A cropping systems perspective on the Danish organic arable LTE

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Background for the Danish organic arable LTE

Need to boost organic farming for sustainability

In 1990's an increasing interest in organic farming, from consumer demands and because it is seen as one of the ways towards sustainable agriculture.

International workshop in June 1999 (Borris, Denmark)

The objective of research on crop rotations is to improve the understanding of the reasons for the benefits obtained by using crop rotations so that the design and management of rotations in practical farming can be improved.

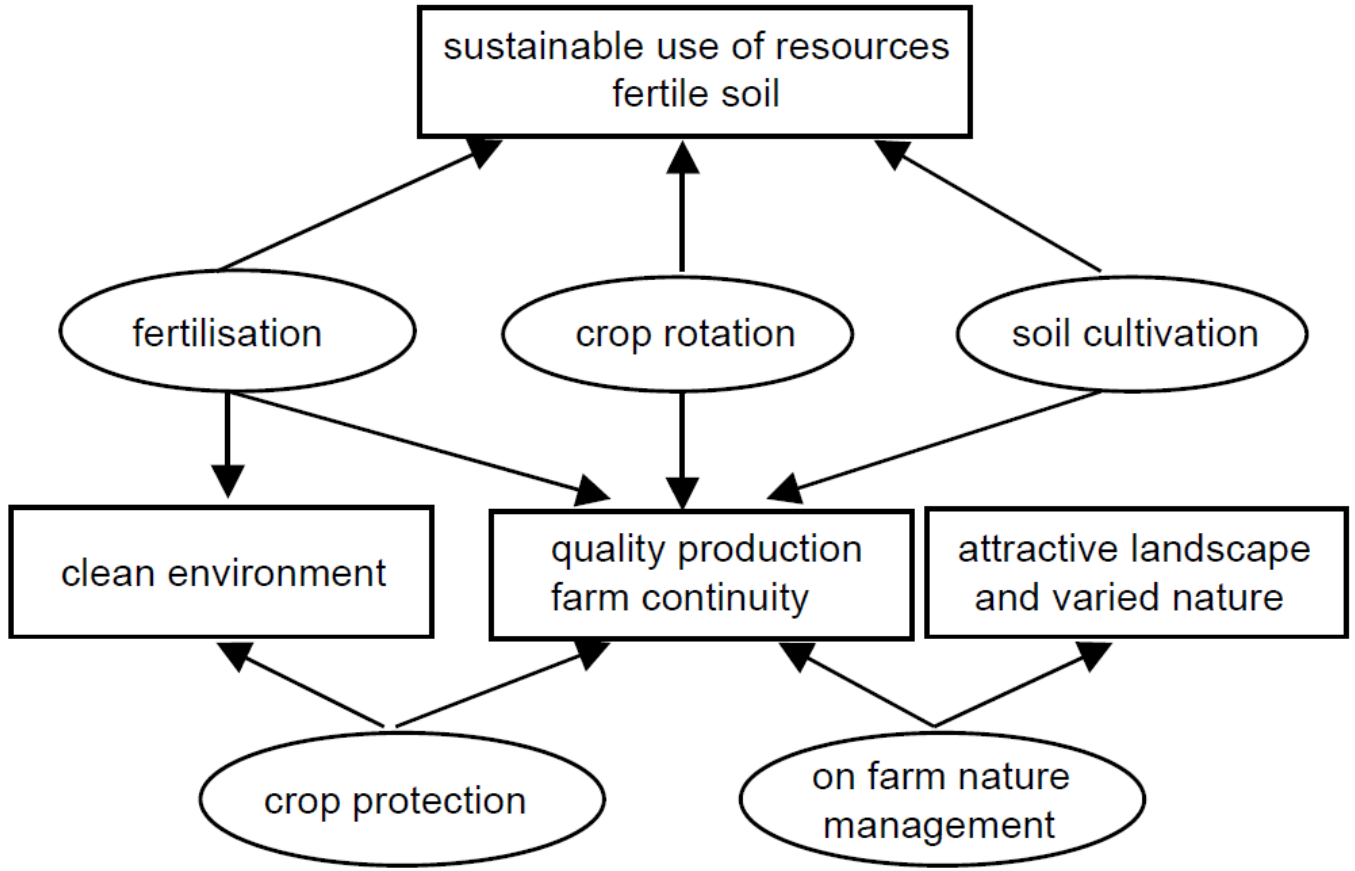
There is a large need for co-ordination of on-going European long-term experiments on organic crop rotations, especially with respect to management, documentation and measurement protocols.

Danish Research Centre for Organic Farming

DARCOF

Subjects for consideration in designing crop rotations

- Soil quality
- Soil biota (microorganisms and fauna), including mycorrhiza
- Nutrient balances and nutrient availability to individual crops in the rotatior
- Productivity and product quality
- Requirements for labour and mechanisation
- Economic viability
- Resource use
- Weeds, pests and diseases
- Allelopathy
- Farming/community cycling of products and wastes
- Region/community context
- Sustainability
- Environment effects and biodiversity
- Rules and regulations
- Site dependency, e.g. soil and climate



Olesen et al. (1999)

Designing crop rotation experiments

- *Flexibility*. There is often a need to change management and include new aspects or investigations
- *Reference*. A static part (treatment) as a reference is desirable
- *Scale*. Plots/fields should be as large as possible.
- *Time*. Often long time periods from time of conversion are required for interpretation.
- *Design*. A factorial design should be used, but kept simple
- *Management*. Detailed guidelines on the practical management of the crops and plots should be formulated
- *Minimum dataset*. A protocol for a minimum dataset should be set up based on existing standards.

Olesen et al. (1999)

The experiment was initiated in 1997 at three sites

Experimental design

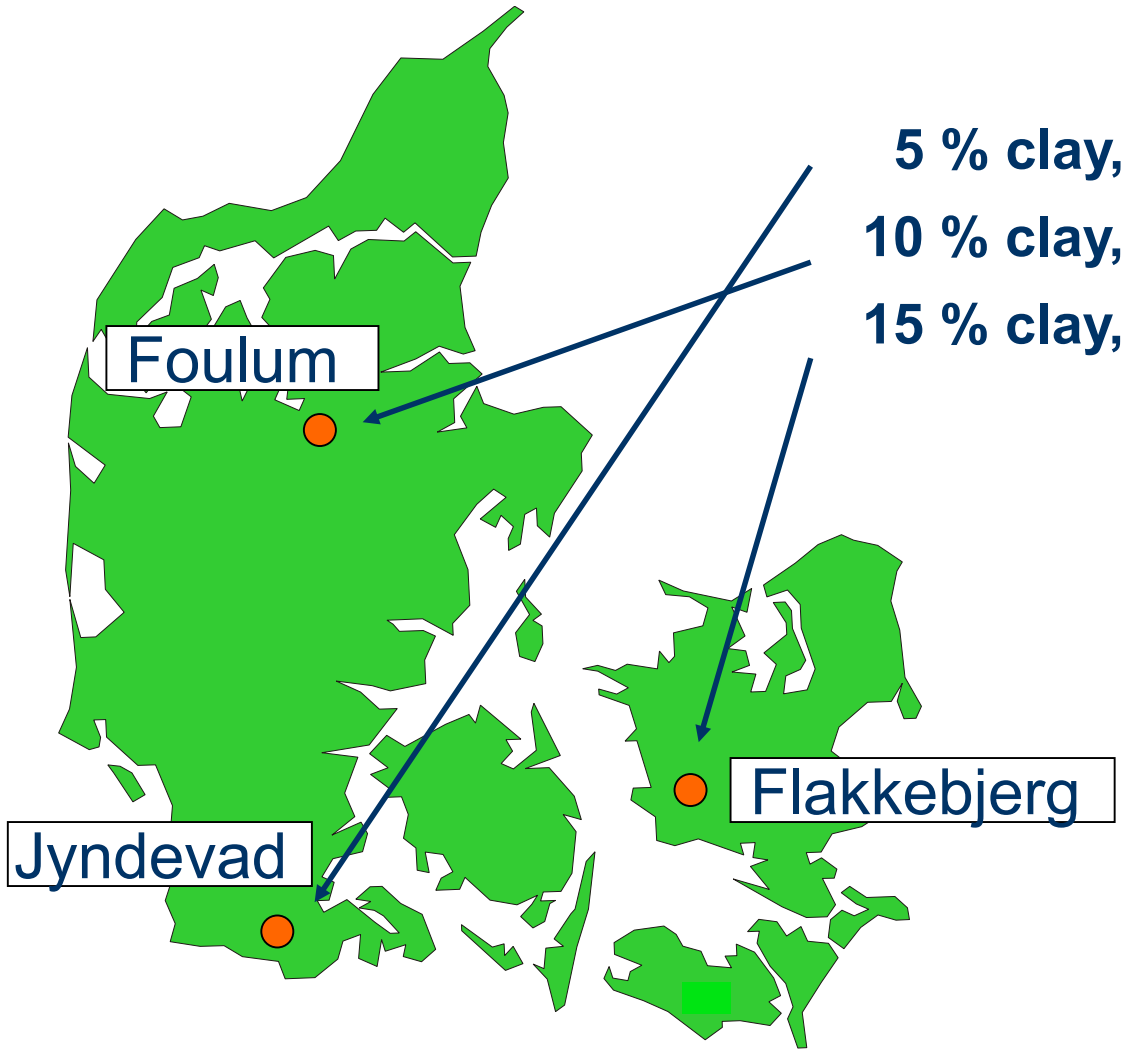
- Factorial design with three treatments
  - Crop rotation (+/- green manure)
  - Cover crops (+/-)
  - Livestock manure (+/- slurry)

Two replicates

Plot design

- Separated to avoid soil transfer
- Subplots for yield and other measurements

Database with all measurements



Experimental factors in the long-term experiment

Experimental factors (1997-2004):

- Production system (organic with and without grass-clover as green manure)
- Catch crops (with: +CC, without: -CC)
- Manure (with: +M, without: -M)

Experimental factors (2005-2008):

- Production system (conventional, organic with and without green manure)
- Catch crops (with: +CC, without: -CC)
- Manure/fertiliser (with: +M, without: -M)

Crop rotation	Production system	-CC +M	+CC -M	+CC +M
O2	Green manure-cash crop-organic	X	X	X
O4	Cash crop-organic	X	X	X
C4	Cash crop-conventional	X		X

M: animal manure (organic) or mineral fertilizer (conventional).
CC: catch crop, '+' is with catch crop and '-' is without catch crop.

Crops in the first five courses

- Organic (O2) and conventional (O4 and C4) rotations
- O2 has a green manure (grass-clover)
- O4 and C4 has a grain legume

- From 2005 the grass-clover in the +M treatments were removed to simulate recycling for fertilization

- Cover crops are legume-based in organic systems, and non-legume in conventional systems

Crop rotations		O2 (org.)	O4 (org.)	C4 (conv.)
Courses	Field			
1st course	1	S. barley:ley	Spring oat^{cc}	
1997-2000	2	Grass-clover	Winter wheat^{cc}	
	3	Winter wheat^{cc}	Winter cereal^{cc}	
	4	Peas/barley^{cc}	Peas/barley^{cc}	
2nd course	1	S. barley:ley	Winter cereal^{cc}	
2001-2004	2	Grass-clover	Spring oat^{cc}	
	3	Winter cereal^{cc}	S. barley^{cc}	
	4	Lupin^{cc}	Lupin	
3rd course	1	S. barley:ley	S. barley^{cc}	S. barley^{cc}
2005-2009	2	Grass-clover	Faba bean^{cc}	Faba bean^{cc}
	3	Potato	Potato	Potato
	4	Winter wheat^{cc}	Winter wheat^{cc}	Winter wheat^{cc}
4th course	1	S. barley:ley	S. barley^{cc}	S. barley^{cc}
2010-2014	2	Lucerne	Hemp	Hemp
	3	Lucerne	Barley+pea^{cc}	Barley+pea^{cc}
	4	Spring wheat^{cc}	Spring wheat^{cc}	Spring wheat^{cc}
	5	Potato$^{(cc)}$	Potato$^{(cc)}$	Potato$^{(cc)}$
5th course	1	S. barley:ley	S. barley^{cc}	S. barley^{cc}
2015-2018	2	Grass-clover	Faba bean^{cc}	Faba bean^{cc}
	3	Spring wheat^{cc}	Spring wheat^{cc}	Spring wheat^{cc}
	4	Winter rye^{cc*}	Winter rye^{cc*}	Winter rye^{cc*}

Yields in the third course (2005-2009)

Main yield effects

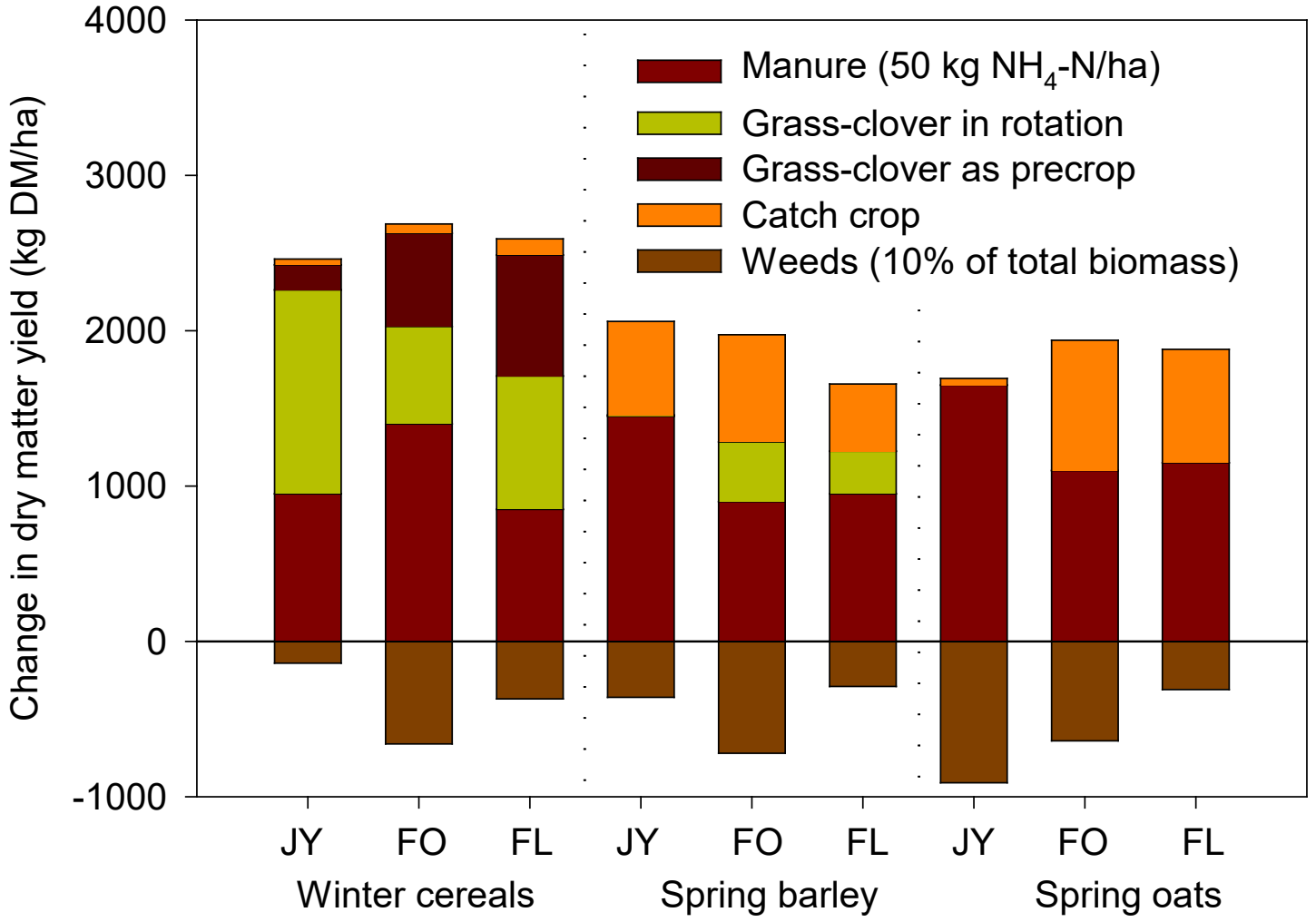
- Small overall site differences (greatest yield at Foulum)
- Green manures increase fertility, but insufficient to compensate for lack of cash crop
- Yield declines from organic varies between sites and in largest at Jyndevad
- Both manure and cover crops increases yield in organic

Yield	Location	Green manure	Conventional	Organic (% of conventional)		
				-M/+CC	+M/-CC	+M/+CC
DM Mg/ha	Jyndevad	With		34	51	59
		Without	22.4	39	63	66
	Foulum	With		56	67	65
		Without	24.2	62	72	79
	Flakkebjerg	With		50	58	61
		Without	21.5	48	62	68
N kg N/ha	Jyndevad	With		25	42	49
		Without	393	39	70	72
	Foulum	With		42	53	54
		Without	524	59	65	75
	Flakkebjerg	With		35	44	47
		Without	428	39	52	57

Shah et al. (2017)

Sources of yield improvement based on 1998-2008 data

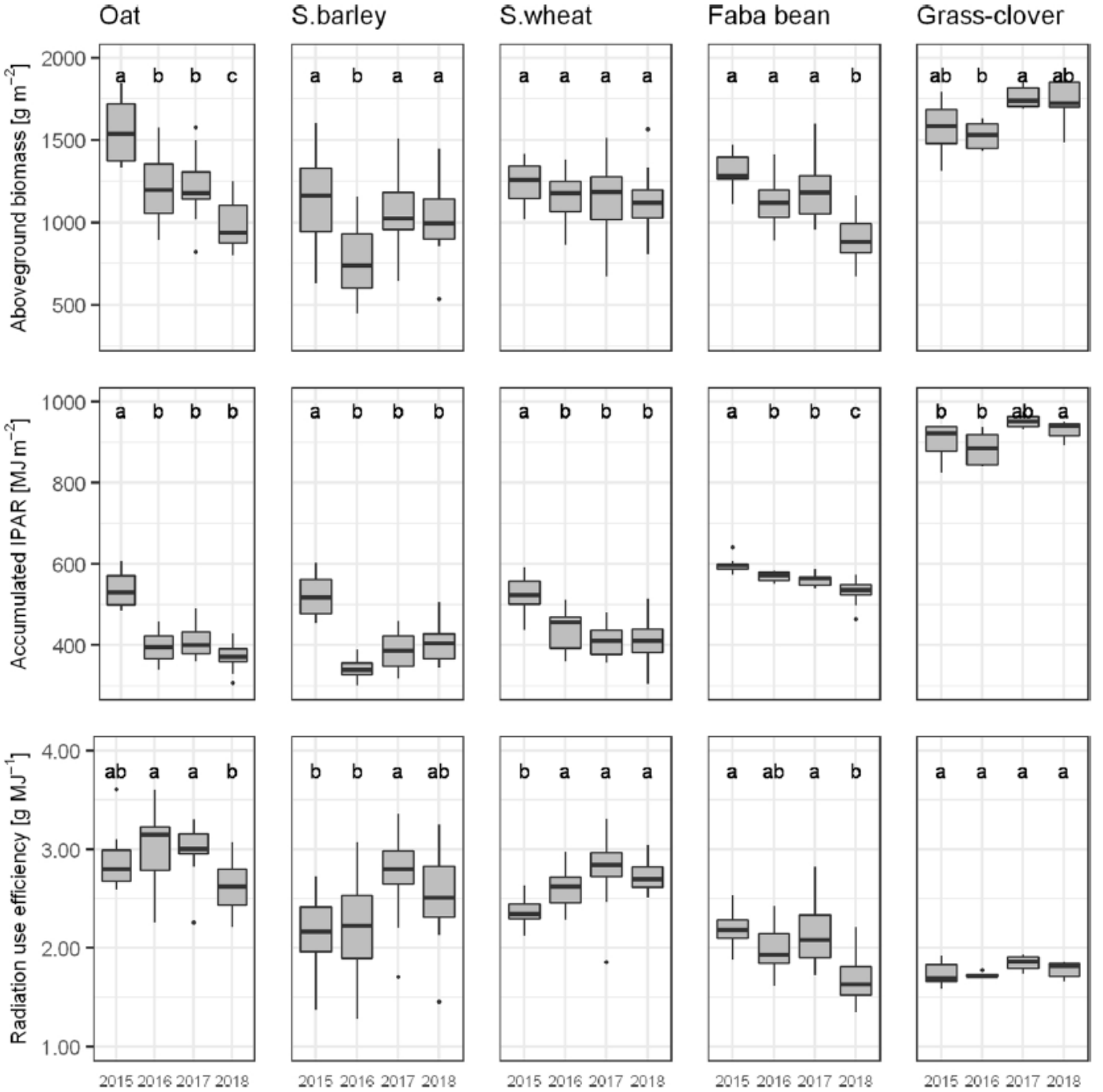
- Manure is the most reliable measure to increase yields
- Grass-clover green manure and cover crops can increase yield, depending on crop and place in rotation
- Weeds reduces yield, but with highly variable effects



Sources of biomass

- Light interception was measures and allowed aboveground biomass to be separated between intercepted PAR (IPAR) and radiation use efficiency (RUE)

- Biomass differences between treatments were mainly driven by IPAR



Harbo et al. (2022)

Current crop rotations

	O2	O4	C4
4th cycle 2010-14	S.barley:ley Lucerne Lucerne S.wheat^{CC} Potato^{CC}	S.barley^{CC} Hemp Pea/s.barley^{CC} S.wheat^{CC} Potato^{CC}	S.barley^{CC} Hemp Pea/s.barley^{CC} S.wheat^{CC} Potato^{CC}
5th cycle 2015-18	S.barley:ley Grass-clover S.wheat^{CC} Oat^{CC}	S. barley^{CC} Faba bean^{CC} S.wheat^{CC} Oat^{CC}	S.barley^{CC} Faba bean^{CC} S.wheat^{CC} Oat^{CC}
6th cycle 2019-22	S.barley:ley Grass-clover S.wheat W.rye^{CC}	S.barley^{CC} Lupin/s.wheat^{CC} S.wheat W.rye^{CC}	S.barley^{CC} Lupin/s.wheat^{CC} S.wheat W.rye^{CC}

8 Treatments:

O2	+M	-M
+CC	✓	✓
-CC	✓	

O4	+M	-M
+CC	✓	✓
-CC	✓	

C4	+F	-F
+CC	✓	
-CC	✓	

M=animal manure; F=mineral fertilizer.

Previous cover crop:

O2/O4: red clover, white clover, ryegrass, chicory

C4: ryegrass

News in the 6th cycle

- No cover crop after s.wheat
- W.rye instead of oat → CC sown after harvest
- New cover crop mixtures

Rotational consideration for cover crops

O2	Cover crop	O4	Cover crop	C4	Cover crop
S.barley:ley	-	S.barley^{CC}	Mix 2	S.barley^{CC}	Mix 3
Grass-clover	-	Lupin/s.wheat^{CC}	Mix 3	Lupin/s.wheat^{CC}	Mix 3
S.wheat	-	S.wheat	-	S.wheat	-
W.rye^{CC}	Mix 1	W.rye^{CC}	Mix 1	W.rye^{CC}	Mix 4

Undersown

After harvest

Mix 1: fodder radish, phacelia, winter vetch, spring vetch

Mix 2: red clover, ryegrass, chicory

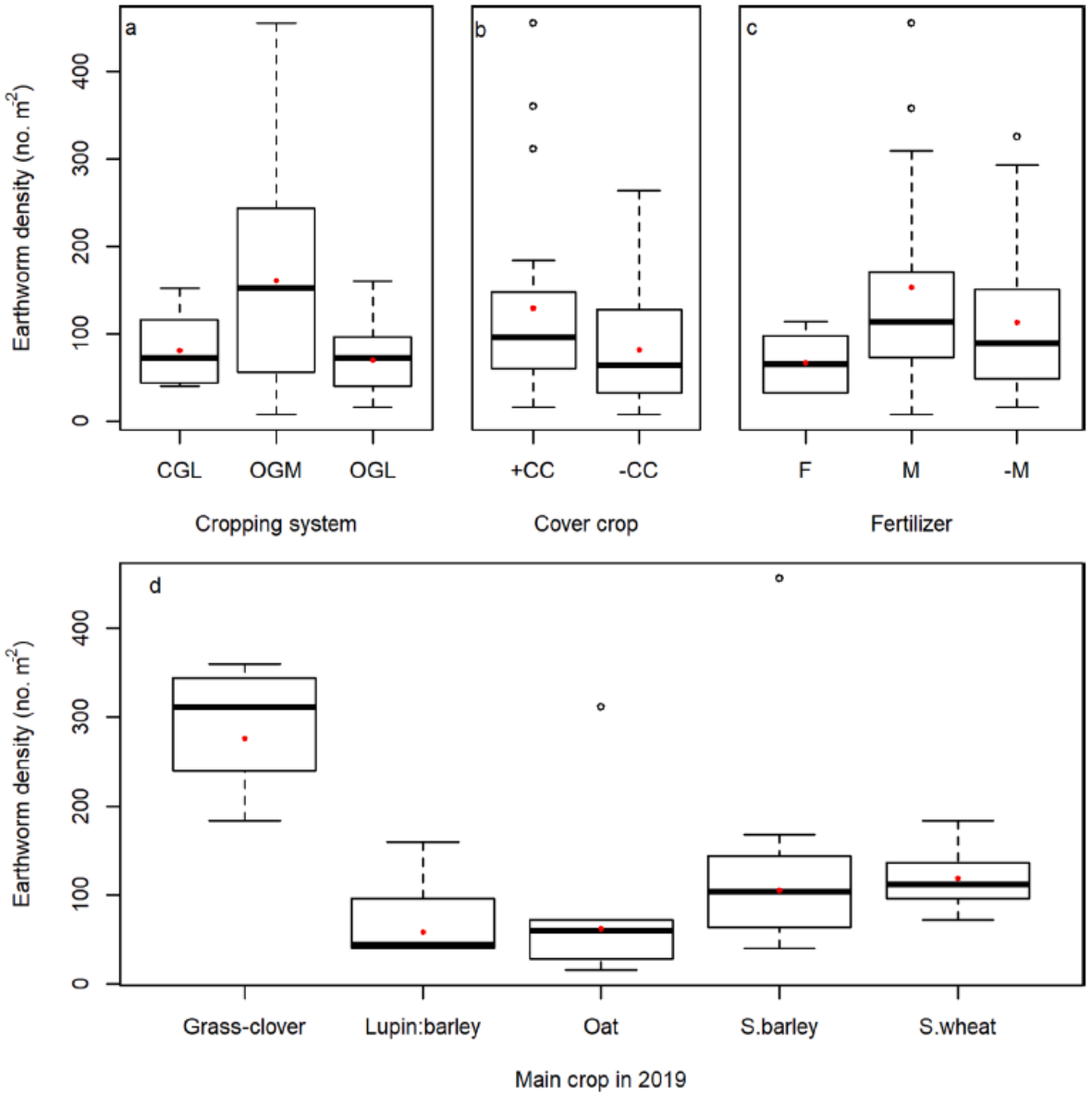
Mix 3: ryegrass, chicory

Mix 4: fodder radish, phacelia

Notes: mechanical weed control after wheat and rye; no clover in O2; no legume after lupin.

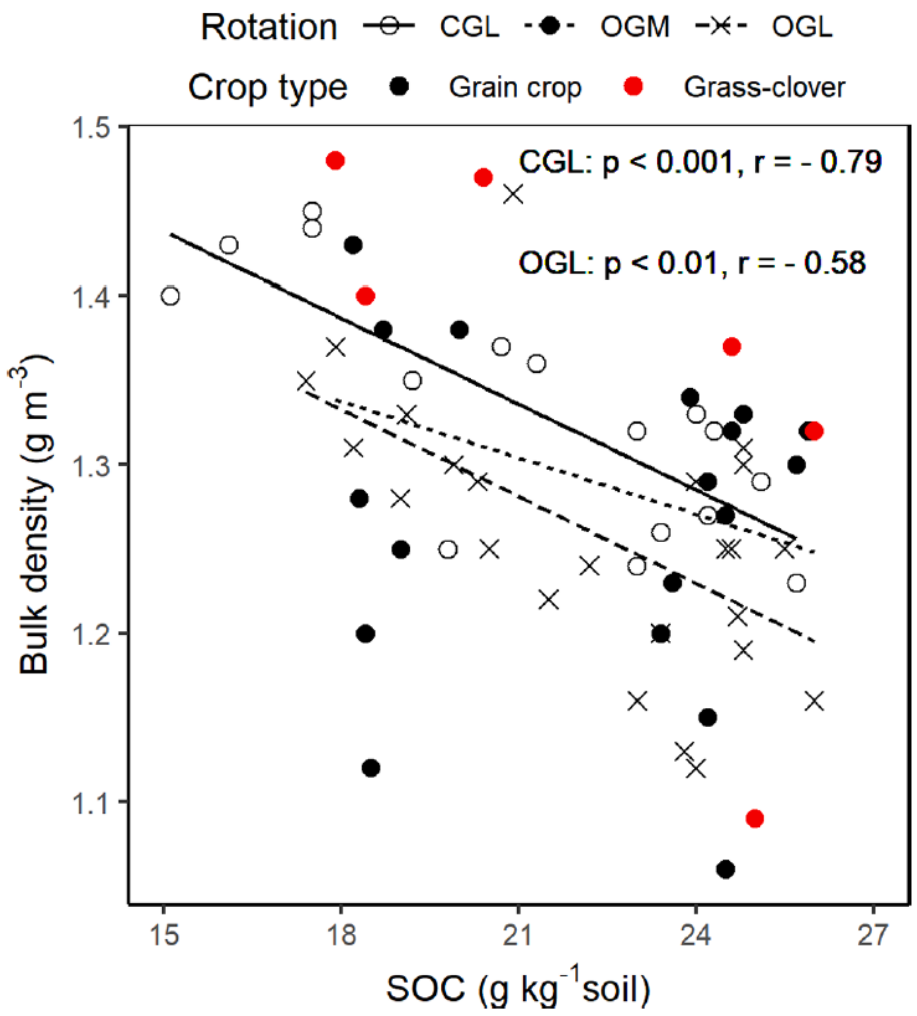
Soil quality: earthworms

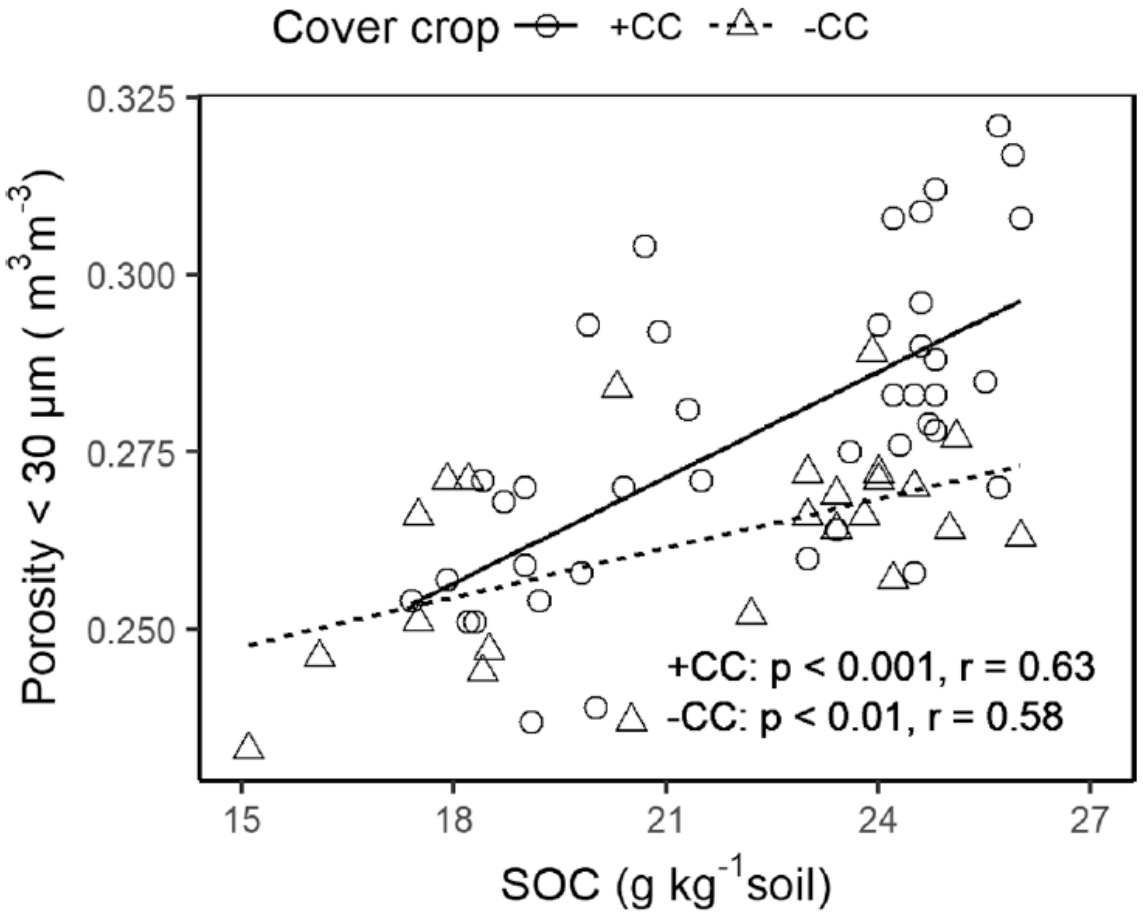
- Earthworm density is mainly determined by residue inputs:
  - Grass-clover
  - Cover crops



De Notaris et al. (2021)

Soil carbon drives soil physical properties





De Notaris et al. (2021)

Reflections

Main drivers of yield

- Nutrients (in particular nitrogen)
- Weeds
- Pests and diseases

Legacy effects

- Nitrogen (through SOM)
- Weeds
- Soil quality (minor?)

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