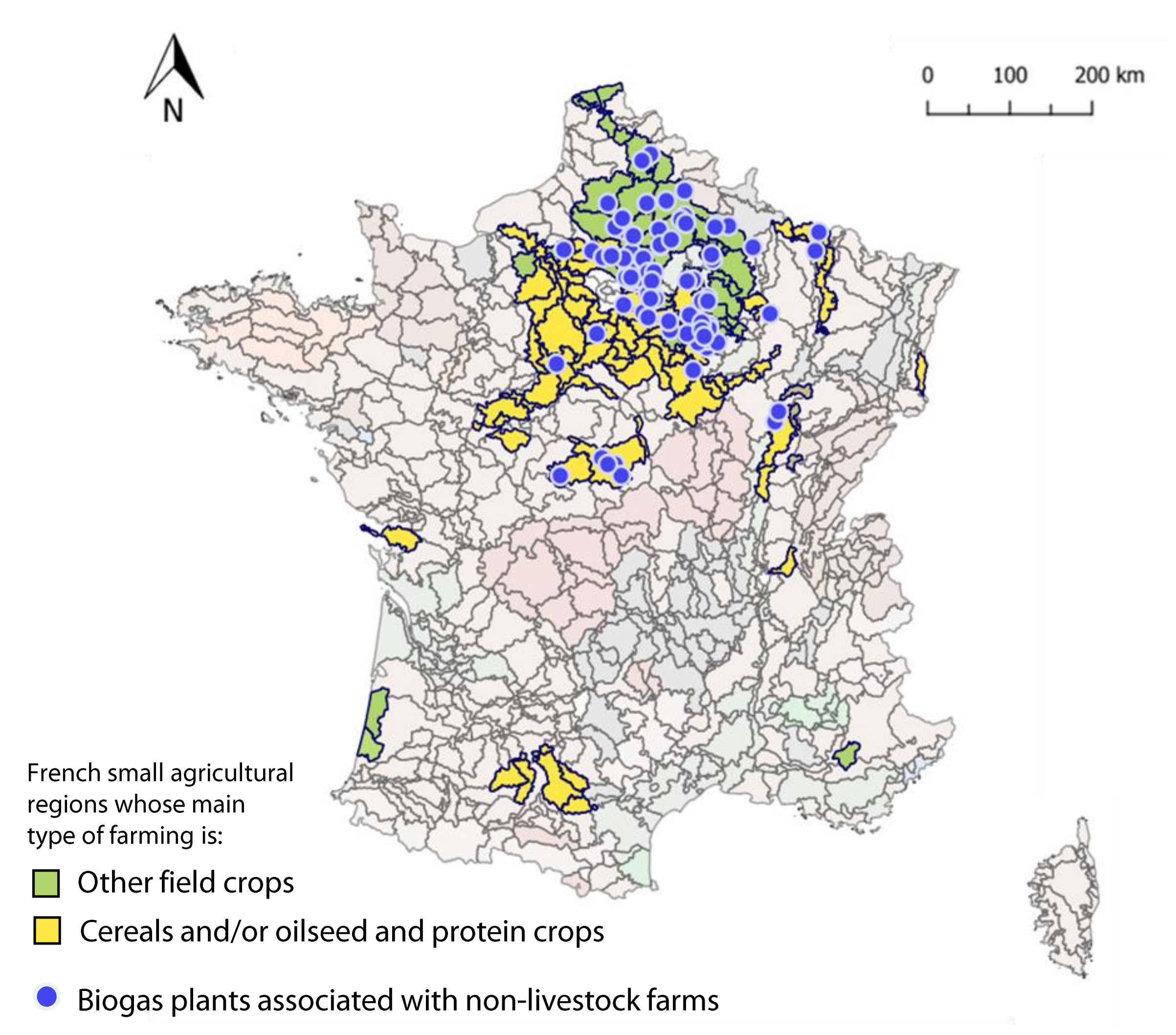
Methods

➔ **Semi-structured interviews with non-livestock farmers owning a biogas plant** in French cereal-growing areas between end 2020 and beginning 2023
(33 farms associated with 24 biogas plants)

➔ **Interview guide focusing on**:

- Farm scale changes linked with AD (crop rotations, fertilization use, level of pesticides applied…)
- ECC management practices
- Digestate management and associated fertilizer savings

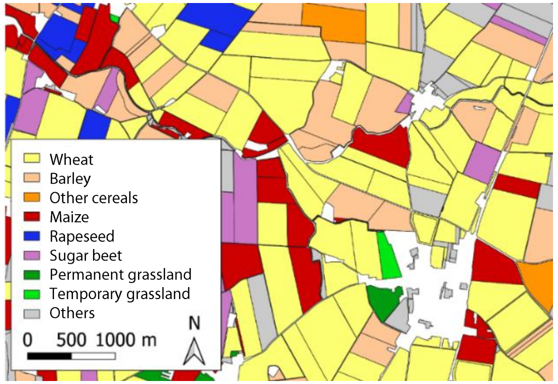
Map of biogas plants in French cereal-growing areas in 2021
(biogas plants to interview are represented in blue)



Methods

> Quantitative and qualitative analysis of the interviews were supplemented with the following calculations:

Comparison of main crop land cover changes before and after anaerobic digestion start-up



> Land cover of farms from 2007 to 2021 were obtained from French Land Parcel Identification System (LPIS)

> **Mean land cover** of interviewed farms before and after AD were compared with the following method:

Y : start-up year of the biogas plant						
Y-4	Y-3	Y-2	Y-1		Y+1	Y+2
Before				After		

Simplified N, P and K balances at the farm scale, in order to determine theoretical fertilizer savings

> For example, simplified N balance after AD is calculated as follows:

$$\Delta N_{ferti} = \sum \left(\text{N exports of main crops} + \textbf{ECC} \right) - \text{Efficient N from digestate}$$

(50% of N available for plant)

Source: SipalingPNG

Source: The Silage Consultant

> **Balances before and after AD are then compared:** if it is **<u>lower after AD</u>**, potential **<u>fertilizer savings are theoretically achievable</u>**

Results

Most encountered ECC during interviews

Winter ECC

Winter barley

Rye

Mean yield ~ 10 t DM.ha^{-1}

Summer ECC

Maize

Sorghum

Mean yield ~ 8 t DM.ha^{-1}

➔ **30% of farm surfaces dedicated to ECC production** in average (n = 33 farms)

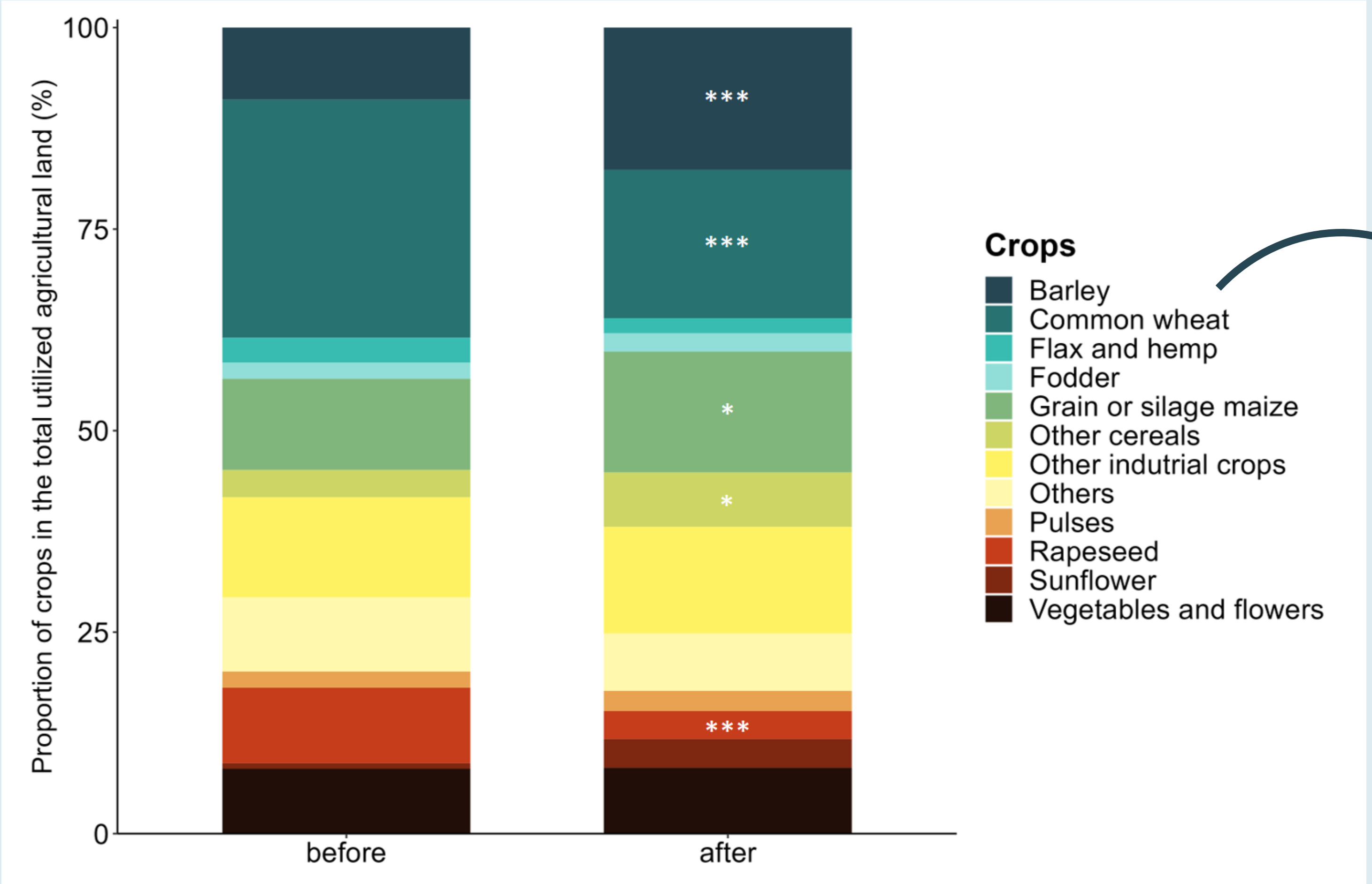
➔ **Growing preference for winter ECC instead of summer ECC** (more stable yield)

ECC management

- **Plant protection product usage:** 30 farms out of 33
  Level of pesticides lower than what is applied on main crops (~50%)
- **Mean fertilization rate:** 133 kg N_{eff}.ha^{-1} on winter ECC
  106 kg N_{eff}.ha^{-1} on summer ECC
- **Summer ECC irrigation:** 17 farms out of 33
- **Varying yield loss on main crops following winter ECC:** -10 to -40%
- **Practices more intensive than those considered in the environmental assessments of anaerobic digestion**

Results

> Significant land cover changes on main crops were observed after AD, due to the introduction of ECC



Mean land cover changes on main crops before and after AD of the interviewed farms

(significant changes are specified by stars (*) p<0.05 ; (***) p<0.001)

Maize, **barley** and **other cereal** surfaces increased while **common wheat** and **rapeseed** surfaces decreased, as their growth period is too long to grow ECC

Results

> Digestate management practices of interviewed farms

➔ **Reported fertilizer savings varied significantly across farms**, ranging from **0% to -60%** of purchased fertilizer volume per year

➔ All interviewed farms used **umbilical systems with trailing hoses** to spread digestate, thus **limiting NH_3 volatilization and soil compaction**

Source: LB Visuel - Tramspread

Digestate spreading using an umbilical system with trailing hoses

Comparison of simplified N balance of the crop systems before and after AD
(P and K results were similar)

(missing information for 9 farms)

17 farms out of 24:

N balance after AD < N balance before AD

Fertilizer savings theoretically achievable

7 farms out of 24:

N balance after AD > N balance before AD

No potential fertilizer savings

➔ Calculated theoretical fertilizer savings **were positively correlated with the amount of agro-industrial waste added to the digester**

Conclusion

1

- Cropping systems in **French cereal farms associated with AD** are **more intensive** than expected (pesticide use and occasional irrigation on ECC, yield loss on main crops following winter ECC, land cover changes . . .)
- **These practices differ from those considered in AD environmental assessments***

➔ **Need to reevaluate AD's environmental impacts taking into account real farming practices to ensure the sustainability of energy transition**

2

- **Half** of the interviewed farms **irrigated their summer ECC**, while **farms without irrigation** experienced **highly fluctuating yields**

➔ **This raises concerns about the resilience of these systems in the face of climate change**

3

- ECC impacts on **food production** are **less severe** than those of energy crops, but **significant land cover changes** were observed, as well as **potential yield losses** in subsequent crops following winter ECC

➔ **This raises the question of where to produce the displaced crops (iLUC issues) and the competition between food and energy crops**

4

- Achievable fertilizer savings are **highly dependent** on the **amount of agro-industrial waste** added to the digester

➔ **This reliance could reduce farmer autonomy, as they become dependent on the waste market and its rising prices**

*(Bacenetti et al. 2016 ; Berger et al. 2022 ; Esnouf et al. 2021 ; Malet et al. 2023 ; Nilsson et al. 2024 ; Riau et al. 2021 ; Styles et al. 2015)

Thank you for your attention

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