N_2O emissions from an organic cropping system as affected by legume-based catch crops

Ph.D. student: **Xiaoxi Li**

Xiaoxi.Li@agrsci.dk

Dept. of Agroecology, Aarhus University, Denmark

Supervisors: Professor, **Jørgen E. Olesen**

Senior scientist, **Søren O. Petersen**

Senior scientist, **Peter Sørensen**

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Outline

- Background
- Objectives & Hypotheses
- Materials & Methodology
- **Field experiment** (2012/09~2013/09)
- **Simulation by DNDC (Preliminary results)**
- Future work plan

Organic farming

- Denmark: >6%, double the area until 2020
- Strict limits of external input
- Much stricter in DK soon

- How to **sustain N inputs** and **higher yields** with **less adverse environmental impact** in organic farming?

Catch crops (CC)

Mixture of red clover and

LBCC

Legume Based Catch Crops

N sources

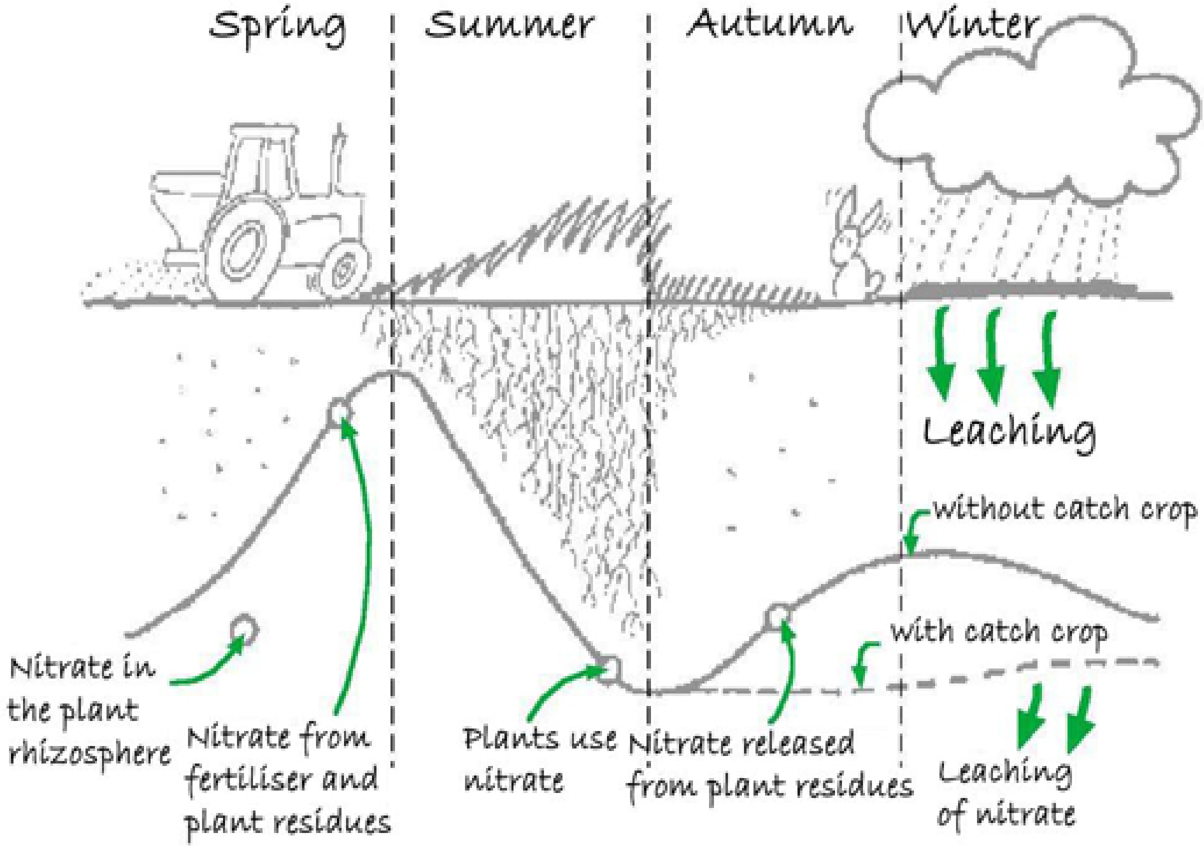
Fodder radish

Non-LBCC

CC can benefit the environment

- Reduction of NO_3^--N leaching –

The **primary purpose** of CC is to obtain an effective assimilation of N in autumn



"Catch" the N

(http://www.balticdeal.eu/measure/catch-crops/)

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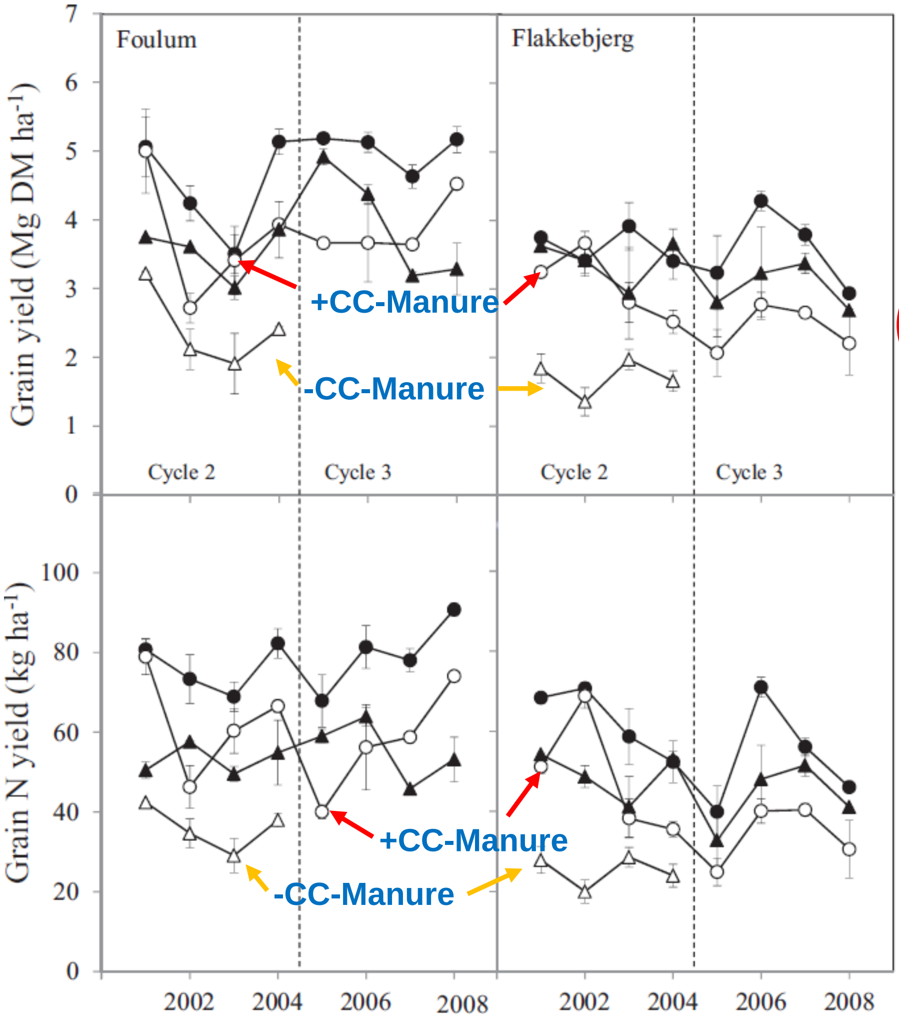
CC can benefit the main crops



(Doltra and Olesen, 2013)

The effect of CC and manure on spring barley yield

Treatment variant	Spring barley, *Hordeum vulgare* L., 2005 grain yield ($Mg\ DM\ ha^{-1}$)	N content ($mg\ N\ g^{-1}\ DM$)	grain N yield ($kg\ N\ ha^{-1}$)
L + NL	3.1ab	14.9a	46ab
L	3.3b	17.3a	57b
NL	2.7a	14.9a	40a
BF	2.7a	16.7a	45ab

(Rinnofner et al., 2008)

The CC species matters

Impact of CC on N_2O emissions?

- N_2O = ~300 times GWP as CO_2, ~10% total GHG
- **~60%** anthropogenic N_2O from **agricultural soils**

Digest CC tops

Cut – digest– return as fertiliser

↓ N_2O by 38% than mulching

(Moller and Stinner, 2009)

Remove CC tops

Remove grass-clover tops

↓ N_2O by 0.37 kg N_2O-N ha^{-1}

than mulching (Nadeem, et al., 2012)

The management matters

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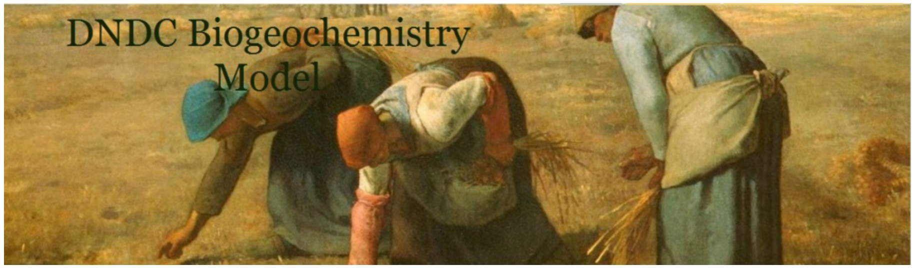
Objectives

- to study the N cycling and N_2O emissions of different **LBCC** under different **management strategies** in organic farming

- to calibrate DNDC for simulation of the N supply and N_2O emissions in **low-input** LBCC systems



Hypotheses

- Using LBCC will induce more N_2O emissions (*vs.* non-LBCC)
- Harvest of CC tops in late autumn can ↓ N_2O emissions
- N_2O fluxes from the LBCC system can be simulated only by assuming specific crop and soil management conditions

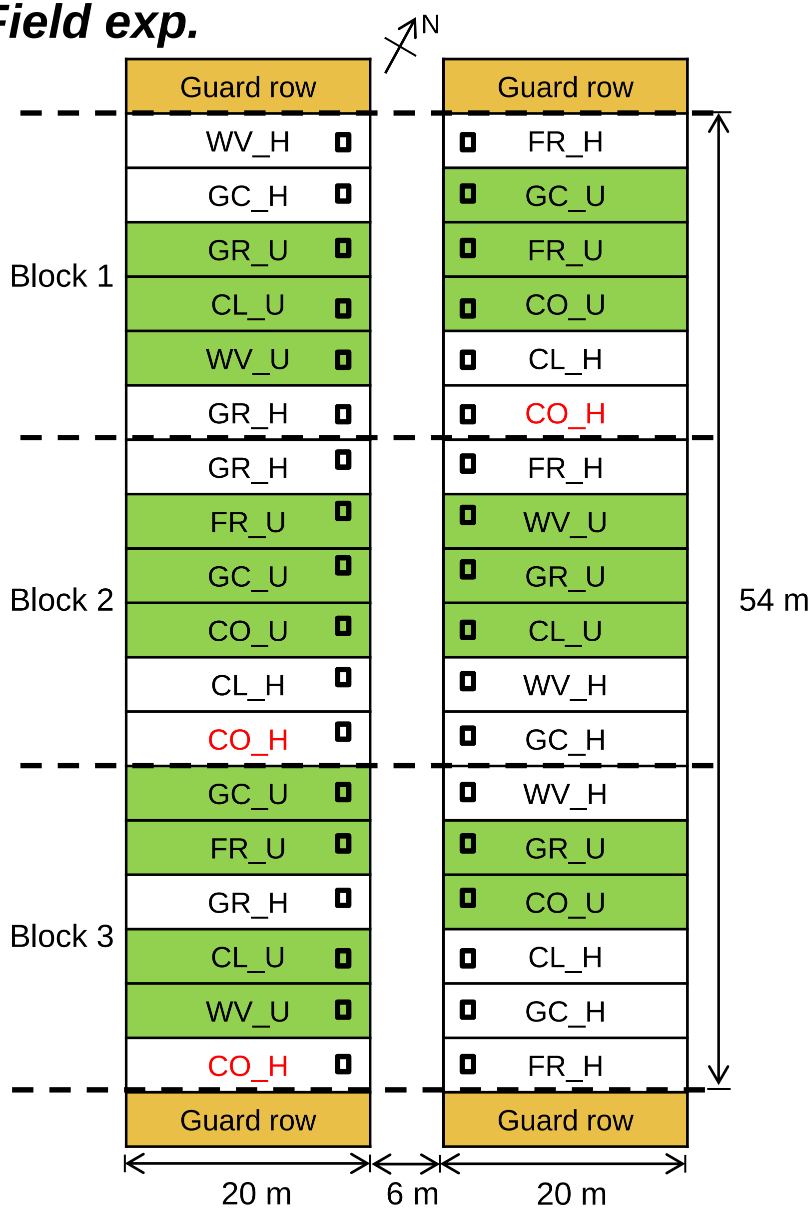
Materials & Methodology

1-yr field exp. on N cycling & N_2O

- **CC**: 5 CC and no CC control
- **Management**: 1) late autumn harvest, 2) spring incorporation

Simulating N_2O fluxes and N supply to spring barley affected by different CC using DNDC

Field exp.



Research Centre, Foulum - AU (56º30'N, 9º34'E)
Loamy sand
Average: 7.3 ℃, 704 mm

6 CC treatments

1.CL - Red clover

2.GC - Red clover-ryegrass mixture

3.WV - Winter vetch

4.FR - Fodder radish

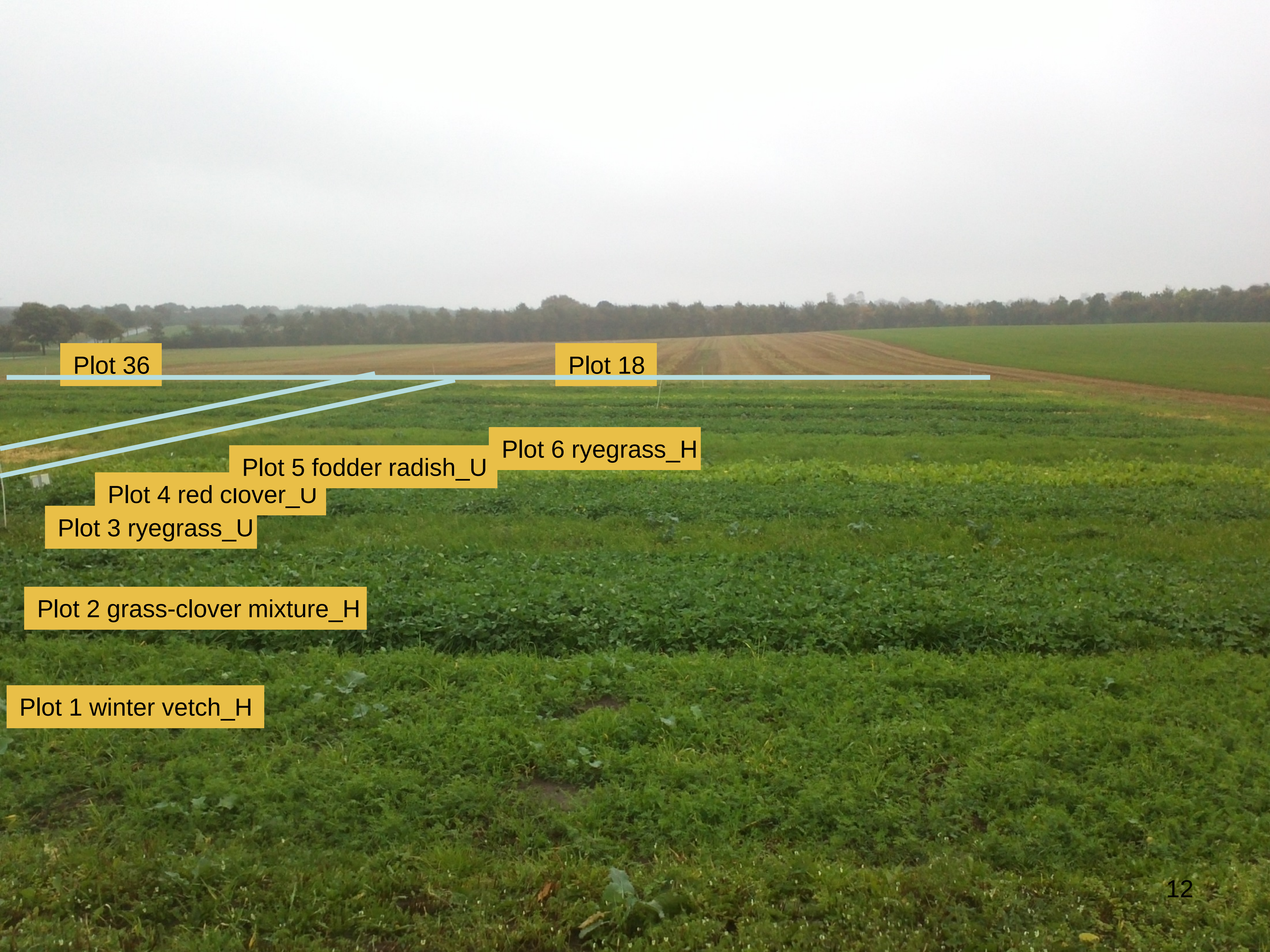
5.GR - Ryegrass

6.CO – Control without catch crop

2 management treatments

H - CC tops harvested early in 2012/11

U - CC left untreated until soil incorporation by ploughing, 2013/04


Plot 36
Plot 18
Plot 6 ryegrass_H
Plot 5 fodder radish_U
Plot 4 red clover_U
Plot 3 ryegrass_U
Plot 2 grass-clover mixture_H
Plot 1 winter vetch_H

LBCC effect on N & N_2O

Measurement (cover 1 yr)

- **N_2O fluxes** (27 times, ~2/month)
- **Soil NH_4-N** & **NO_3-N, moisture** (0~30 cm, 19 times, ~1/month)
- **Climate data, soil T** by sensors **(5 cm)** and **water (30 cm)** by TDR

1 year

- **DM** & **N accumulation** (End Oct. 2012)

CC 2012 late autumn

- **RVI** (Ratio Vegetation Index) (12 times, 1/week)
- **DM** & **N** (4 times)
- **Final DM, grain** & **N yield** (End Aug. 2013)

Spring barley 2013

Field operation

Field operation	Date
Cattle slurry application (80 kg N/ha)	15/03/2012
Spring barley sowing	17/04/2012
CC sowing (CL/GC/GR)	15/05/2012
Spring barley harvest	09/08/2012
CC sowing (FR/WV)	10/08/2012
	10/09/2012
CC harvest (H plots)	30/10/2012
CC ploughing (~22 cm) (H + U plots)	22/04/2013
Spring barley sowing	23/04/2013
Spring barley harvest	21/08/2013
	10/09/2013

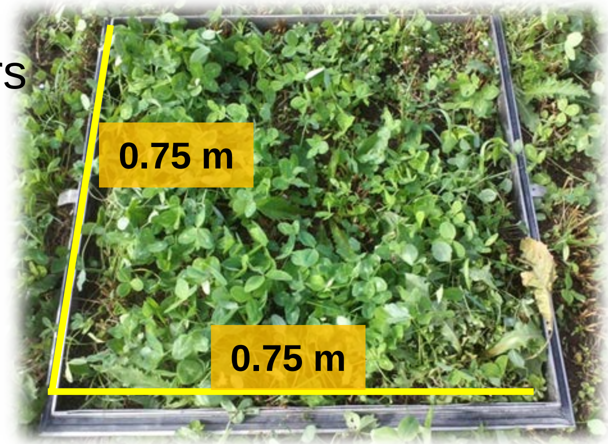
SB season

CC season

SB season

Monitoring period

Static chambers for N_2O

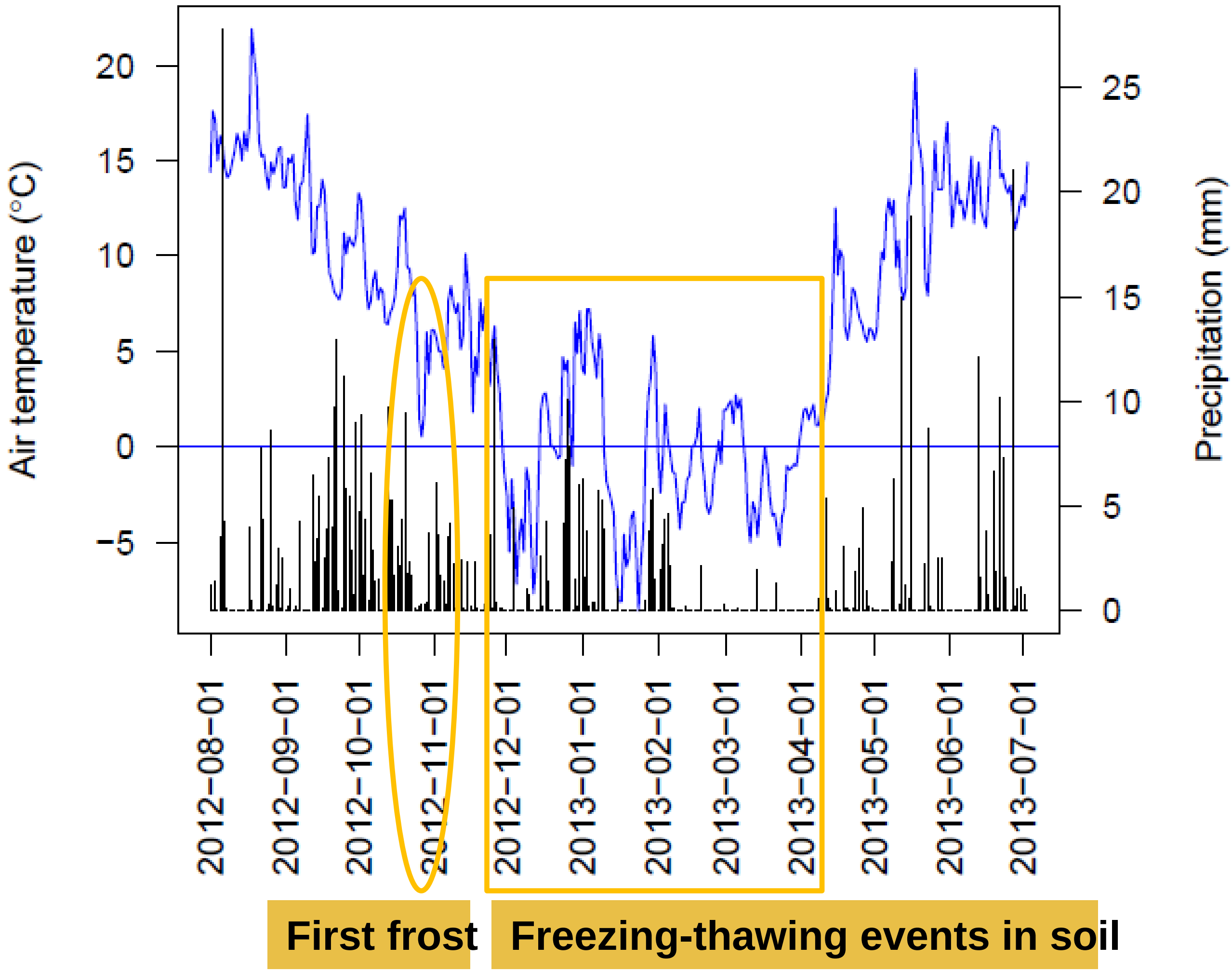


Every campaign:

36 plots,
5 samples/plot over a time course of ~75 min

Field exp.

Climate data (01/08/2012 - 03/07/2013)



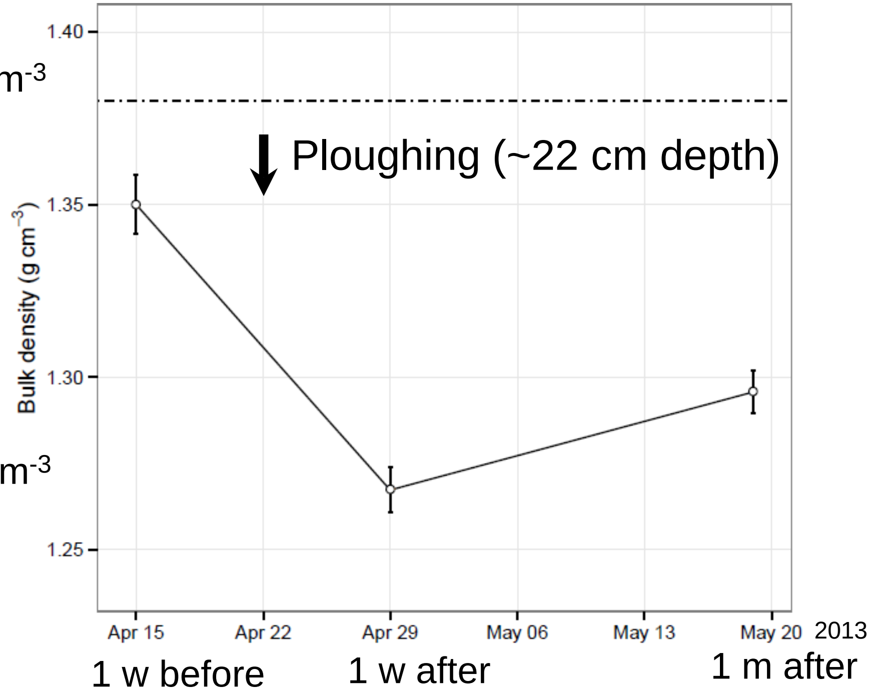
Basic soil properties

Soil layer	SOC g/kg	Total N g/kg	P mg P/100 g	K mg K/100 g	pH	CEC meq/100 g
0~30 cm	18	1.6	3.3	12.0	6.4	9.1

Bulk density (0~10 cm)

1.38 g cm^{-3} 2012/09

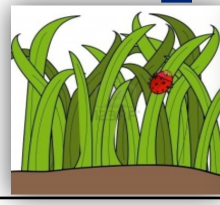
1.28 g cm^{-3} 2013/04



Ploughing influences the soil-atmosphere gas exchange (N_2O fluxes)
Such a change may need to be considered during a simulation period.

Field exp.

Cumulative N_2O emissions

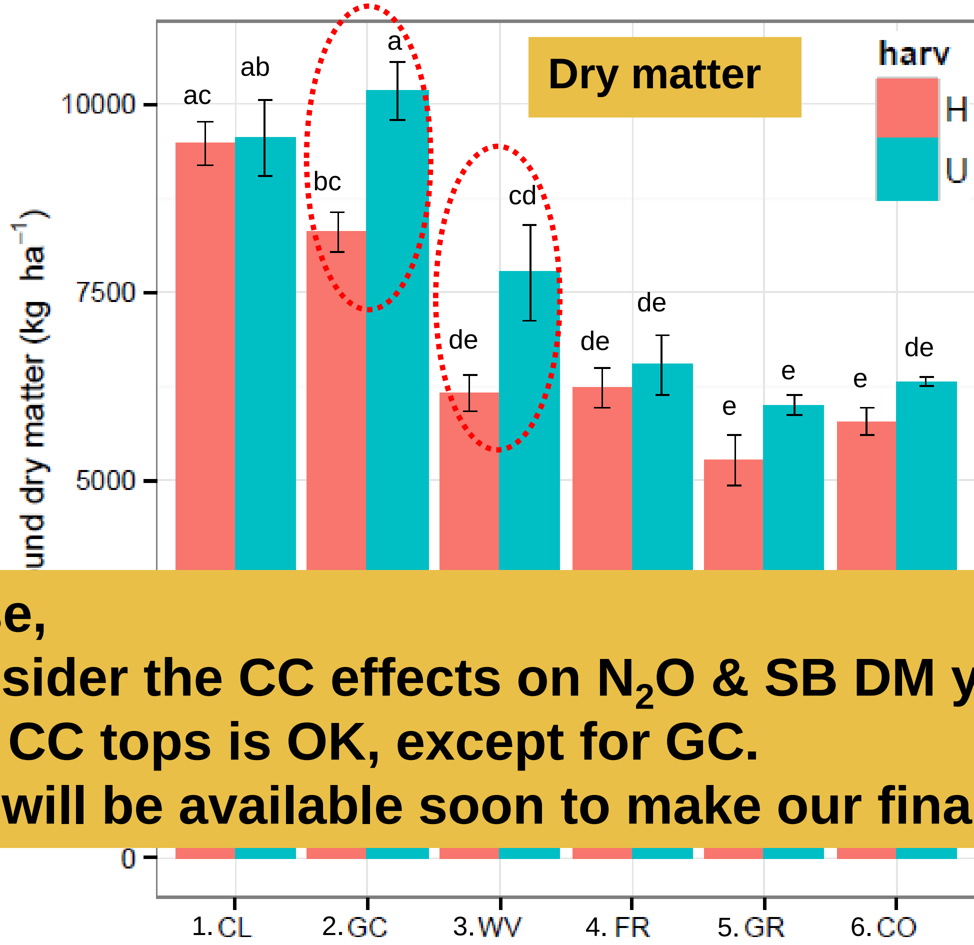
	cc	harv	Autumn (52 d)	Winter (172 d)		Spring (46 d)		Total 3 seasons (270 d)			
			Cumulative emissions					Cumulative		Mean daily	
			g N/ha					g N/ha		g N/ha/d	
Legume	1.CL	H	24	507	b	222	ab	753	b	2.8	bc
		U	39	375		343		757		2.8	bc
	2.GC	H	46	425	bc	292	a	763	b	2.8	bc
		U	36	203		456		695		2.6	bc
	3.WV	H	14	520	b	152	bc	686	b	2.5	bc
		U	61	347		241		649		2.4	bc
Non-legume	4.FR	H	49	1437	a	101	c	1588	a	5.9	a
		U	16	878		201		1095		4.1	ab
	5.GR	H	20	48	c	374	a	442	b	1.6	c
		U	29	9		390		429		1.6	c
Control	6.CO	H	105	414	b	56	c	574	b	2.1	bc
		U	72	459		201		731		2.7	bc

	Autumn	Winter	Spring	Total cumulative	Total mean daily
cc effect harvest effect	cc, $p>0.05$ harv, $p>0.05$	cc, $p<0.001$ U < H, $p<0.01$	cc, $p<0.001$ U > H, $p < 0.001$	cc, $p<0.001$ harv, $p=0.2$	cc × harv $p=0.09$


GC_U
CO_H
CL_H
CO_U
GC_U
Barley 14/06/2013

Field exp.

Aboveground DM - spring barley (14/08/2013)



- CC early harvested
- CC left untreated until spring tillage

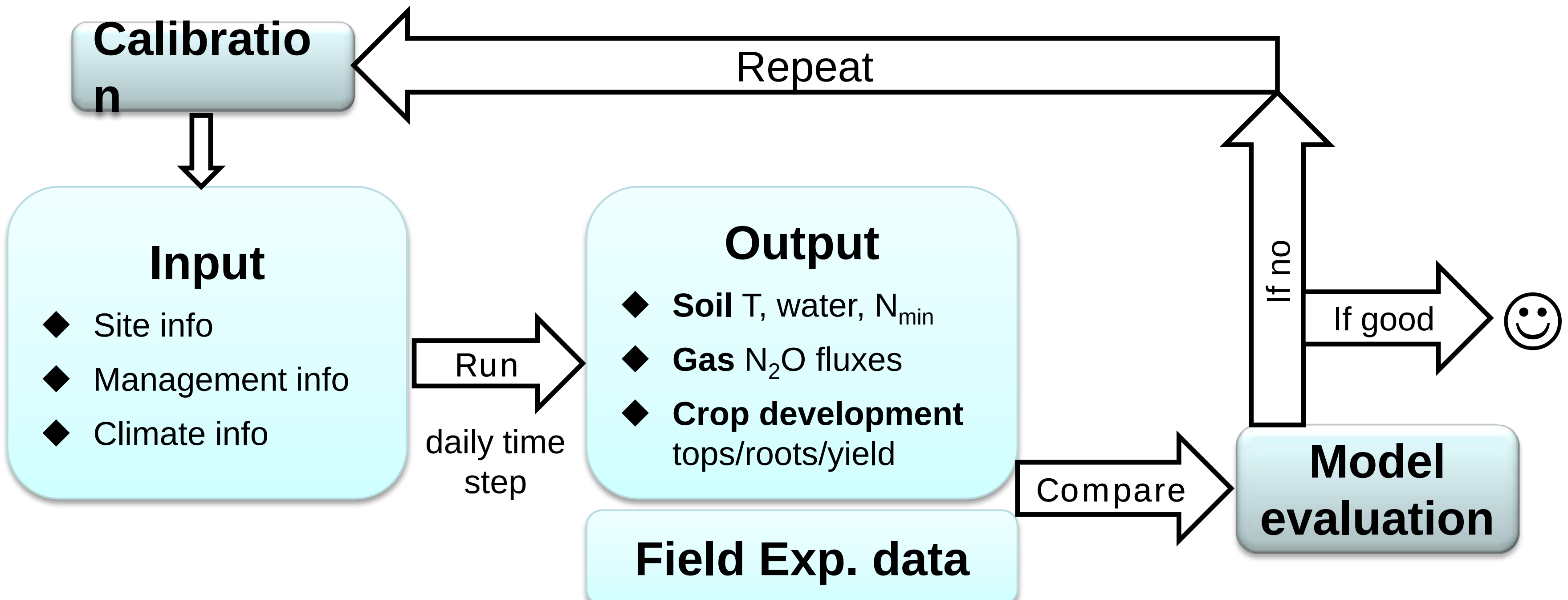
To summarise,

- **If only consider the CC effects on N_2O & SB DM yield, CL / GC better.**
- **Removing CC tops is OK, except for GC.**
- **More data will be available soon to make our final conclusions.**

First try with DNDC

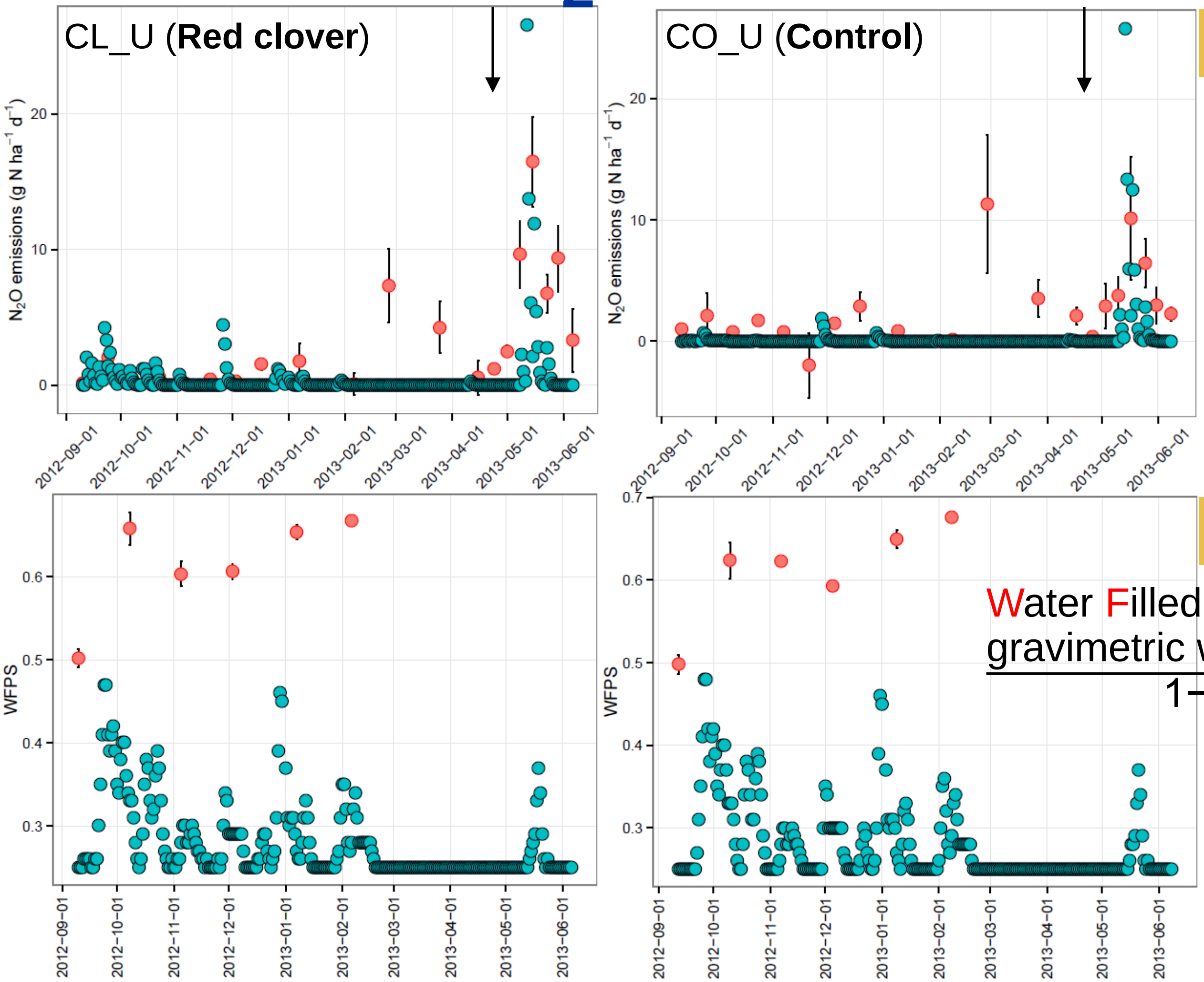
2 treatments: Red clover & control (CL_U & CO_U)

Change the values of initial input variables as many as possible



Preliminary simulation by DNDC

Simulated N_2O fluxes & WFPS



N_2O fluxes

WFPS (0~30 cm)

Water Filled Pore Space =

$$\frac{\text{gravimetric water content} \times \text{bulk density}}{1 - \text{bulk density}/2.65}$$

(2.65, particle density)

Preliminary simulation by DNDC

Cumulative N_2O & sensitivity analysis

Cumulative N_2O emissions during three seasons (g N ha^{-1}, 10/09/2012 ~ 06/06/2013)

Treatment	Bulk density (g cm^{-3})	Observed	Modelled	Difference	Relative deviation (%)
CL_U	1.38	757.2	130.7	-626.5	-83%
	1.34		127.2	-630.0	-83%
	1.28		121.8	-635.4	-84%
CO_U	1.38	731.3	85.7	-645.6	-88%
	1.34		83.3	-648.0	-89%
	1.28		79.6	-651.7	-89%

Difference = Modelled - Observed

Relative deviation (%) = Difference / Observed

- **Underestimation**
- **Little change with change of bulk density**
- **More work needed to improve the simulation**

Future work plan

1. To achieve a better simulation
2. To evaluate the model performance using different statistical indexes (RMSE etc.)
3. Scenario studies: different LBCC species, different management scenarios, different climate scenarios
4. May also try another model (FASSET) and compare the model performance

Some questions

- How does the model consider:

1) the concurrent growth stage of spring barley and undersown catch crops (like in intercropping)
2) the change of some physical parameters like bulk density change over time?

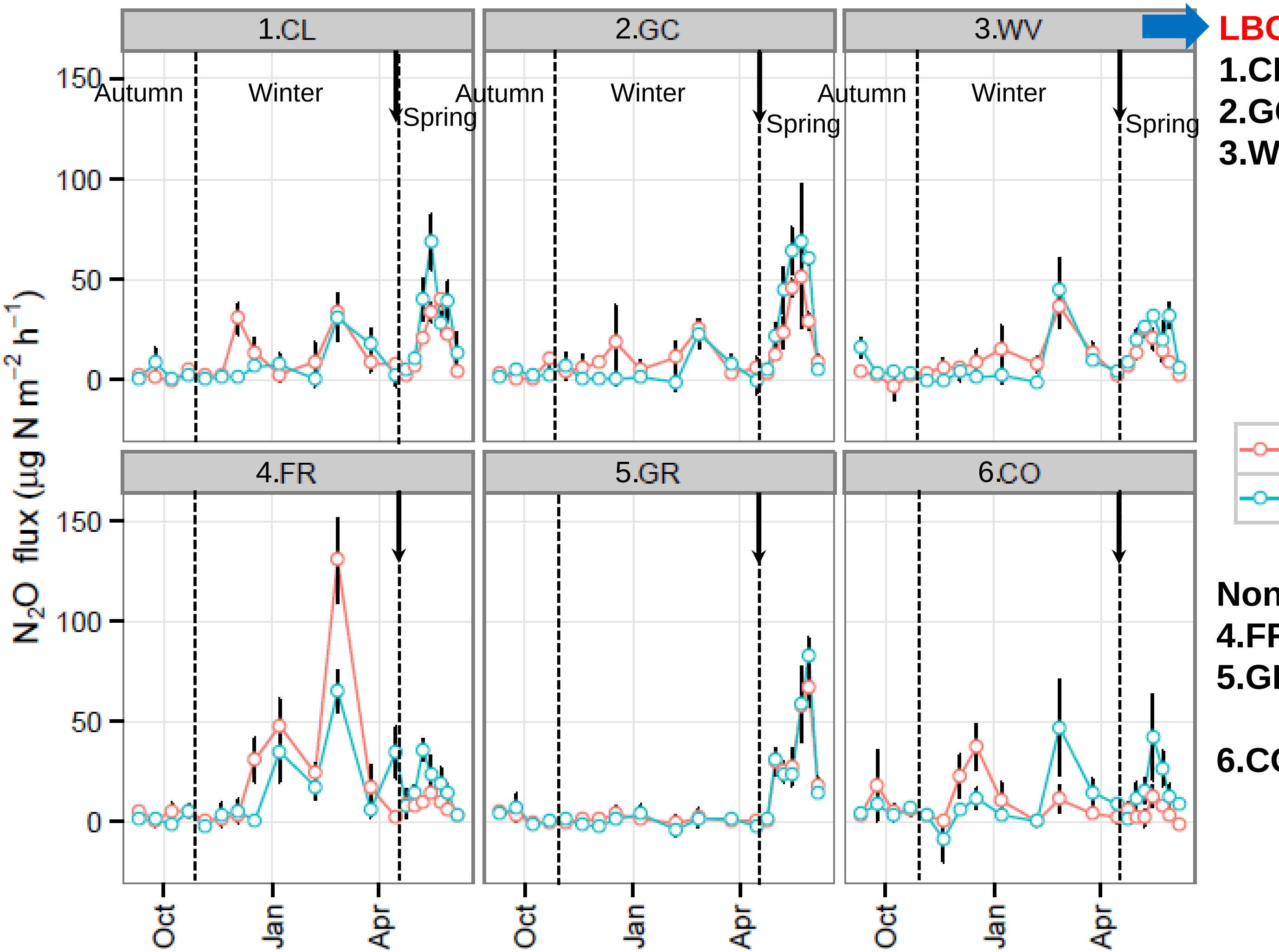
- To do the iterative calibration, where is the end of calibrating a model? Endless job?

Acknowledgements

- My three supervisors
- All the kind help from lots of technicians
- All the kind help from my colleagues
- HighCrop Poject

Field exp.

N_2O fluxes (10/09/2012 - 06/06/2013)



LBCC

1.CL - Red clover
2.GC - Grass clover mixture
3.WV - Winter vetch

Non-LBCC

4.FR - Fodder radish
5.GR - Ryegrass

6.CO - Control without CC

Site and climate data

DNDC input variable	CL	CO
Latitude (degree)	56.5º N	
N concentration in rainfall (mg N L^{-1})	0.000*	
Atmospheric CO_2 concentrations (ppm)	394	

Soil properties

DNDC input variable	CL	CO
Soil texture	Sandy loam	
Clay fraction	0.086	
Soil pH	6.4	
Initial organic C content at surface soil (kg C kg−1)	0.018	
Initial soil NO3- (mg N/kg)	2.29	3.28
Initial soil NH4+ (mg N/kg)	0.31	0.61
WFPS at field capacity	0.25*	
WFPS at wilting point	0.13*	
Hydroulic conductivity (m/hr)	0.5628*	
Soil porosity	0.411*	
Depth of water-retention layer (>0.5 m)	9.99*	
Drainage efficiency (0-1)	1*	

Crop data (year=1)

Crop type	Legume hay	Fallow
Plant time	10/08/2012	
Harvest time	22/04/2013	
Cover crop	Yes	
Fraction of leaves + stems left in field after harvest	1 (100%)	
Leaf fraction	0.4*	
Leaf C/N ratio	12	
N fixation index (crop N/N from soil)	5*	

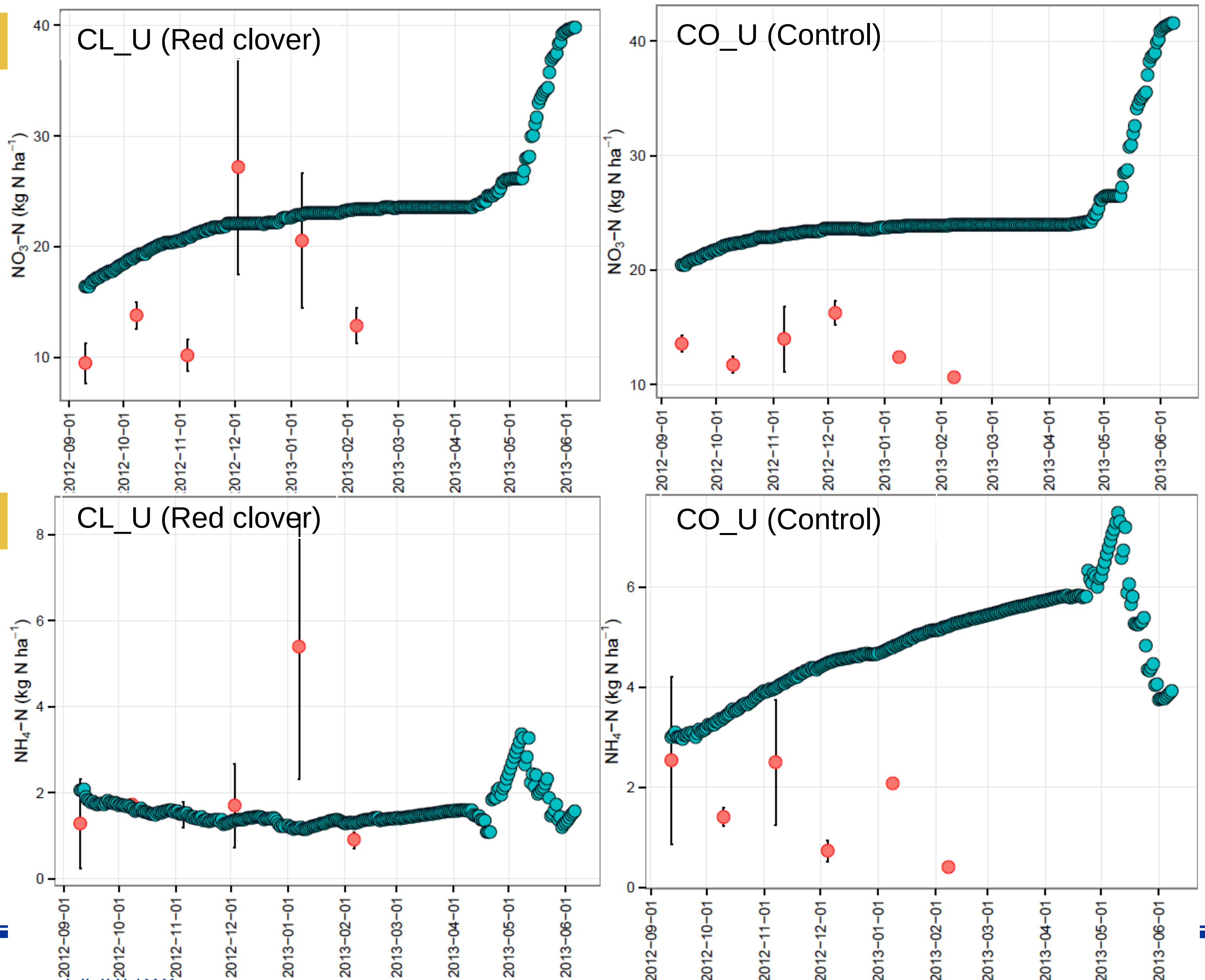
Crop data (year=2)

Crop type	Barley
Plant time	23/04/2013
Harvest time	15/08/2013
Cover crop	No
Fraction of leaves + stems left in field after harvest	0.05
Tillage (Ploughing with moldboard, 20 cm)	22/04/2013

*Default value of DNDC

NO_3-N

NH_4-N


CL_U (Red clover)
CO_U (Control)
CL_U (Red clover)
CO_U (Control)
NO_3-N (kg N ha^{-1})
NH_4-N (kg N ha^{-1})
2012-09-01
2012-10-01
2012-11-01
2012-12-01
2013-01-01
2013-02-01
2013-03-01
2013-04-01
2013-05-01
2013-06-01