Digestates from cover crop, straw and cattle slurry mixtures as nutrient source in organic cropping system

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INTRODUCTION

Yields in organic arable farming are way below the potential. The reasons are due to the lack of nutrients and poor synchrony between nutrient availability and crop demand (Möller and Müller, 2012). Nitrogen (N) is often the most limiting nutrient for biomass production. Nitrogen available in soil is taken up by plant almost exclusively in mineral form. Yet, limitation of mineralized N in soil is often the problem especially in organic farming. In crop management systems using only organic substrates, the challenge is to increase the N mineral fertilizer value of organic substrates in order for organic farming to rely on organic fertilizer sources. Anaerobic digestion has the potential to increase the nutrients availability (Webb et al., 2013). Cover crops (CC) are useful to reduce nutrient leaching losses and they have the potential to produce extra biomass for biogas production. If a CC with symbiotic N fixation is used the CC can also contribute with extra N to the system. The biomass production in cover crops is influenced by the main crop harvest time and probably by the straw management. The aim of the current study is to quantify the influence of main crop harvest time and straw management and the inclusion of anaerobic digestion of cover crops and straw on N utilization and on potential biogas production. A comparison between mono- and co-digestion of cover crops, straw and cattle slurry is also included.

MATERIALS AND METHODS

In 2017, a field experiment was established with spring barley and an under-sown cover crop (mixture of red clover, grass and chicory) comparing early and late barley harvest time and different straw management, including a treatment with high stubble. The harvested CC was ensiled and used for digestion tests in pilot digesters.

Seven continuous stirred tank reactors (CSTRs) with 15L working capacity running at thermophilic temperature (51°C) were daily fed with different substrates as described in Table 1. The experiment was running for 85 days which represents more than 3 hydraulic retention time (HRT). Gas composition was measured twice a week using a gas chromatograph. Total Kjeldahl Nitrogen, ammonium nitrogen (NH_4^+-N), pH and dry matter (DM) of the digestates, silages and cattle manure were measured at the end of the experiment.

In 2018, the fertilizer value of cattle manure, digestates and raw silages from continuous experiment is tested in a new spring barley crop in confined microplots. Initially, the different fertilizers were placed at 10 cm depth to avoid ammonia volatilization and to simulate an injection before sowing the spring barley. The concentration of total N applied was similar for each fertilizer (approximately 100 kg N/ha). Mineral N fertilizer at 4 different N levels were also included as a reference. Yields and N uptake of spring barley will be measured and the fertilizers value of digested materials will be compared with corresponding raw silages and cattle manure. In addition, the fate of N in the system with different silage mixtures and digestion management (mono- vs. co-digestion) will be compared.

RESULTS AND DISCUSSION

The dry matter (DM) yield of CC in October was 2.5 t/ha (74±5 kg N/ha) by early barley harvest and 2.3 t/ha

(72±4 kg N/ha) by late harvest. By early barley harvest and high stubble an extra dry matter yield of 1.1 t/ha (8±1 kg N/ha) was obtained in October. The CC:straw fraction varied between 3.8:1 (fresh weight basis) if the straw was harvested late and removed from the field before being mixed with catch crop, and 11:1 if the high stubble of straw was harvested together with the catch crop in October.

Tab. 1: Mixtures of catch crops (CC), cattle manure (CM) and straw used in AD tests

Reactor	Substrates				Digestion management
		% silage	% CM	% water	
R1	CC:straw 1:0	75	-	25	Mono-digestion
R2	CC:straw 10:1	39	-	61	Mono-digestion
R3	CC:straw 3:1	31	-	69	Mono-digestion
R4	CC:straw 1:0 + CM	63	17	20	Co-digestion
R5	CC:straw 10:1 + CM	30	33	37	Co-digestion
R6	CC:straw 3:1 + CM	20	38	42	Co-digestion
R7	Cattle manure	-	100	-	-

The results from anaerobic digestion is summarized in Table 2. Anaerobic digestion increases the fraction of NH_4^+ in total N, for example an increase from 0.07 to 0.41 in R1 was observed after AD. This increase was lower for reactors fed with higher ratio of straw in the silage mixture such as R3 and R6 where the fraction of NH_4^+ in total N increased from 0.08 to 0.26 and from 0.36 to 0.52, respectively.

Tab. 2: Chemical composition of substrates and digestates before and after AD, and methane yields from CSTRs

Reactor	DM after AD (%)	pH after AD	Total N before AD (kg N/ton)	Total N after AD (kg N/ton)	NH_4^+-N/total N before AD	NH_4^+-N/total N after AD	CH_4 yield (ml CH_4/ g VS)
R1	5.34	7.94	3.20±0.05	3.06±0.01	0.07	0.41	323±36
R2	4.8	7.66	1.48±0.03	1.84±0.01	0.07	0.37	216±35
R3	5.53	7.42	1.38±0.02	1.36±0.01	0.08	0.26	184±49
R4	5.55	8.14	3.42±0.04	3.36±0.04	0.17	0.48	317±45
R5	4.74	8.05	2.54±0.03	2.74±0.02	0.30	0.53	243±30
R6	5.99	8.05	2.48±0.02	2.48±0.01	0.36	0.52	228±29
R7	5.47	8.39	4.19±0.01	4.23±0.01	0.51	0.61	159±21

It is expected that the N fertilizer value of the materials is equivalent to their ammonium content (Webb et al., 2013) and therefore the N fertilizer value of the digestates will be higher than the undigested materials.

CONCLUSION

Harvesting the high stubble of straw together with the following CC allowed to collect 1.1 t/ha (DM) of additional biomass for biogas application. Combination of CC and straw increased the methane yield compared to the AD of straw alone. Increasing proportions of straw in the substrates decreased the proportion of mineral N in digestates derived from CC, but showed nearly no effect on the proportion of mineral N in digestates from co-digestion with manure.

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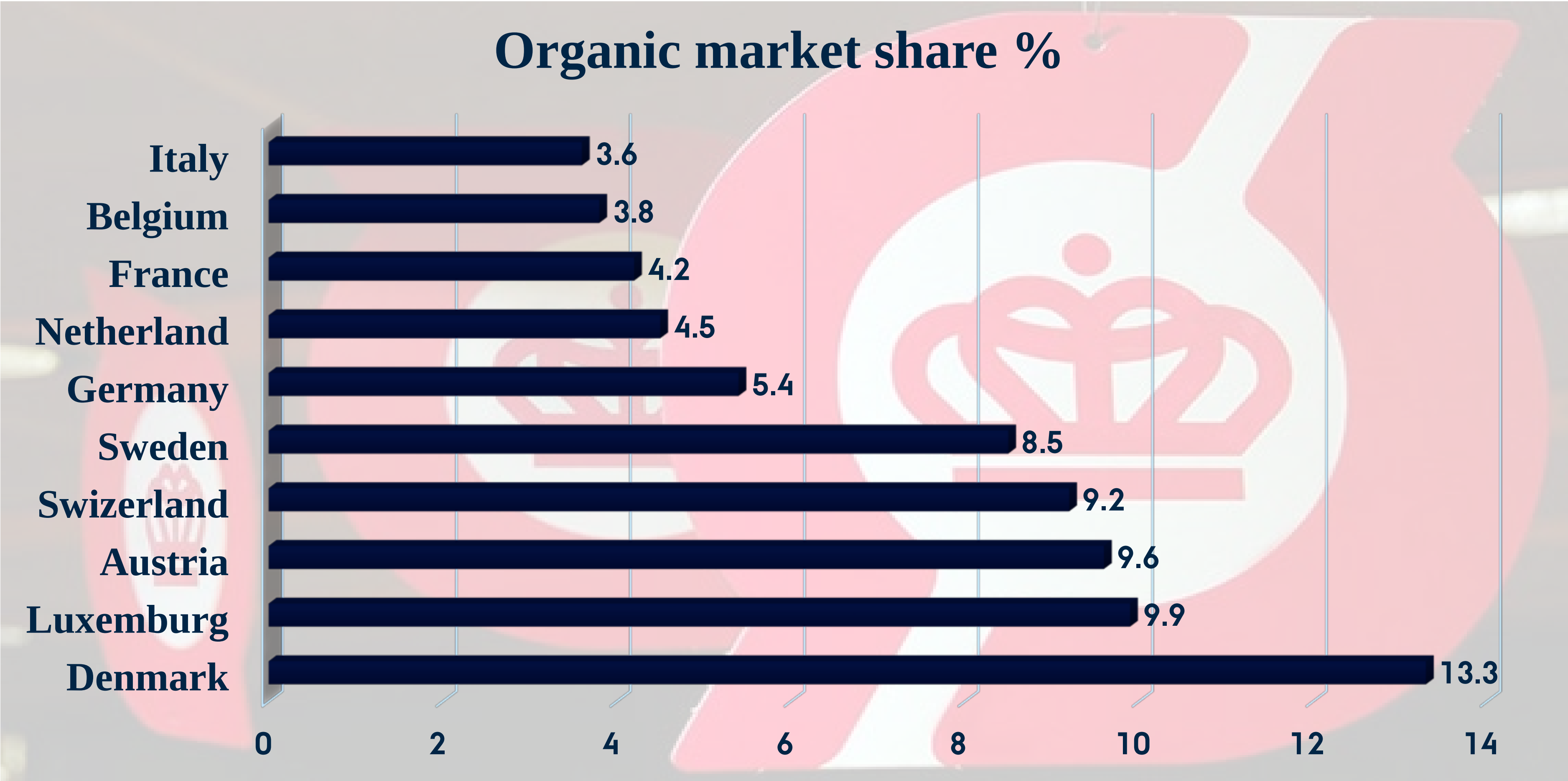
Project

NUTHY : NUTrients for Higher organic crop Yields



Source: 2017 estimate by Organic Denmark

Nutrient N limitation in organic farming

Lack of

N supply

Digestate from AD

- Organic ressources
- Higher mineral N content

Poor syn

between nutrient availability and plant demand

Improvement of N utilization

Substrates

		Harvested separately : Barley straw in Summer CC in Autumn	Harvested together : Barley straw + CC in autumn
Barley straw	(tons FM/ha)	5.0	1.8
Cover Crop (CC)	(tons FM/ha)	18.0	19.6
Ratio CC:Straw		3.6	11.0






Substrates

Barley straw

Cover crop (CC)

(88% red clover, 11% chicory, 0.5% weeds)

Silage of CC + straw with ratios 1:0, 3:1, 10:1 (w/w)

Lab-scale reactors

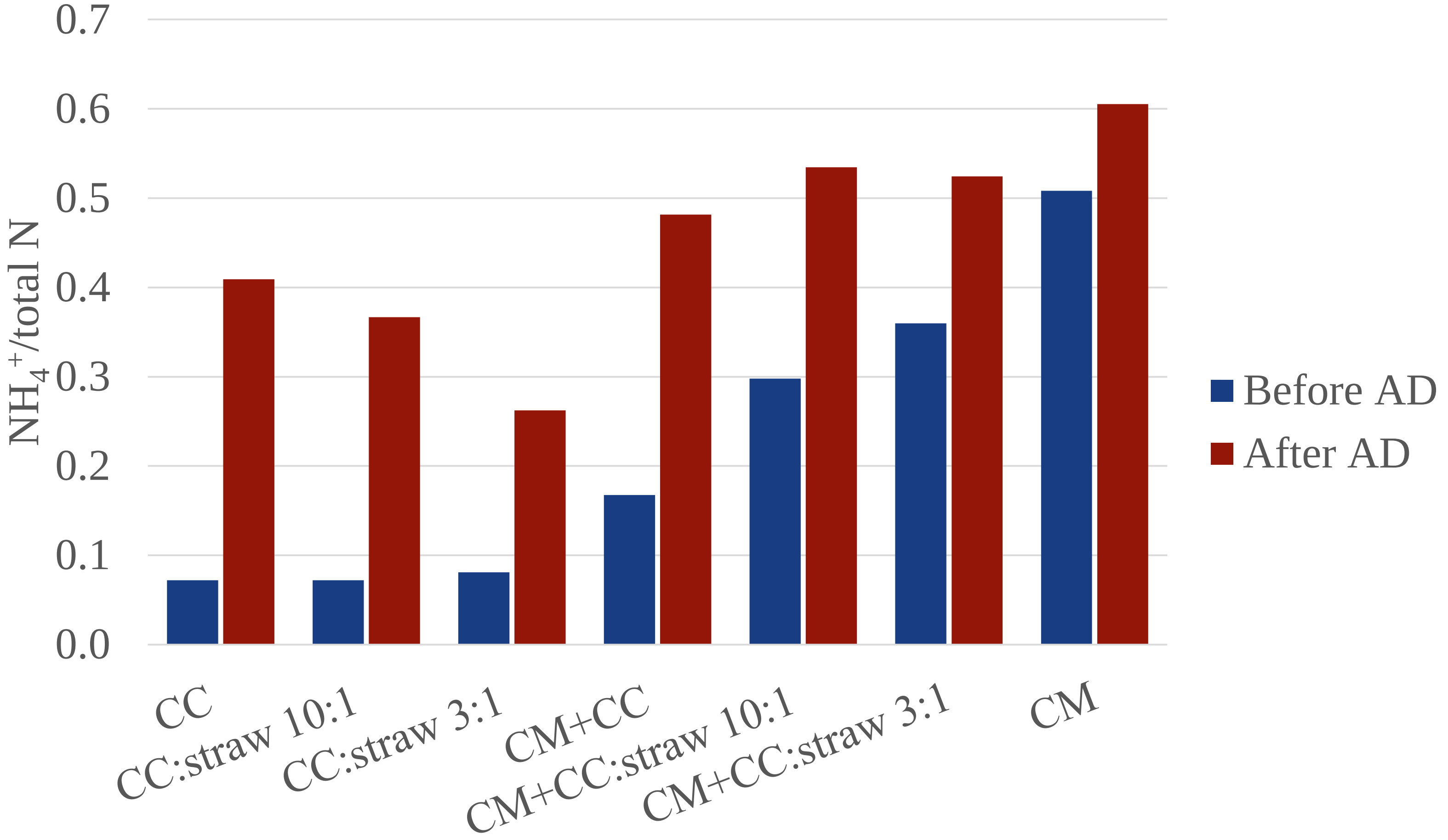
Reactor	Substrates feeding				Digestion management
	Mixtures	% silage	% CM	% water added	
R1	CC:straw 1:0	75	-	25	Mono-digestion
R2	CC:straw 10:1	39	-	61	Mono-digestion
R3	CC:straw 3:1	31	-	69	Mono-digestion
R4	CC:straw 1:0 + CM	63	17	20	Co-digestion
R5	CC:straw 10:1 + CM	30	33	37	Co-digestion
R6	CC:straw 3:1 + CM	20	38	42	Co-digestion
R7	CM	-	100	-	-

CM: Cattle manure

Substrates and digestates composition and methane yields

Feeding mixtures	VS (%)		pH	Total N (kg N/ton FM)	CH_4 yield (ml CH_4/gVS)
	before AD	after AD	after AD	After AD	
CC:straw 1:0	7.8	4.3	7.9	3.1	323
CC:straw 10:1	6.5	4.4	7.7	1.8	216
CC:straw 3:1	8.9	5.0	7.4	1.4	184
CC:straw 1:0 + CM	7.8	4.6	8.1	3.4	317
CC:straw 10:1 + CM	7.4	4.4	8.0	2.7	243
CC:straw 3:1 + CM	8.4	5.6	8.0	2.5	228
CM	7.0	4.3	8.4	4.2	159
Average reduction (-) or increase (+) between before and after AD	- 39 %		+ 0.9	0	-

Mineral N transformation



- AD increases fraction of NH_4^+ in total N
- Lowest increase for reactor fed with higher ratio of straw
- No effect on the proportion of NH_4^+ in digestates from co-digestion with manure

Field experiment in microplots

- N fertilizer response
- 15 treatments
- 1 control
- 4 references of N

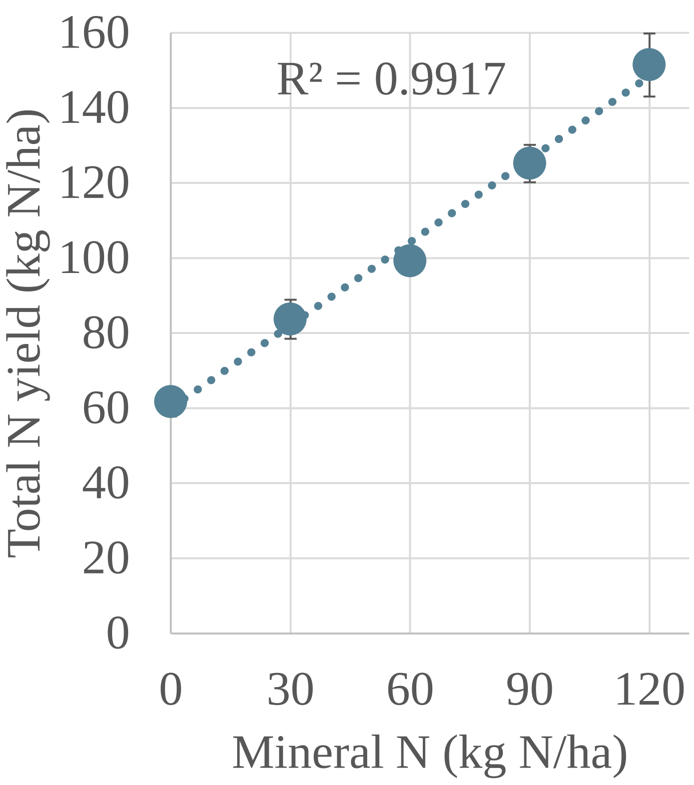
April 2018

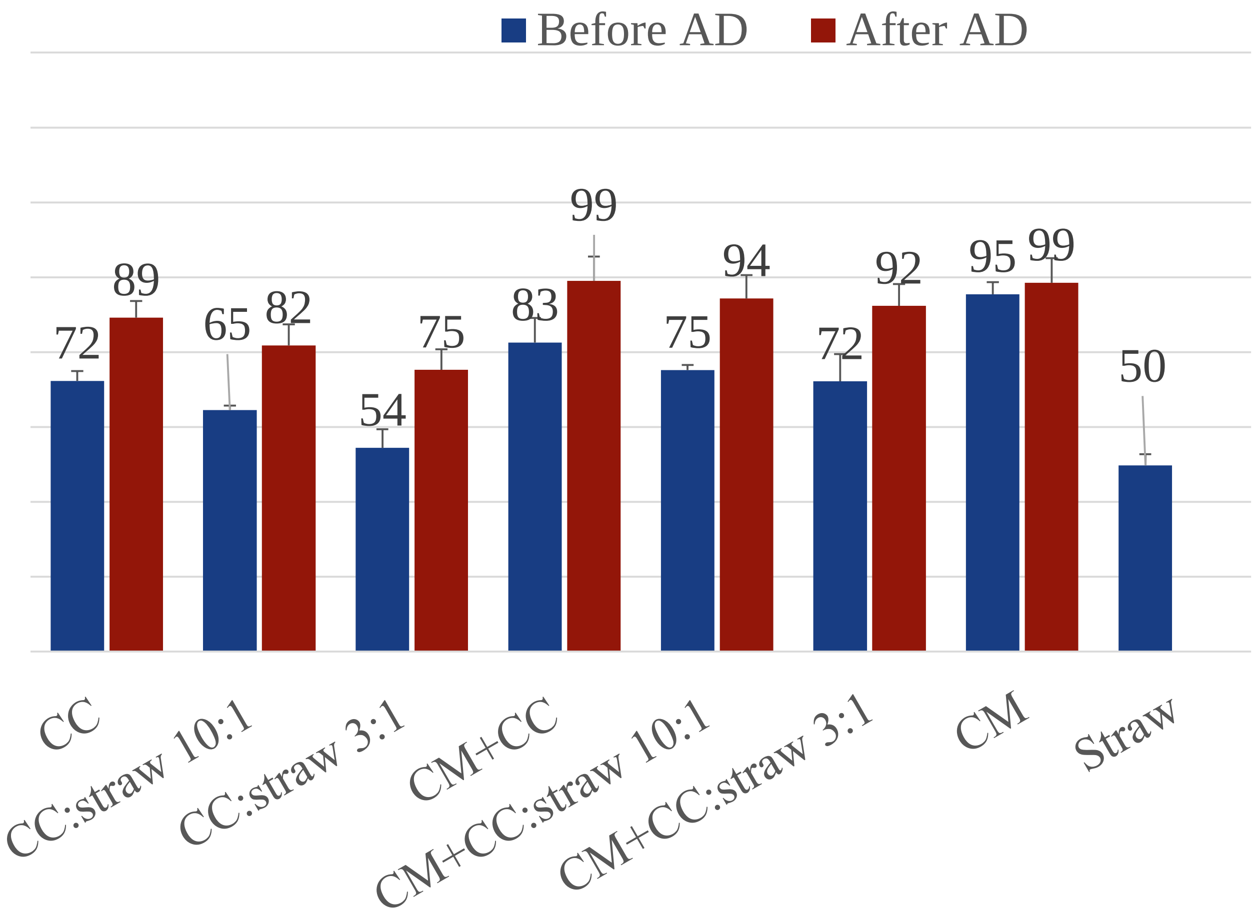
- ➢ Injection of digestates/manure
- ➢ Sowing Spring Barley

August 2018

- ➢ Harvest
- ➢ Yield response & N uptake

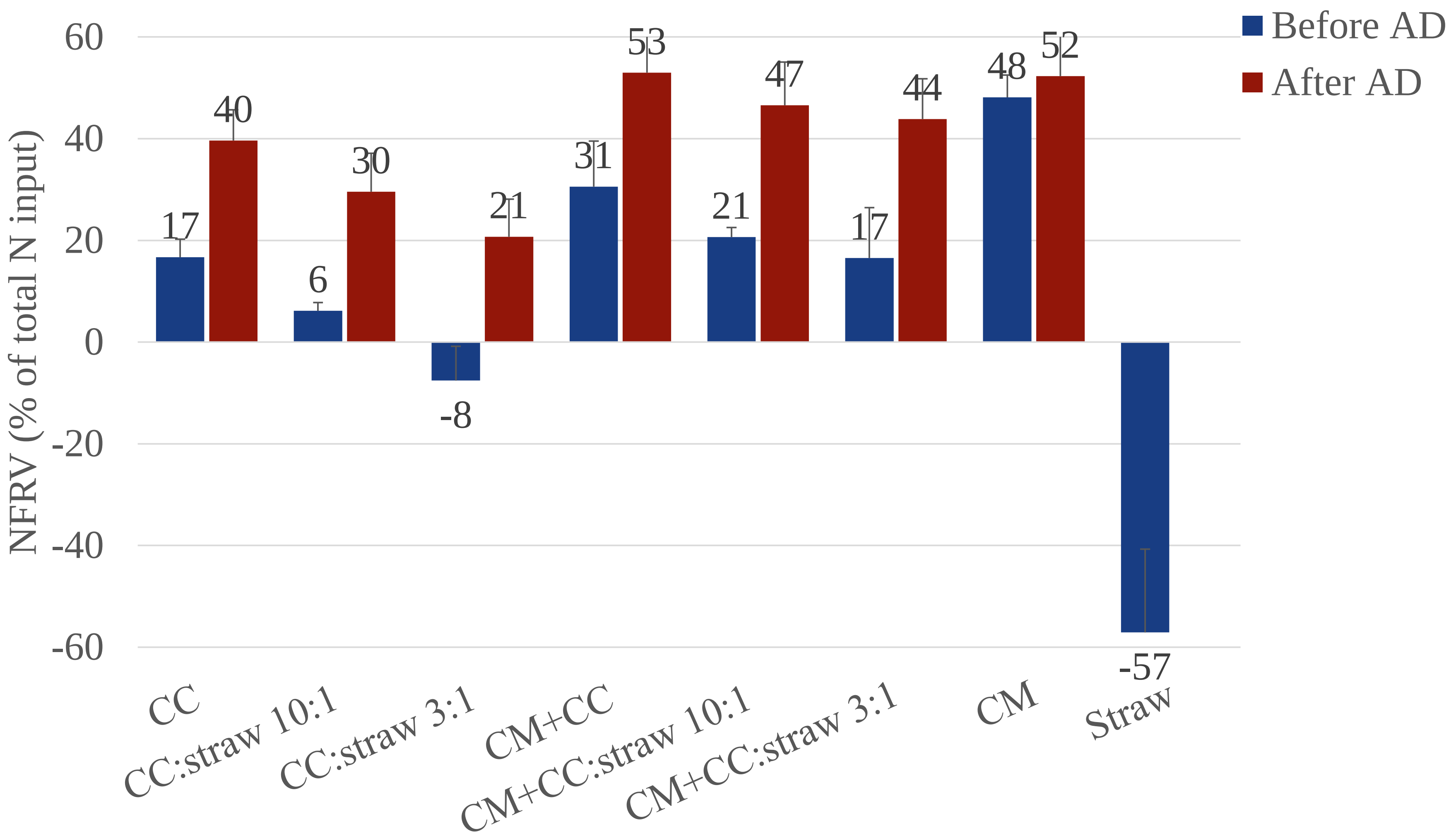
Crop N uptake





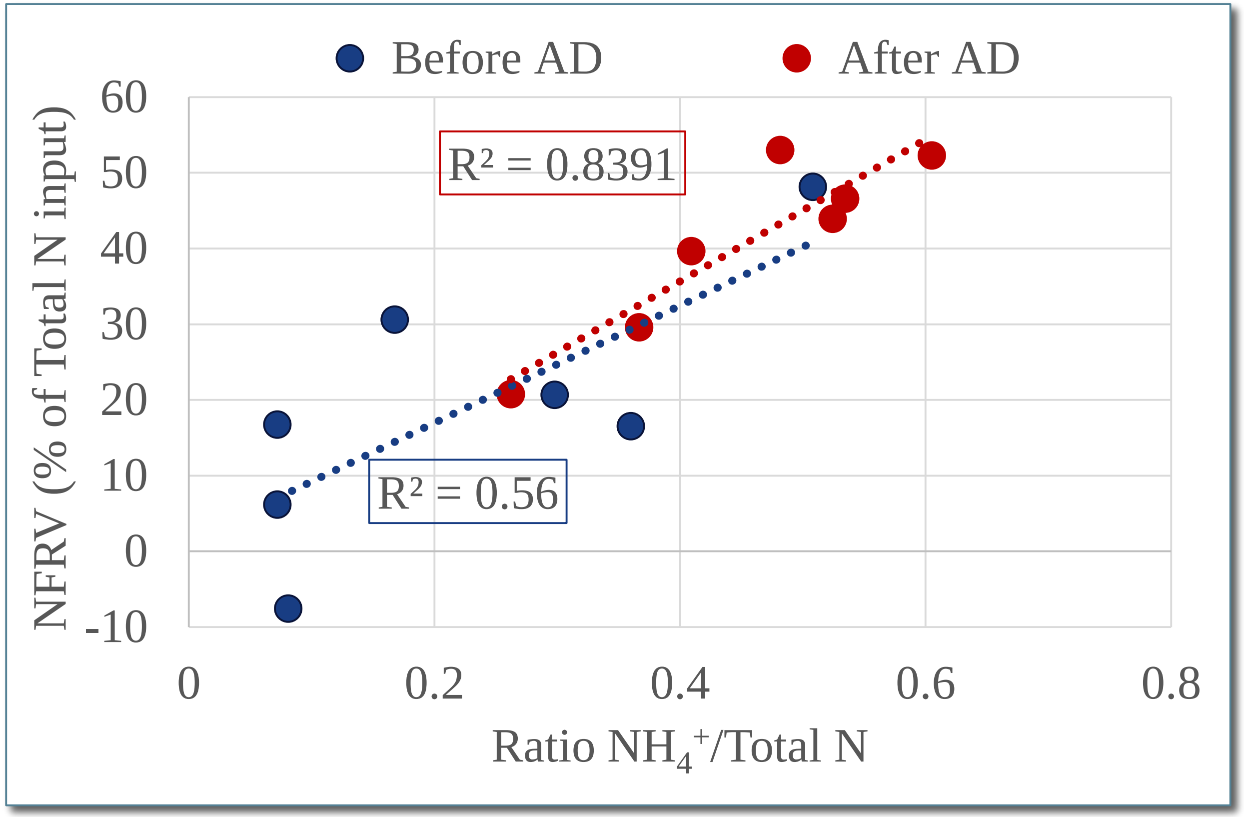
- Higher crop N uptake after application of digestates
- Average increase: 16 kg N/ha between before AD (74) and after AD (90)

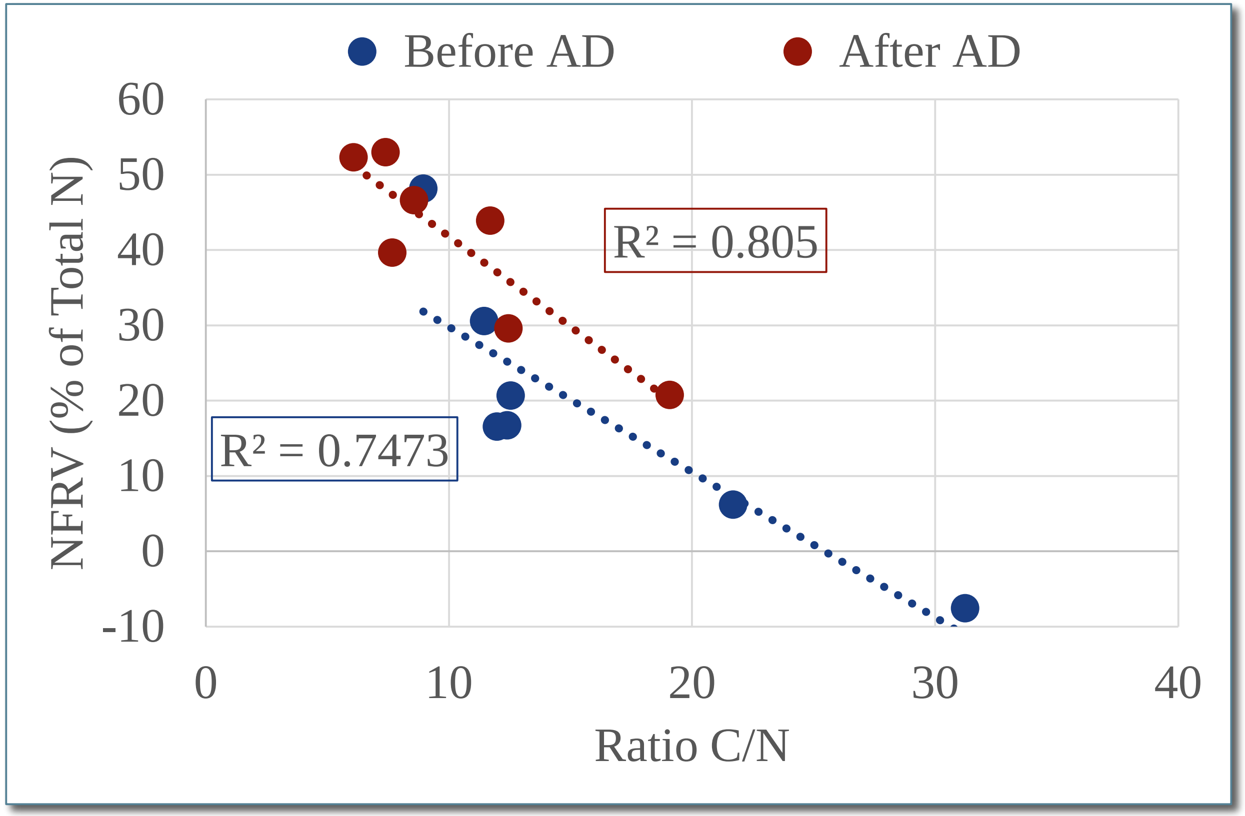
Nitrogen fertilizer replacement value



- Negative NFRV of substrates with high straw contents
- Average NFRV increase from 14% (before AD) to 39% (after AD)

Nitrogen fertilizer replacement value





- ➢ Increase NH_4^+/total N ratio → higher crop N uptake
- ➢ Lower C/N ratio → reduction of potential for immobilisation

Conclusion

Anaerobic digestion improves the use of crop residues and cover crops in organic farming systems :

- ➢ Increase fraction of NH_4^+ in total N
  - ➢ Increase N fertilizer replacement value from 14% to 39%
- ➢ Reduction of C/N ratio
  - ➢ Less immobilisation, improve synchrony with crop demand

- ➢ Additional biogas yields

- ➢ Other benefits:
  - ➢ Mobile manure → Spatio-temporal application
  - ➢ Less residual N in soil → reduce risk of N leaching

Thank you for your attention

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