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Estimating nitrogen supply and cereal crop yield in organic crop production

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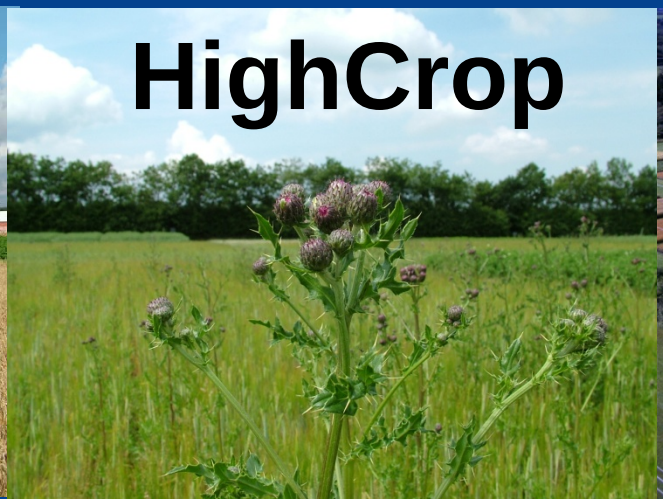

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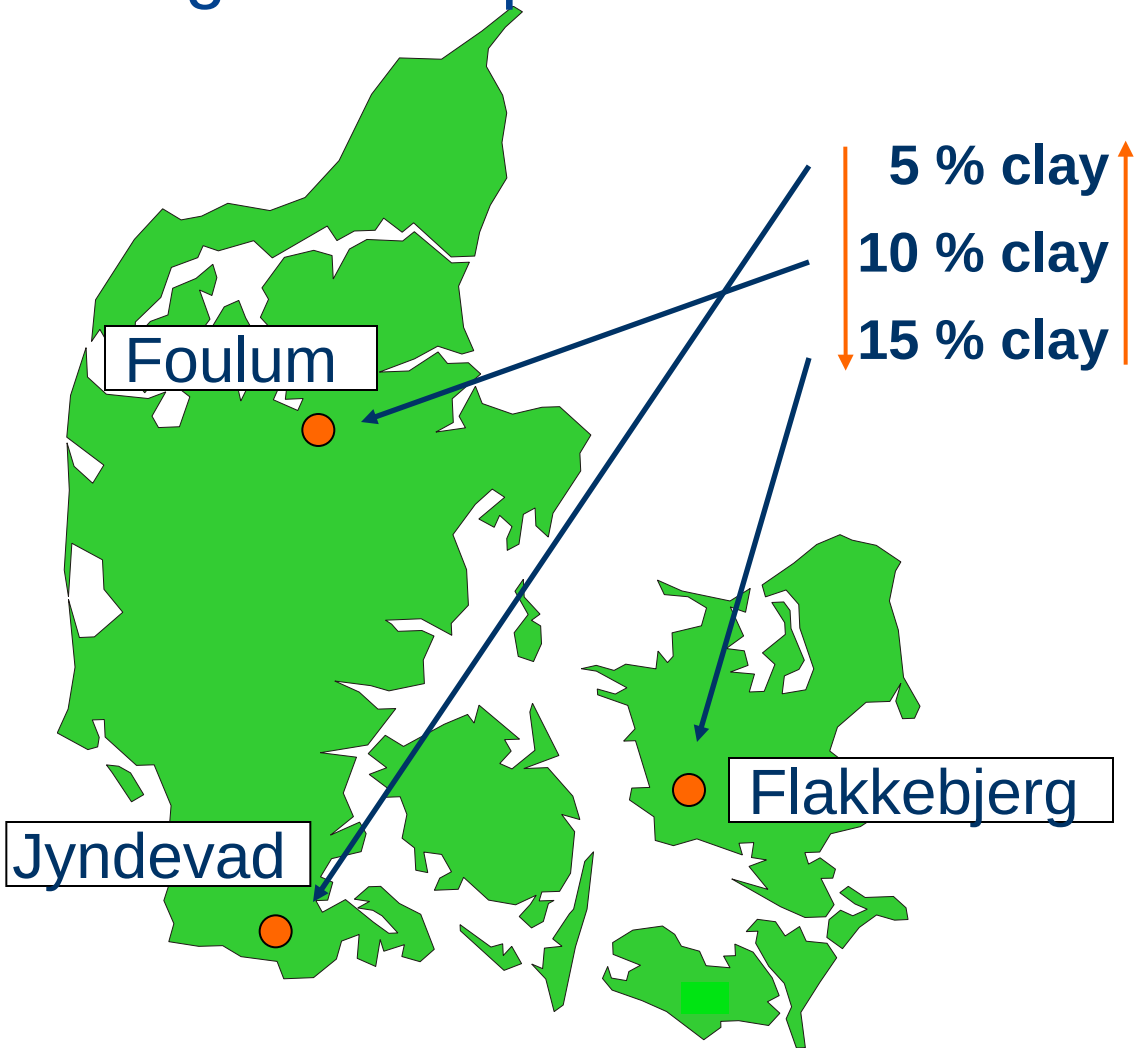
Long-term experiments with arable crop rotations



5 % clay	950 mm
10 % clay	700 mm
15 % clay	600 mm

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Experimental factors

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-):

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

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Experimental treatment combinations (since 2005)

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.

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Crop rotations

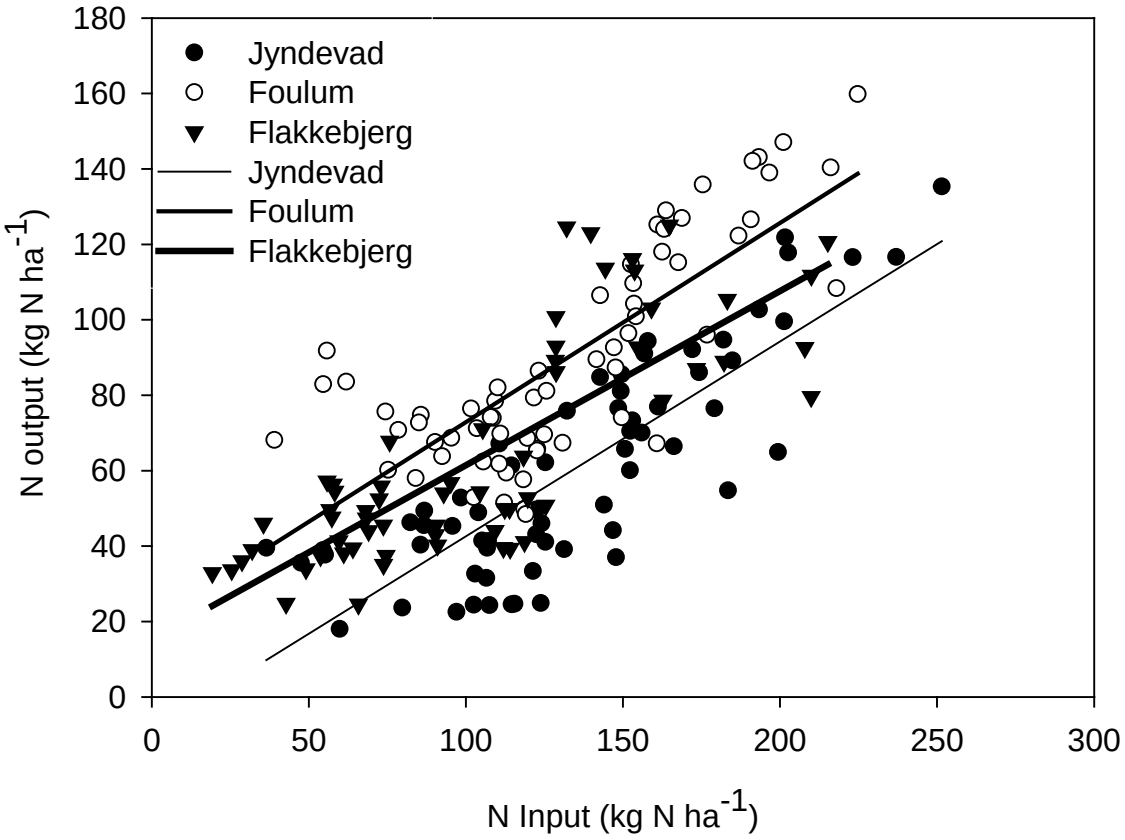
	Field	O2	O4	C4
1st course 1997-2000	1	S. barley:ley	Spring oat^{CC}	
	2	Grass-clover	Winter wheat^{CC}	
	3	Winter wheat^{CC}	Winter cereal^{CC,1}	
	4	Pea/barley^{CC}	Pea/barley^{CC}	
2nd course 2001-2004	1	S. barley:ley	Winter wheat^{CC}	
	2	Grass-clover	Spring oat^{CC}	
	3	Winter wheat^{CC}	S. barley^{CC}	
	4	Lupin/barley^{CC}	Lupin	
3rd course 2005-2009	1	S. barley:ley	S. barley^{CC}	S. barley^{CC}
	2	Grass-clover	Faba bean^{CC,2}	Faba bean^{CC,2}
	3	Potato	Potato	Potato
	4	Winter wheat^{CC,3}	Winter wheat^{CC,3}	Winter wheat^{CC,3}

N-fixing catch crops in organic crop rotations (O2 and O4)
Non N-fixing catch crops in the conventional rotation (C4)

Nitrogen flows at Foulum (2005-2008)

Cropping system	BNF	Input	Output	Surplus	Recycled	Leaching	Neff
	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg N/ha	%
O2/+M/-CC	84	104	69	34	43	39	71
O2/-M/+CC	88	108	55	53	138	43	51
O2/+M/+CC	86	106	70	36	57	37	69
O4/+M/-CC	42	132	85	47	46	57	64
O4/-M/+CC	61	81	78	4	86	27	118
O4/+M/+CC	55	144	98	46	81	46	70
C4/+M/-CC	55	178	130	48	80	55	73
C4/+M/+CC	54	174	132	42	93	36	76

Nitrogen yield (output) at rotation level (2005-2008)



Sources of nitrogen for crop N supply

- Long-term:
  - Soil organic matter (N in humus)
- Medium-term
  - Added organic N over the crop rotation(s) (previous 10 years)
- Short-term
  - Grass-clover or other green manure crops
  - Catch crops (with and without legumes)
  - Ammonium-N in manure

Model of yield of cereals and other non-legumes

The dry matter yield (Y_d) is assumed to be a non-linear function of N uptake:
$Y_d = b_1 N_w + b_2 N_w^2$
b_1 and b_2 are assumed to depend on crop type only.

The N-uptake in grain with weeds (N_w) is estimated from the following equation:
$N_w = N_u (c_1 W_a + c_2 W_p)$
where W_a and W_b is the biomass of annual and perennial weeds, respectively in proportion of total biomass at heading in the cereals.

The N-uptake in grain (N_u) in a weed-free situation is estimated from the following equation:
$N_u = a_1 N_s + a_2 N_f + a_3 N_c + a_4 N_g + a_5 N_a$
where

N_g Nitrogen in pastures and green manure crops, which may be one or more years of grass-clover, lucerne etc.

N_c Nitrogen returned in catch crops during winter and spring. This is estimated from above-ground measurements only.

N_r Nitrogen returned in other crop residues (primarily straw and stubble). This is estimated from above-ground measurements only.

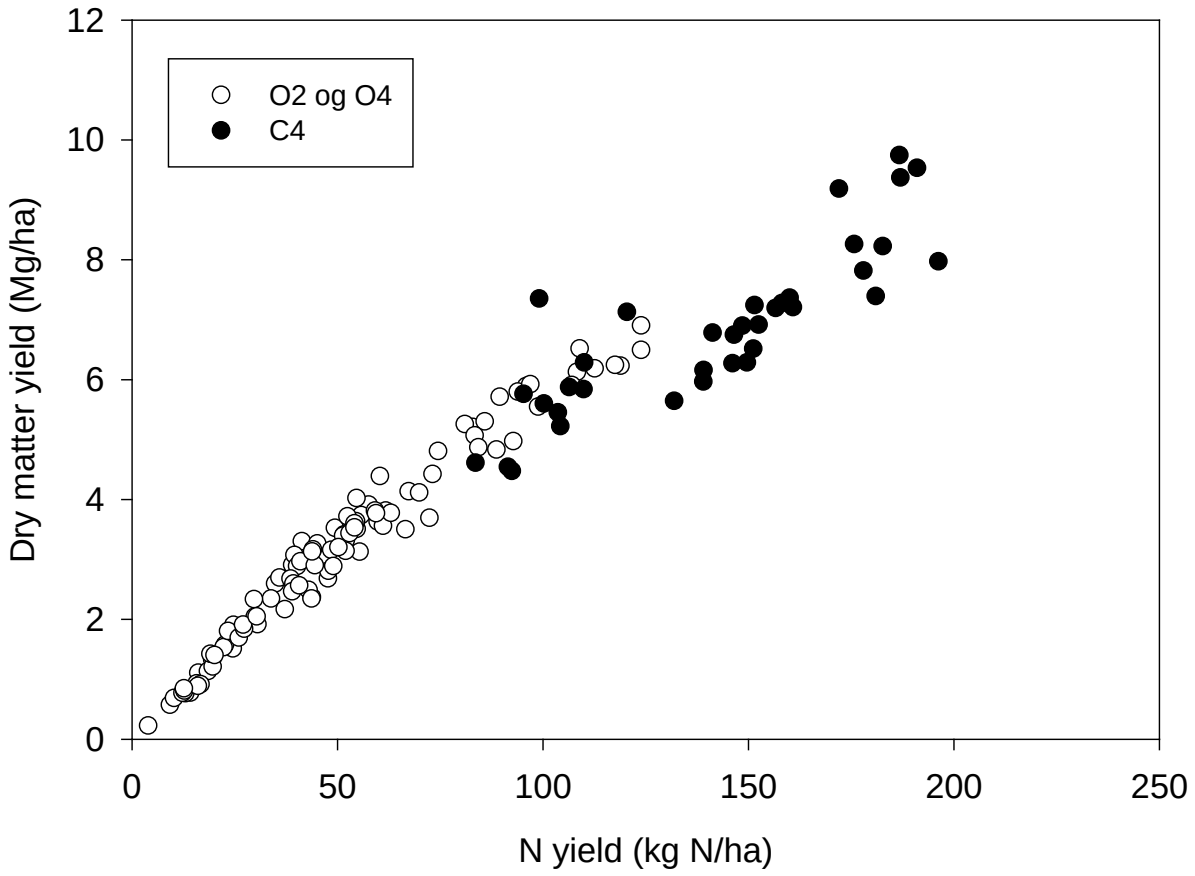
N_a Ammonium N applied in manure.

N_m Total N applied in manure.

N_s Soil total N in 0-25 cm depth.

The medium-term effects are estimated by taking the average of the contributions of organic matter inputs over the past 10 years (excluding the previous year), i.e. $N_f = \sum N_g + N_c + N_r + N_m - N_a$

Grain dry matter yield versus grain N yield



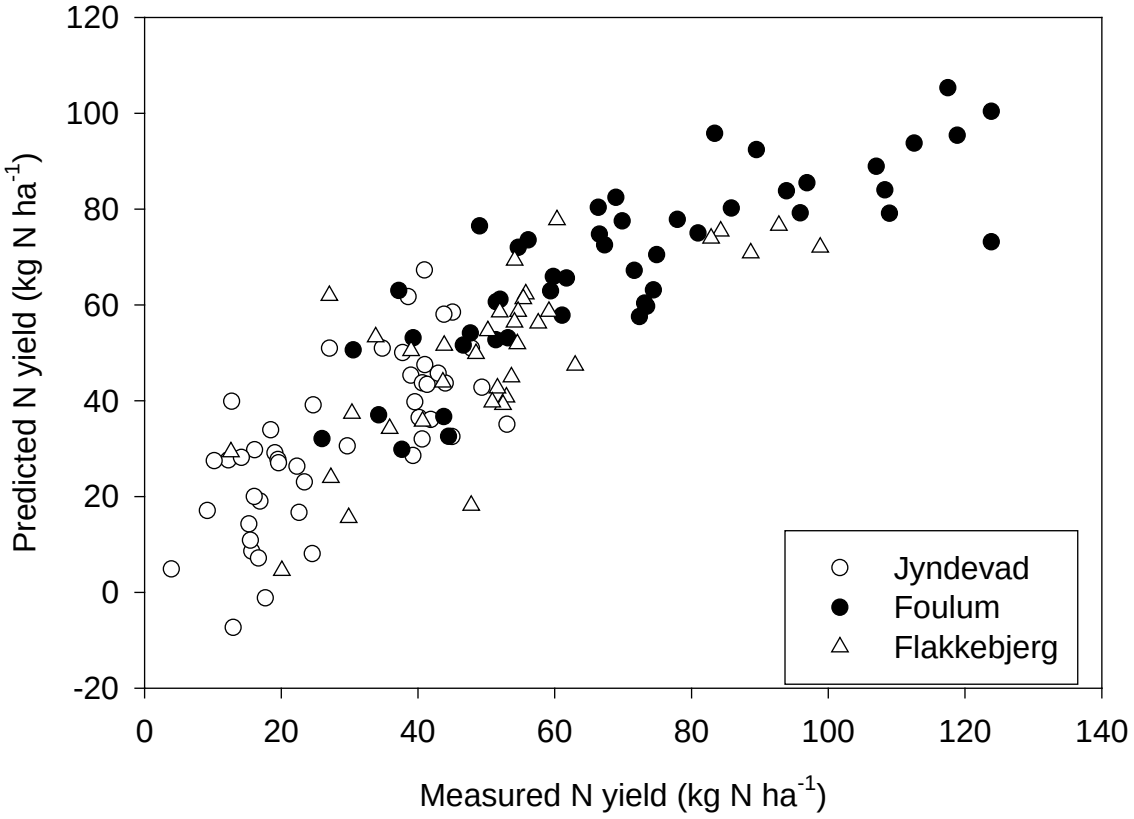
Response of grain N yield to N input and weeds

Variable	Winter wheat	Spring barley
Soil N	0.0036	0.0038
Annual organic N inputs	0.19	0.20
N in catch crops	-	0.37
Ammonium-N (Jyndevad)	0.18	0.56
Ammonium-N (Foulum)	0.56	0.46
Ammonium-N (Flakkebjerg)	0.40	0.45
Weeds	-0.53	-1.06

Response to N input is kg N in yield per kg N in input
Response to weeds is kg N in yield per % weed at flowering

R^2 for winter wheat is 0.74 and for spring barley 0.69

Predicted N yield in winter wheat



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Estimated mean effects on grain yield in the crop rotation experiment

	Winter wheat		Spring barley	
	Input	Yield (Mg/ha)	Input	Yield (Mg/ha)
Soil organic N (kg N/ha)	4732	1.11	4733	1.17
Rotation N input (kg N/ha)	127	1.56	130	1.69
Catch crop N (kg N/ha)			13	0.31
Manure ammonium (kg N/ha)	55	1.43	30	0.90
Weeds (%)	10	-0.34	4	-0.25
Total		3.76		3.81

HighCrop
Crop rotation planner
Excel-spreadsheet

20130308_TNT_Crop_Model(34)_JEO [Read-Only]

Scenarie: A

Input

Ar	Sædskifte? (vælg)	Planterester (Vælg)	Ukrudtsstrategi: Forud for etablering (Vælg)	Ukrudtsstrategi: Efter etablering (Vælg)	Ukrudtsstrategi: Efter høst (Vælg)	TYPE (vælg)	Sum dækning (100%=ingen reg.)	Faktiske udbytte (tons TS pr. ha) e. række afstd. reg	Faktiske udbytte (tons TS pr. ha) e. Ukrudt reg.
1	Majs	Ingen halm	Pløjning + falsk såbed	Radrensning	Stubharvning_A1	Korsblomstret	100	7.8	7.8
2	Vinterrug	Halm snittet	Pløjning	Blindstrigling + alm. ukrudtsharvning	Stubharvning_A2	Vinterrug	100	3.2	3.2
3	Havre	Halm fjernet	Stubharvning + pløjning	Blindstrigling + alm. ukrudtsharvning	Pløjning_A3	Korsblomstret	100	4.8	4.8
4	Vårsæd (korn undt. Havre)	Halm fjernet	Stubharvning + pløjning	Ingen	Stubharvning_A4	Korsblomstret	100	5.4	5.4
5	Vintersæd (korn undt. rug)	Ingen halm	Stubharvning +	Ingen	Stubharvning_A5	Vinterrug			

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Conclusions

- Manure application is the most important factor for enhancing yields in organic crop production
- Grass-clover and catch crops have both short- and long-term effects on cereal grain yields.
- Grain yields can be increased by
  - Increasing inputs of N from BNF (green manure, catch crops)
  - Converting organic N to mineral in manures applied in spring
  - Maintaining low weed pressure
- Effects of different sources of N can be reliably predicted using a simple equation that can be used in strategic planning

Acknowledgements to ICROFS and Organic RDD