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GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

# Session 3 - Cover crops, legumes and emissions at rotation scale

Chair: Charles Rice

Co-chair: Elizabeth Pattey

**Key note lecture -** Bob Rees

**Short oral presentations:**

- Marie-Hélène Jeuffroy, Pierre Cellier
- Xiaoxi Li
- Alberto Sanz-Cobeña

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# Key note lecture

## Cover crops, legumes and $N_2O$ emissions at rotation scale

Bob Rees, SRUC, UK

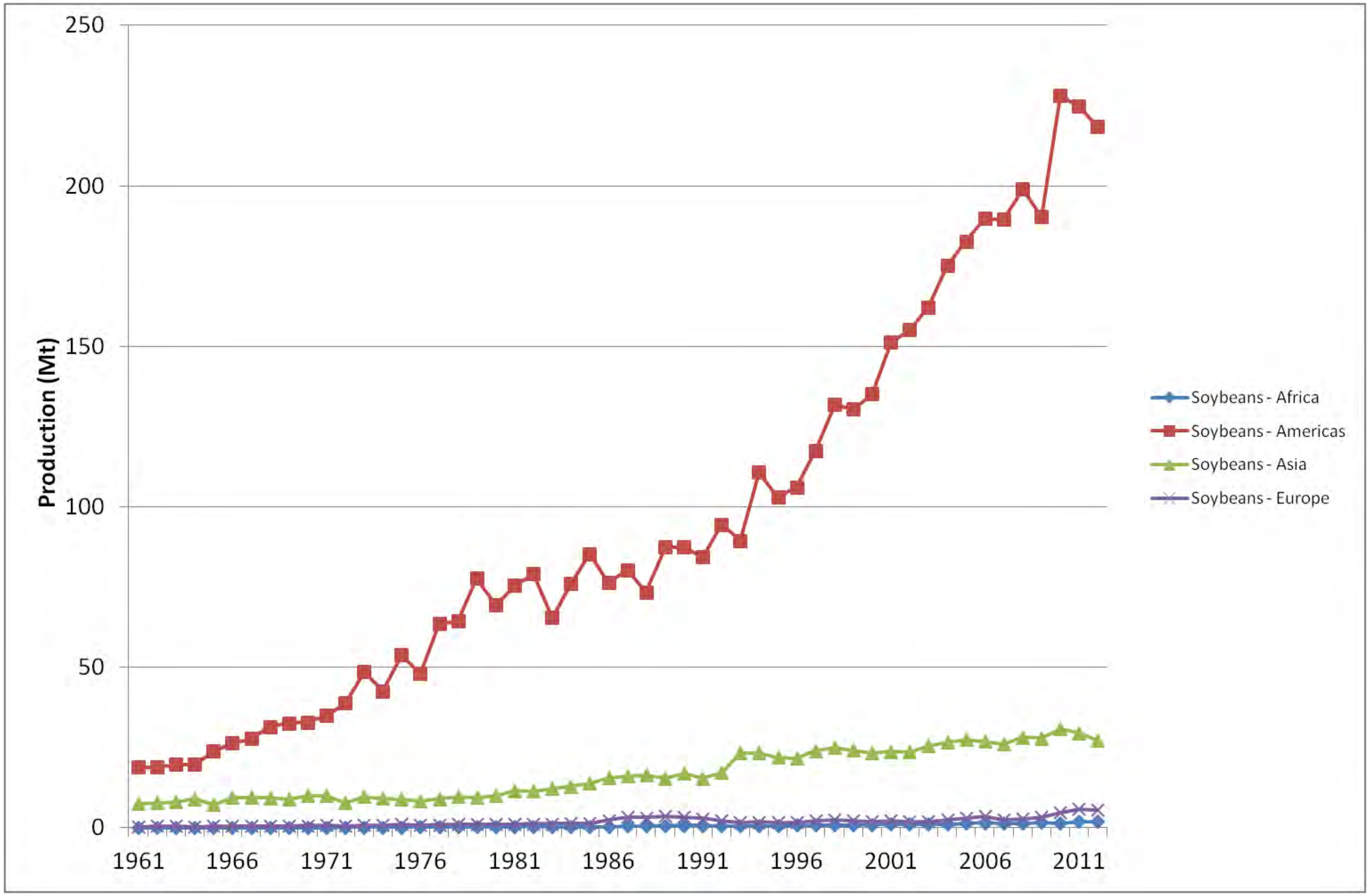
Angelopoulos, N, Eory V, Maire J, Dequiedt B, Iannetta PPM, Kuhlman T, Murphy-Bokern D, Pappa V, Reckling M, Sylvester-Bradley R, Schlaefke N, Smith K, Stoddard F, Thorman R, Topp CFE, Watson CA, Williams M, and  Zander P.

17-19 March 2014
PARIS

Workshop "Experimental databases and model of N2O emissions by croplands: do we have what is needed to explore mitigation options?"

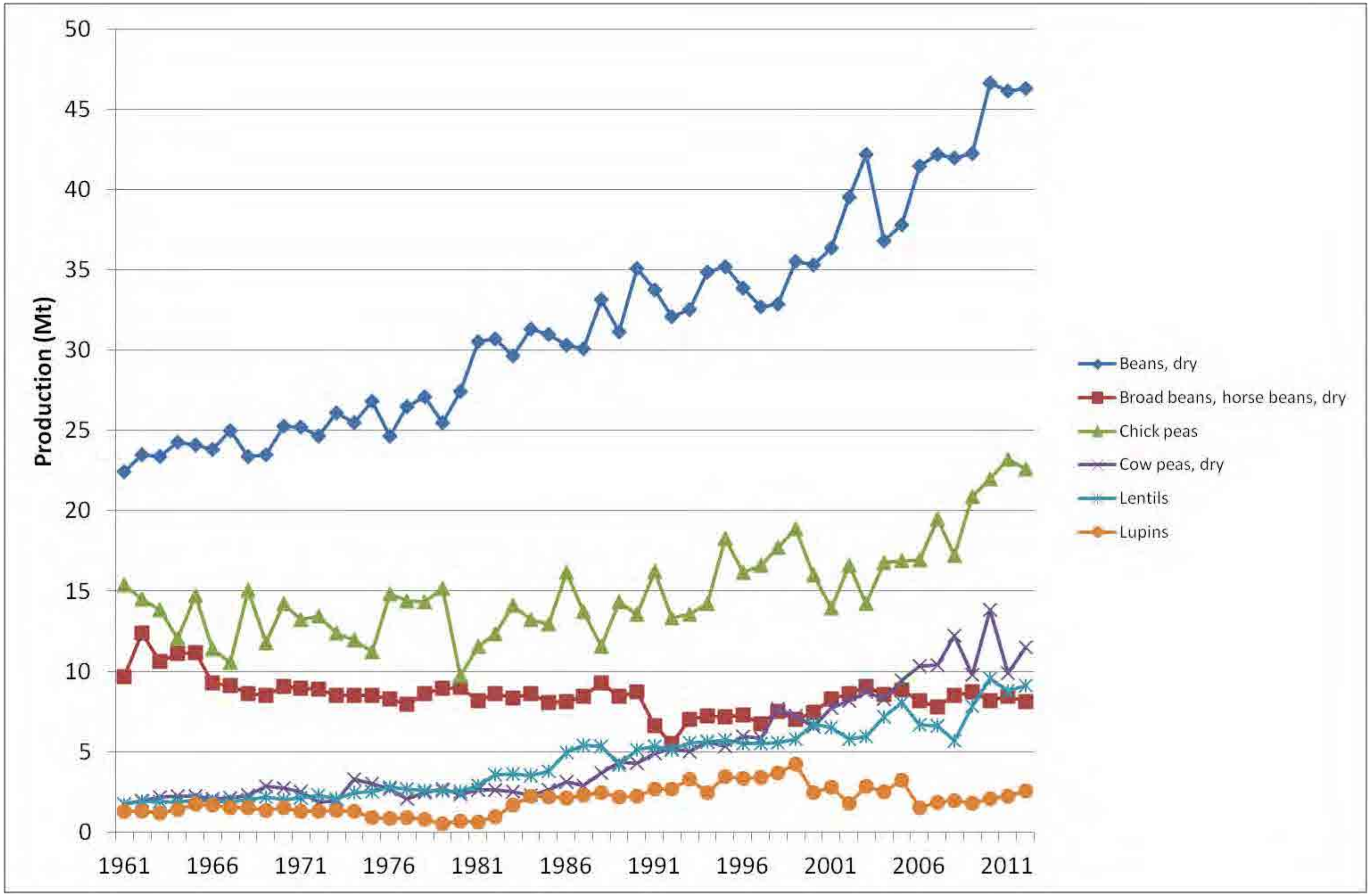


# Soyabean production




FAOSTAT 2013

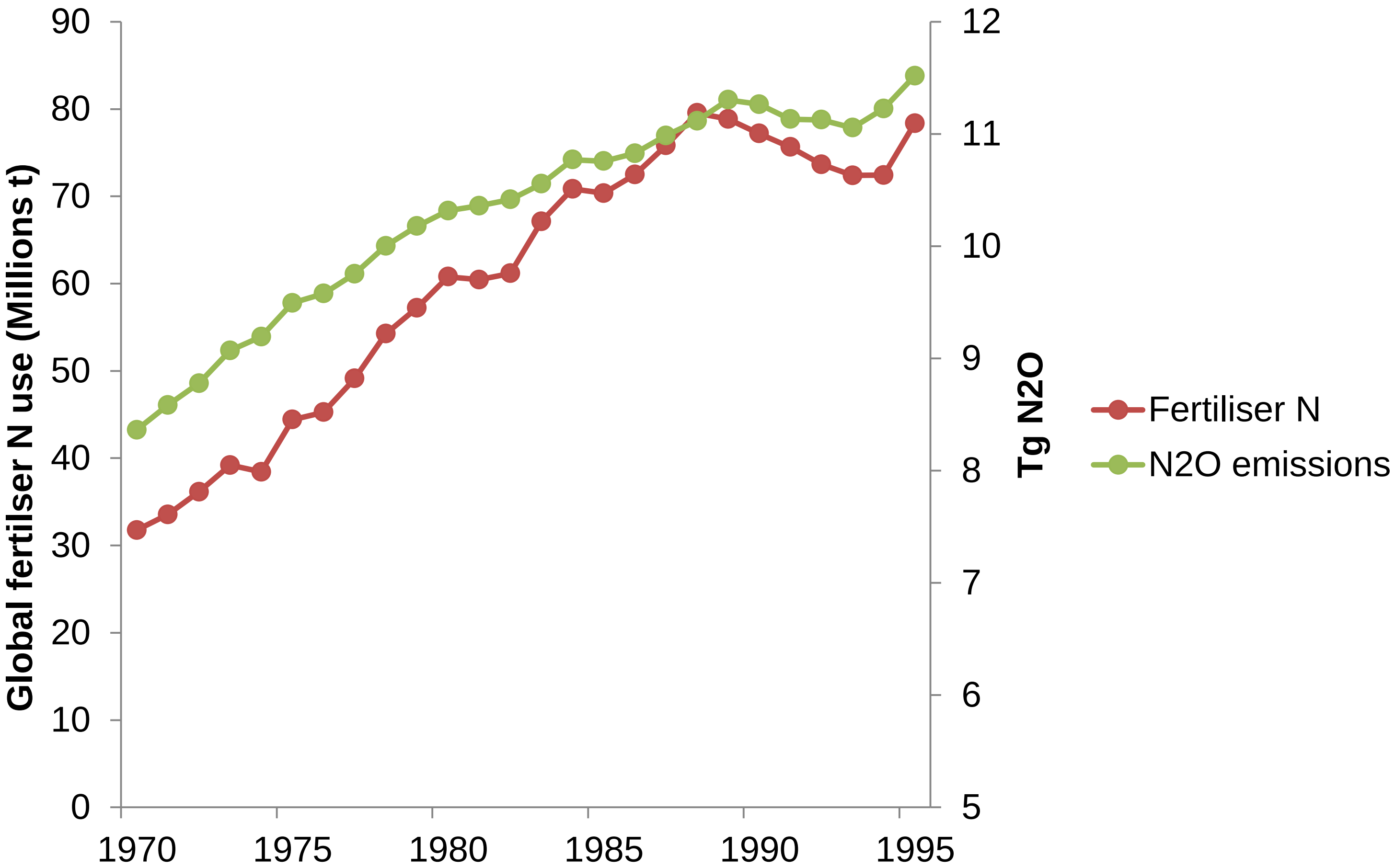
# Global grain legume production




FAOSTAT 2013



# Global fertiliser use and $N_2O$ emissions




FAO stat

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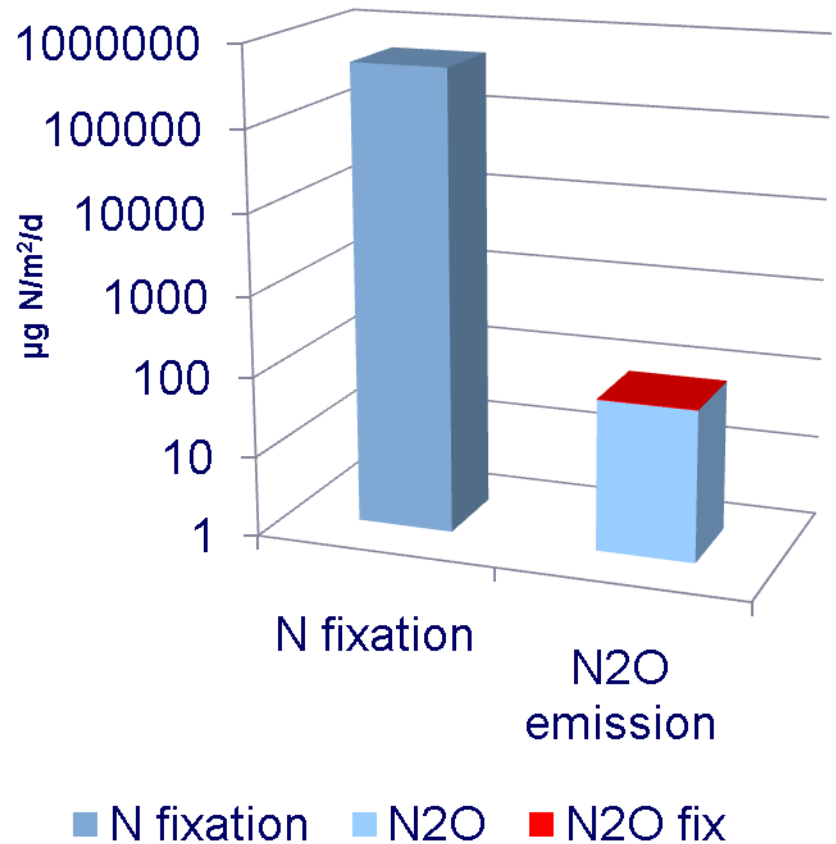
# The contribution of N fixation to $N_2O$ emissions

- Clover grown in an atmosphere labelled with $^{15}N_2$
- Allows direct measurement of N fixation and $N_2O$ produced from recently fixed N




Carter and Ambus, 2006; NCA 74;13-26



# Summary

- Legumes are a vital global component of agricultural systems and their low $N_2O$ emissions would appear to offer mitigation potential
- The use of legumes for $N_2O$ mitigation can be economically favourable, but supportive policies would probably be necessary to promote wider adoption
- Emissions of $N_2O$ from crop residues and cover crops is poorly understood, and likely to be influenced by residue quality and management

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# Short presentation

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## Introducing pea crop in arable crop successions: an efficient way to decrease greenhouse gas emissions from cropping systems

Marie-Hélène JEUFFROY, Pierre CELLIER
INRA, France



# Context

- $N_2O$ emissions in the European cropping systems are mainly linked with the use of mineral nitrogen fertilizers
- Decreasing the use of N fertilizers without reducing crop production is allowed by introducing legumes in cropping systems. Among them, pea is the most grown legume in Europe.
- Yet, the effect of legumes on $N_2O$ emissions is still debated in the literature *(Rochette & Janzen, 2005)* due to :
  - Possible $N_2O$ emissions during the $N_2$ fixing process
  - Their residue, rich in Nitrogen
  - The large amount of N rhizodeposition in the soil
- Few data on $N_2O$ emissions on pea are available, especially in comparison with other crops grown in the same conditions, while emissions vary with climate, soil characteristics, the cropping system considered.



# Aims

- to quantify $N_2O$ emissions from a pea crop in comparison with wheat and oilseed-rape crops, fertilized or not, during spring
- To quantify $N_2O$ emissions during autumn, after a pea crop, a wheat crop or an oilseed rape crop
- To quantify $N_2O$ emissions in various rotations



# Material and Methods

## 3 years field experiment

| 2006/2007 | 2007/2008 | 2008/2009 | 2009/2010 |
|---|---|---|---|
| | Wheat (N/no N) | OilSeedRape | Wheat (N/no N) |
| | Wheat (N/no N) | Pea | OilSeedRape |
| Wheat | Wheat (N/no N) | Pea | Wheat (N/no N) |
| or | Wheat (N/no N) | Wheat (N/no N) | OilSeedRape |
| | OilSeedRape | Wheat (N/no N) | Wheat (N/no N) |
| Barley | OilSeedRape | Wheat (N/no N) | Pea |
| | Pea | OilSeedRape | Wheat (N/no N) |
| | Pea | Wheat (N/no N) | Wheat (N/no N) |

*Fertiliser rates calculated with the balance-sheet method*
*(adapted according to the preceding crop)*

→ Comparison of crops, preceding crops and rotations



# Material and Methods

Crops are grown on a same field → similar soil and weather conditions for $N_2O$ emissions

3 years of measurements

$N_2O$ measurement with static chambers (6 per treatment)

- *Every month during the crop cycle ; twice a week in the two weeks following a N fertilizer application*
- *Measurement of $N_2O$ in the chamber at closure of the chamber, and 45 min, 90 min, and 135 min later*

→ *20 measurements in spring and 10 measurements in autumn, in average.*

+ agronomic measurements (N in soil, SWC, yield, …)

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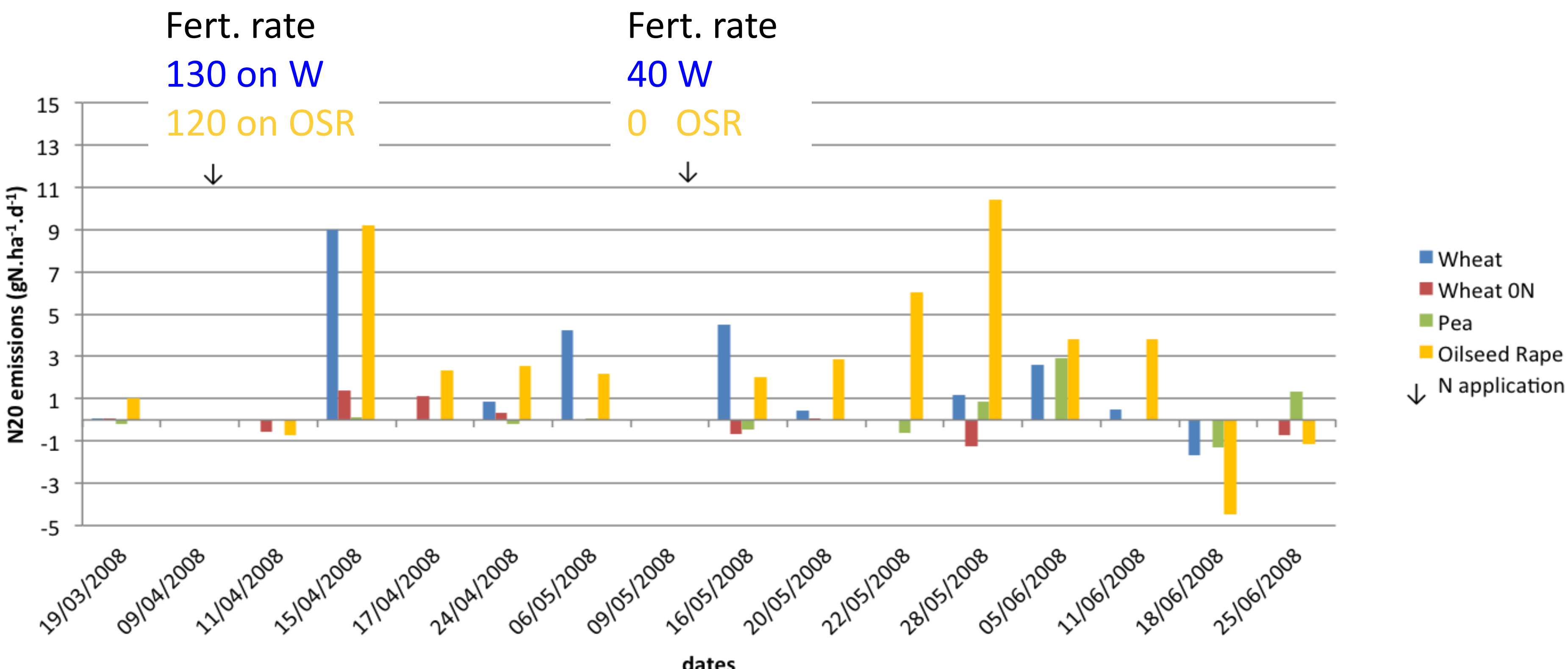
# Pea *vs.* other crops *(case of spring 2008)*



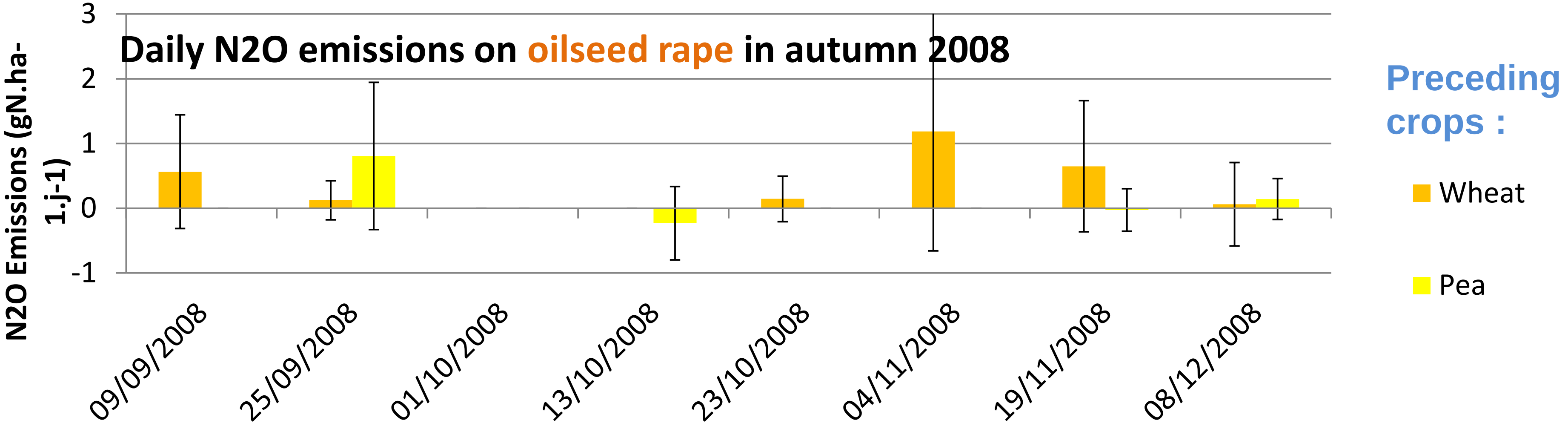

→ A high variability in $N_2O$ emissions across the spring

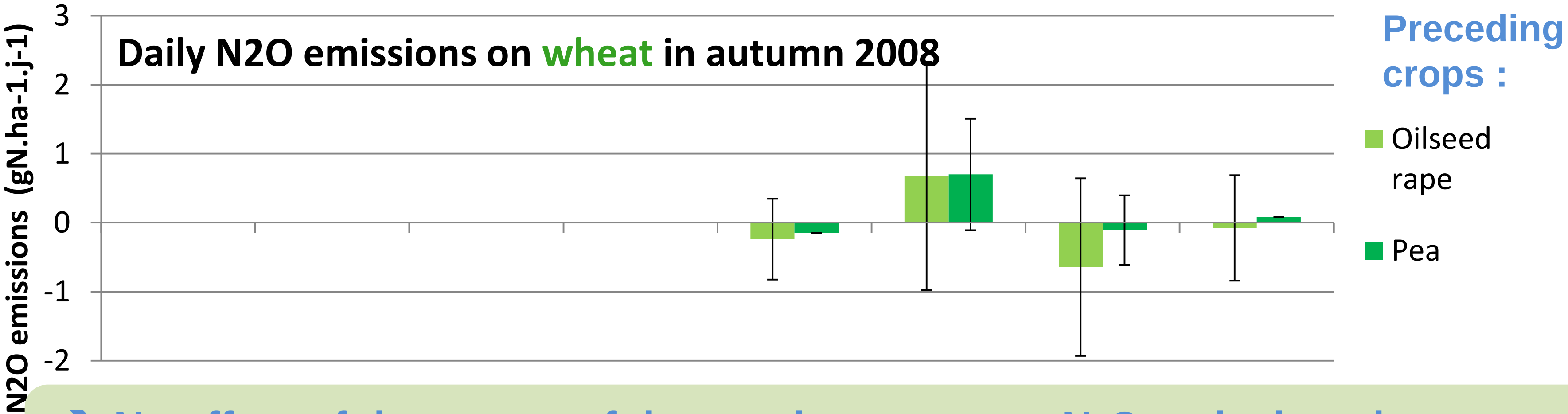
→ Fertilized crops (W and OSR) have higher emissions than unfertilized wheat

→ The emissions on pea are similar to those of unfertilized wheat

→ The same results were observed during the three years


# Effect of the residues *(case of autumn 2008)*




➔ No effect of the nature of the previous crop on $N_2O$ emissions in autumn, even though mineral N conc. was higher in the soil after the pea crop

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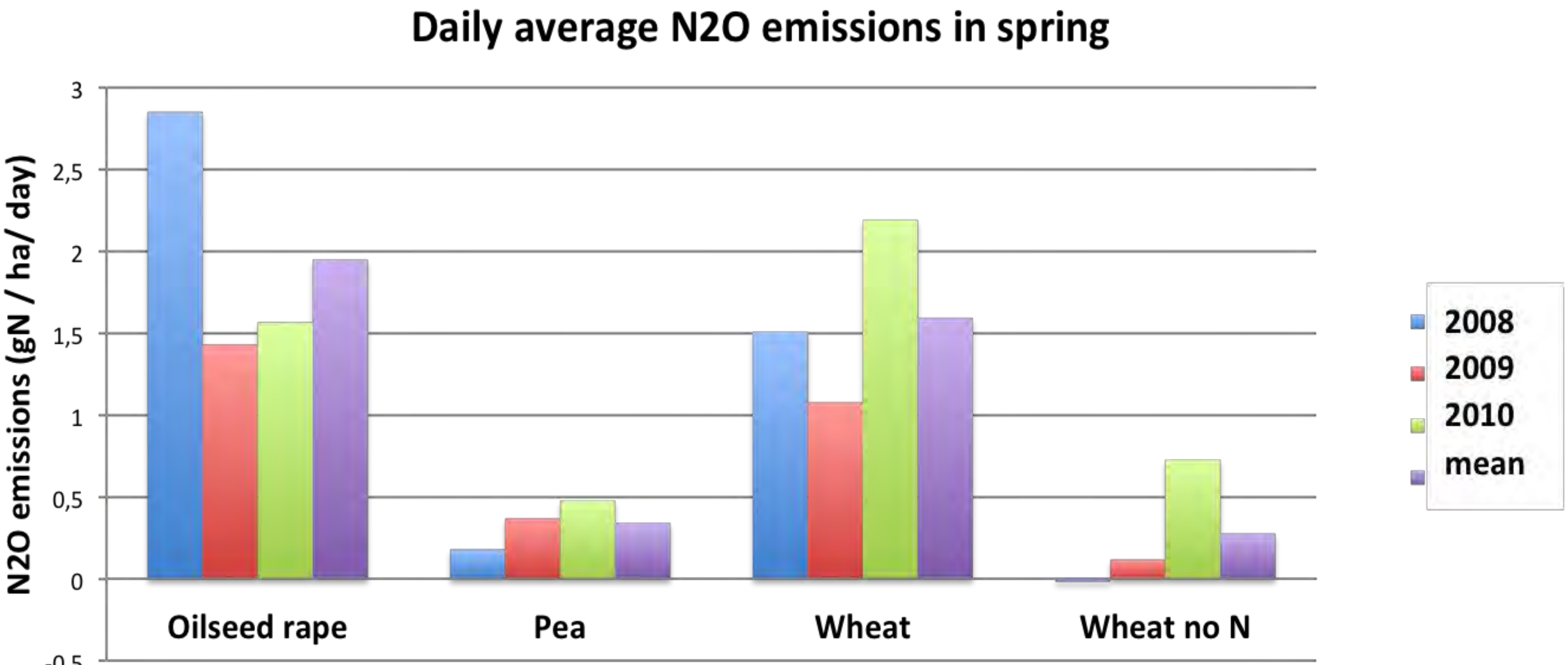
# Comparison of crops

## *(cumulated values from January to July)*

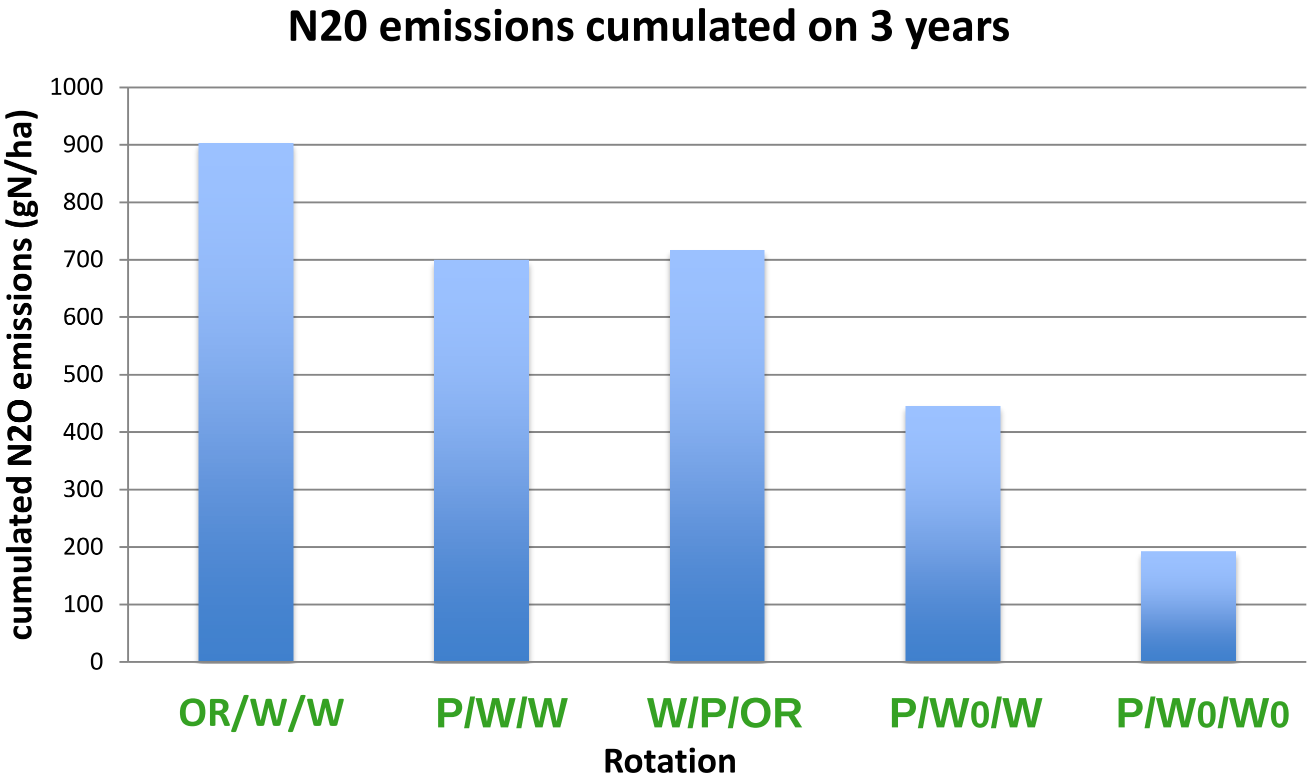



→ **An effect of the year (due to the weather when N fertilizer was applied)**

→ **A strong difference on pea, with emissions lower than that over fertilized wheat or oilseed rape, but similar to unfertilized wheat, whatever the year**



# Comparison of rotations




P = Pea
OR = Oilseed Rape
W = Wheat
W0 = unfertilized Wheat

- → A strong effect of the rotation on the cumulated $N_2O$ emissions (for 3 years)
- → The rotation without pea has the highest emissions
- → Rotations including 1 Pea and 2 fertilized crops have 20% less emissions
- → Rotations with 1 pea and 1 unfertilized crop have 50% less emissions



# Conclusion and perspectives

- ✓ This study provided new data on $N_2O$ emissions on grain legumes and at rotation scale
- ✓ In the field, $N_2O$ emissions were very low on pea, during the crop and the intercrop. No effect could be observed during the following crop
- ✓ These results are in agreement with the IPCC reference, which does not take into account $N_2O$ emissions from $N_2$ fixation

- ✓ The introduction of one pea crop in a 3-year rotation could allow a reduction of more than 20% of $N_2O$ emissions !
- ✓ The effect of GHG budget should be larger, when accounting for the ernegy saved from not using industrial fertilizers

*In a near future, we will use models in order to simulate the daily emissions, to be able to make a better integration of $N_2O$ emission along the season.*

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# Thank you !

Biogeosciences, 10, 1787–1797, 2013
www.biogeosciences.net/10/1787/2013/
doi:10.5194/bg-10-1787-2013


Biogeosciences Open Access

## Nitrous oxide emissions from crop rotations including wheat, oilseed rape and dry peas

M. H. Jeuffroy[1,2], E. Baranger[1,2], B. Carrouée[3], E. de Chezelles[1,2], M. Gosme[1,2], C. Hénault[4], A. Schneider[3], and P. Cellier[5,6]

PROLEA UNIP

INRA SCIENCE & IMPACT

Study funded by the Ministry of Agriculture



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# Short presentation

## Nitrous oxide emissions from an organic cropping system as affected by catch crop type and management


**Xiaoxi Li**, Aarhus Univ., Denmark

Søren O. Petersen, Peter Sørensen

Jørgen E. Olesen

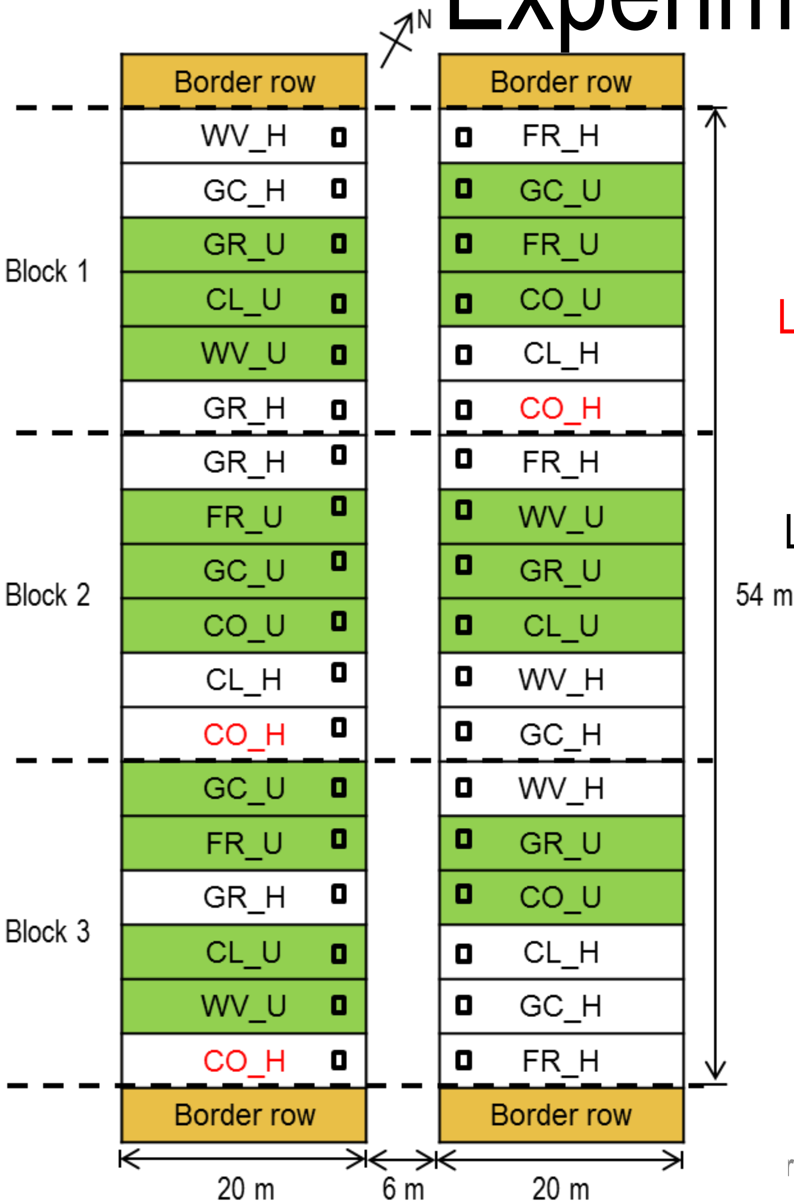
AARHUS UNIVERSITY



# Organic farming and CC

- **Expanding** in Denmark: >6%, double by 2020
- **No manure** input from conventional sources, 2022
- How to **sustain N inputs** and **higher yields** with **less GHG emissions** in organic farming?
- Increasing interest in using CC as biogas feedstock
- **Hypothesis**: a) LBCC, more N, higher risk of $N_2O$, lower yield-specific emissions; b) Harvest CC can reduce soil $N_2O$ emissions


# Experimental design




- **Factor I -- 5 CC types + 1 no CC control**

LBCC
1.CL Red clover sown in May 2012
2.GC Ryegrass/clover
3.WV Winter vetch sown in Aug 2012

Non-LBCC
4.FR Fodder radish
5.GR Ryegrass

6.CO Control without CC

- **Factor II -- 2 management**

H - autumn harvest end Oct 2012

U - spring incorporation late Apr 2013

**Spring barley**: Apr – Aug 2013

and model of N2O emissions by croplands:
re mitigation options?"



# LBCC can give substantial C and N input

| Catch crop type | | Dry matter ($Mg\ ha^{-1}$) | | Top/root ratio | N content (%) | | Total N ($kg\ ha^{-1}$) | | Top/root N ratio |
|---|---|---|---|---|---|---|---|---|---|
| | | Top | Root* | | Top | Root | Top | Root | |
| LBCC | Red clover | 1.9 a | 1.4 a | 1.5 a | 3.4 a | 3.1 a | 66 a | 41 a | 1.5 a |
| | Grass / clover | 1.9 a | 1.2 a | 1.5 a | 3.2 ab | 2.7 ab | 59 a | 32 a | 1.8 a |
| | Winter vetch | 1.7 ab | 1.2 a | 1.4 a | 4.0 a | 2.7 ab | 67 a | 32 a | 2.2 a |
| Non-LBCC | Fodder radish | 1.7 ab | 1.3 a | 1.2 a | 2.4 b | 2.1 bc | 40 b | 26 a | 1.4 a |
| | Ryegrass | 1.3 b | 1.3 a | 1.0 a | 2.5 b | 1.6 c | 32 b | 23 a | 1.5 a |
| Weeds | Control (no CC) | 1.4 ab | | | 2.2 b | | 31 b | | |

* Root (0-20 cm), >40% of DM, > 33% of total N

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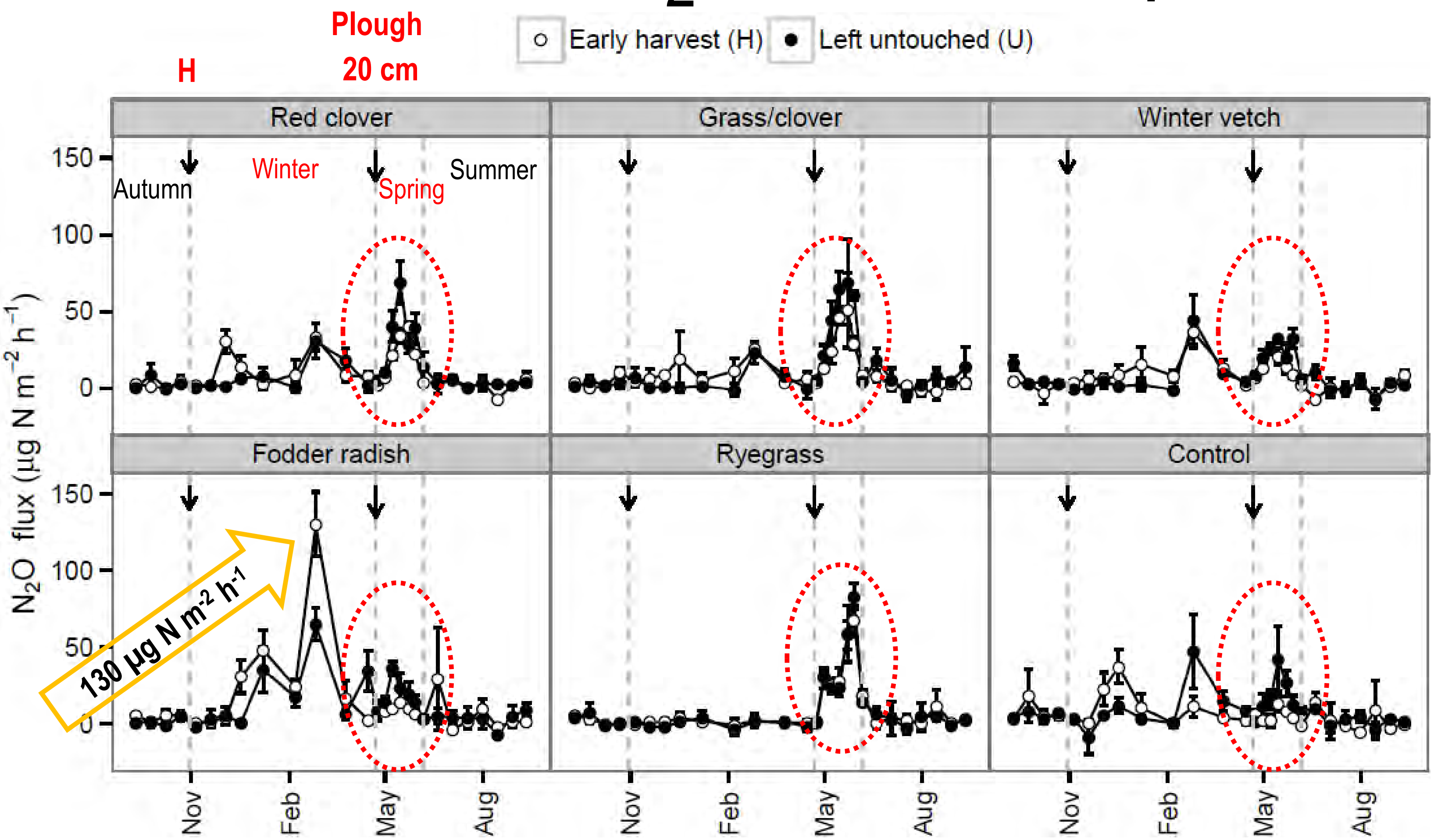
# Different seasonal $N_2O$ emission patterns

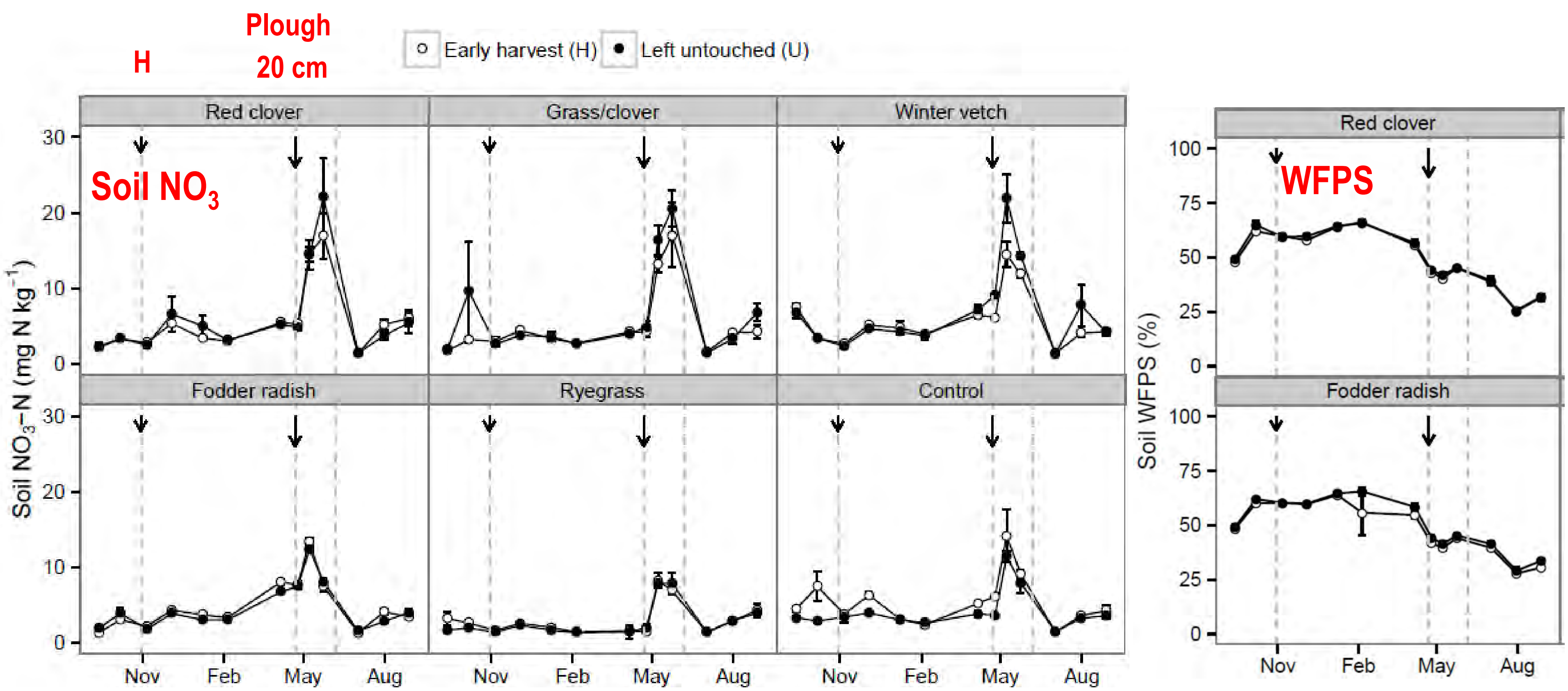
LBCC

Non-LBCC



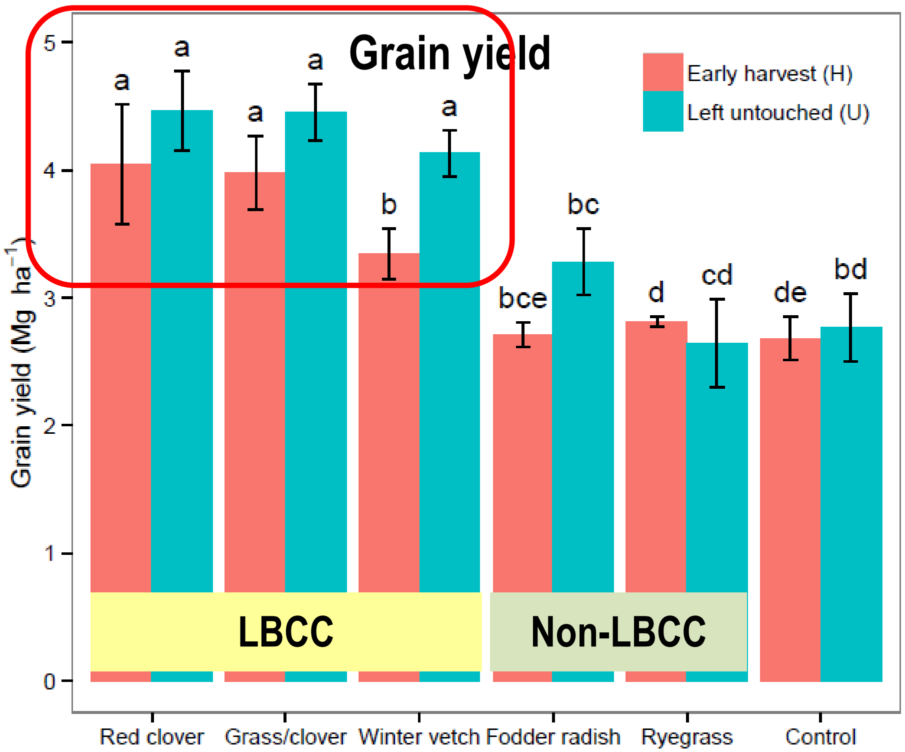


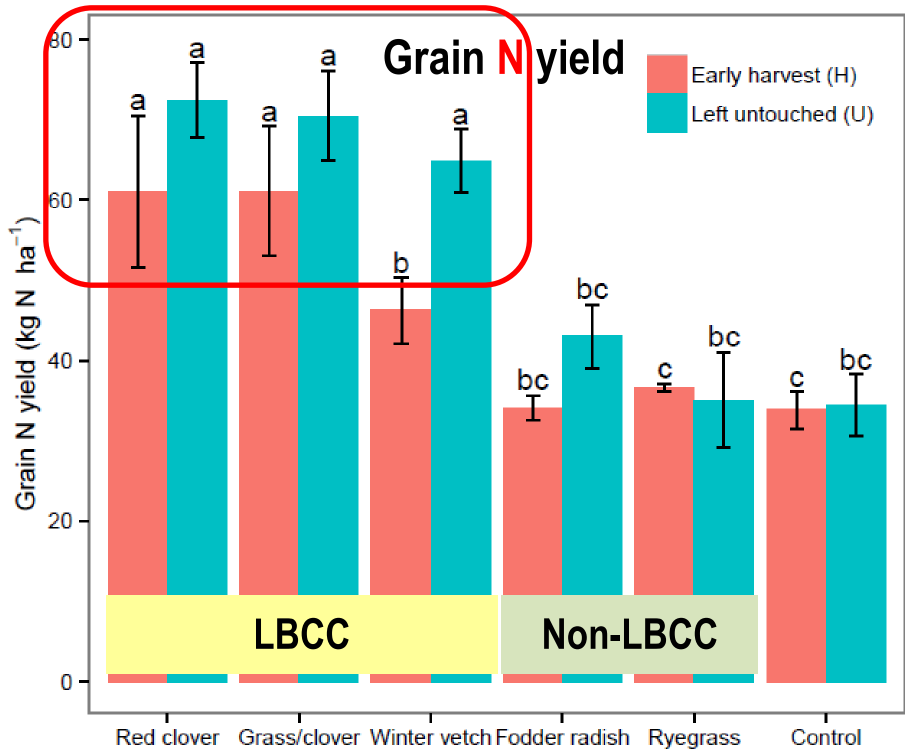
# Mineral N increase after incorporation, differs among CC





# Higher yield of barley in LBCC and non-harvest plots





# Conclusions

- LBCC did increase the crop yield, but will not necessarily increase annual or yield-specific $N_2O$ emissions
- Harvest of CC may reduce crop yield (i.e. WV), unless the harvested N is recycled to the field in manure of digested biomass; little effect on total $N_2O$ emissions
- Long-term study (dif soil, climate & management), micro-scale soil process study and simulation study will help elucidate how LBCC can benefit a sustainable organic farming system



# Short presentation

## Implications of introducing cover crops in a maize cropping system: N uptake, $NO_3^-$ and $N_2O$ losses

Alberto Sanz-Cobeña,
Technical University of Madrid, Spain

POLITÉCNICA
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CAMPUS DE EXCELENCIA INTERNACIONAL



# Cover crops

- Crops introduced to cover the soil within the period in which this is not protected by the main crop.

- Aiming to increase the sustainability of the cropping system




✓ Improvement of crop quality

✓ Nutrients recycling

✓ Reducing nitrate leaching

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Spring | Summer | Autumn | Winter | Spring | Summer

**RAINFALL**

**Cash crop: Maize**

**Intercrop period: Fallow**

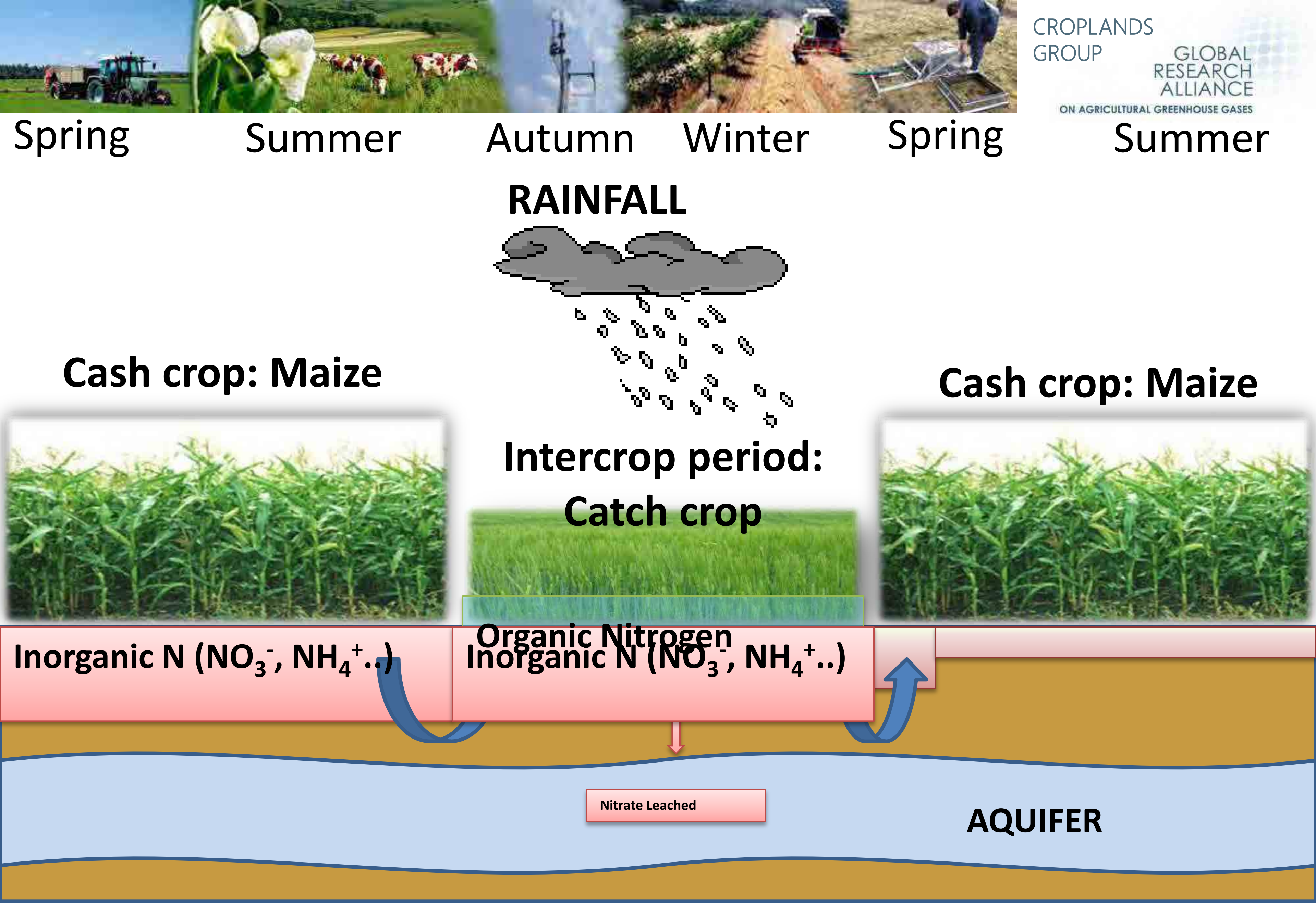
**Cash crop: Maize**

**Inorganic N ($NO_3^-$, $NH_4^+$..)**

**Inorganic N ($NO_3^-$, $NH_4^+$..)**

**Nitrate Leached**

**AQUIFER**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ON AGRICULTURAL GREENHOUSE GASES
Spring
Summer
Autumn
Winter
Spring
Summer
RAINFALL
Cash crop: Maize
Cash crop: Maize
Intercrop period:
Catch crop
Organic Nitrogen
Inorganic N ($NO_3^-$, $NH_4^+$..)
Inorganic N ($NO_3^-$, $NH_4^+$..)
Nitrate Leached
AQUIFER



# Field experiments

- 2006 -2010 in CC (barley, vetch and rape)-maize rotation.
- Objectives:

**Intercrop period (autumn-winter)**

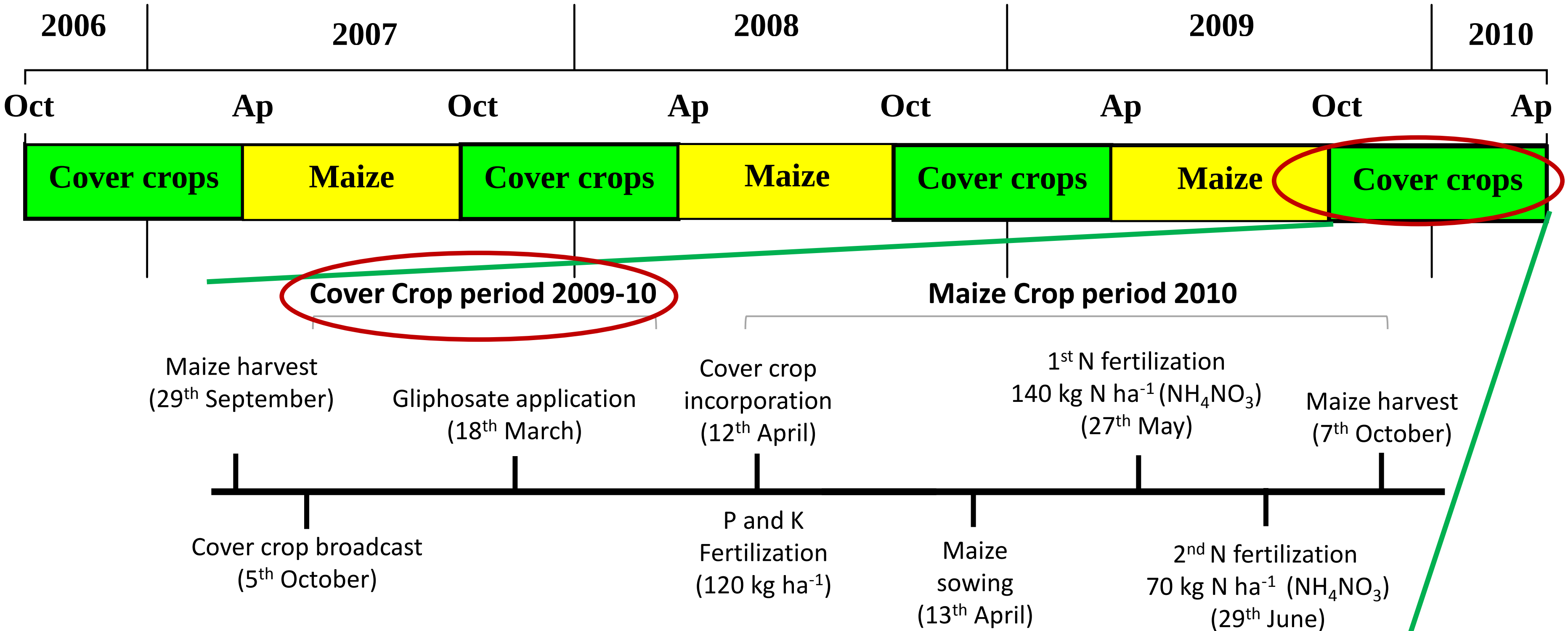
- To study the effect of CC over N uptake, $NO_3^-$ leaching and GHG emissions (only in 2009-2010).

**Maize crop period (spring-summer)**

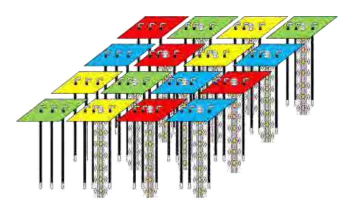
- To study the effect of (previous) planted CCs over maize N uptake and $NO_3^-$ leaching.
- To study the effect of incorporating CC residues (i.e. green manure from previous CC) to the soil over mineral N and GHG emissions ($N_2O$, $CO_2$, $CH_4$).

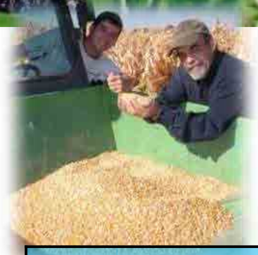


- **Experimental design**




- Soil: moisture, temp., NMIN ($NH_4^+$+ $NO_3^-$) (0.2 m depth).
- Maize: yield, aerial biomass, N uptake.
- GHG: **$N_2O$**, $CO_2$, $CH_4$.
- Drainaje & $NO_3^-$ leached.
- Weather conditions (air temp., pp, $ET_0$, etc.)



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# Results: maize yield

| | | Biomass (kg dm ha$^{-1}$) | | N Concentration (%) | | N Content (kg N ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|
| Year | Treat. | Grain | Total plant | Grain | Biomass | Grain | Biomass | Total plant |
| 2007 | Vetch | 14546 | 24129 | 1.16 | 0.49 | 168.7 | 44.8 | 213.5 |
| | Barley | 14922 | 25243 | 1.20 | 0.40 | 179.0 | 40.1 | 219.1 |
| | Fallow | 14351 | 24646 | 1.22 | 0.48 | 175.1 | 47.8 | 222.9 |
| 2008 | Vetch | 11590 | 22195 | 1.36 | 0.66 | 157.3 | 66.3 | 223.6 |
| | Barley | 11708 | 21805 | 1.30 | 0.61 | 151.4 | 58.2 | 209.6 |
| | Fallow | 11438 | 22281 | 1.30 | 0.61 | 147.3 | 61.4 | 208.8 |
| 2009 | Vetch | 11831 | 22477 | 1.35 | 0.72 | 158.7 **a** | 71.2 | 230.0 **a** |
| | Barley | 9796 | 18792 | 1.35 | 0.75 | 129.0 **ab** | 63.2 | 192.2 **ab** |
| | Fallow | 8446 | 17115 | 1.35 | 0.8 | 110.3 **b** | 62.2 | 172.5 **b** |
| Year | | * | * | * | * | * | * | NS |
| Treatment | | NS | NS | NS | NS | NS | NS | NS |



# Results: N uptake by the maize crop

N from the fertilizer → NRF

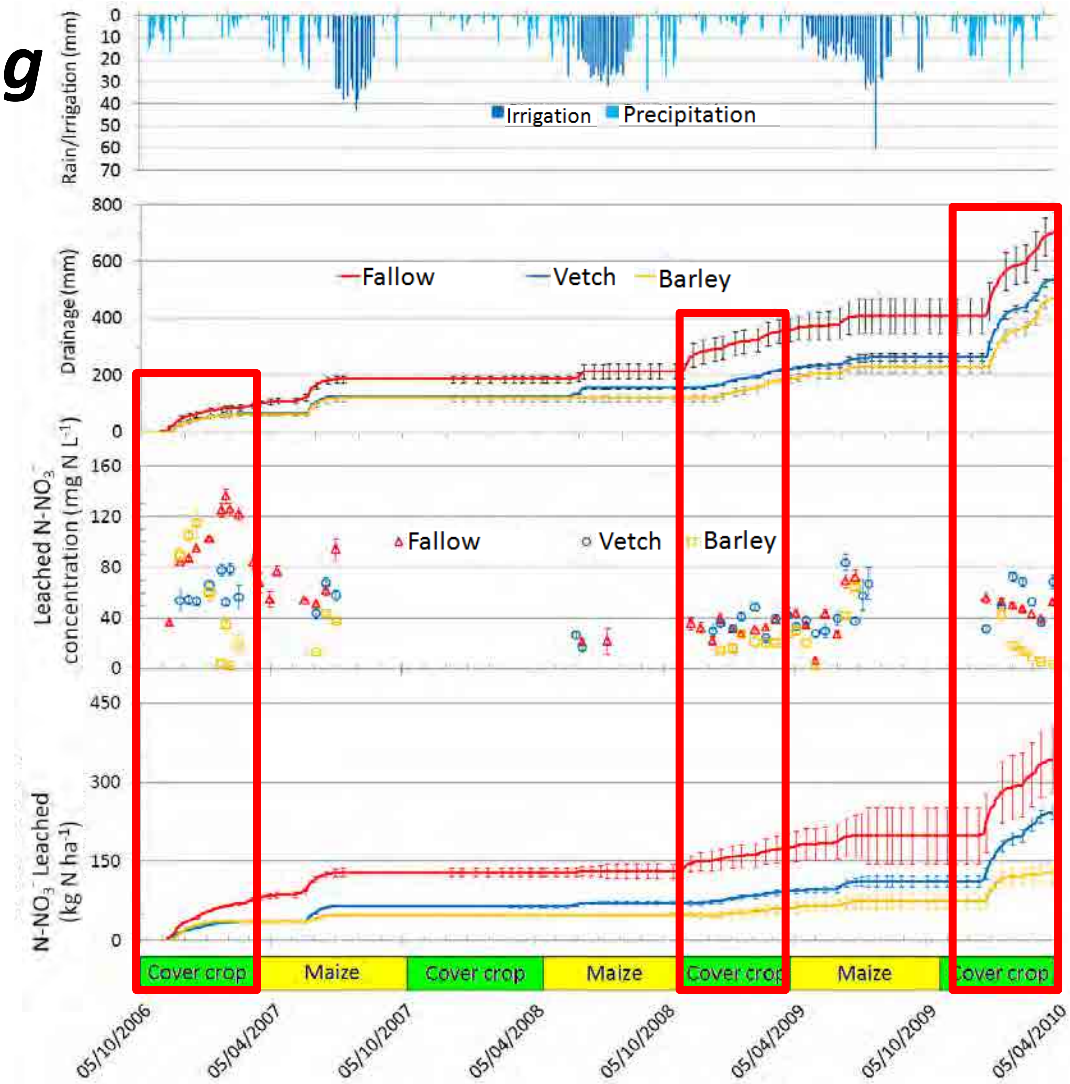
N from organic sources → NOS

| Year | Treat. | $^{15}N$ concentration (%) Grain | | Biomass | | $^{15}N$ recovered (kg N $ha^{-1}$) Grain | Biomass | Total | NRF (%) | NOS (kg N $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | Vetch | 1.10 | | 1.07 | | 66.9 | 17.2 | 84.1 | 40.0 | 129.4 | |
| | Barley | 1.18 | | 1.18 | | 79.2 | 17.7 | 97.0 | 46.2 | 122.1 | |
| | Bare fallow | 1.13 | | 1.10 | | 77.8 | 20.9 | 98.7 | 47.0 | 124.2 | |
| 2008 | Vetch | 1.17 | **b** | 1.19 | **b** | 69.1 | 29.8 | 99.0 | 47.1 | 124.6 | **a** |
| | Barley | 1.27 | **a** | 1.29 | **a** | 77.0 | 30.6 | 107.6 | 51.2 | 102.0 | **b** |
| | Bare fallow | 1.29 | **a** | 1.29 | **a** | 73.7 | 30.4 | 104.1 | 49.6 | 104.7 | **b** |
| 2009 | Vetch | 1.16 | **b** | 1.19 | **b** | 68.2 | 31.9 | 100.1 | 47.7 | 129.9 | **a** |
| | Barley | 1.29 | **a** | 1.33 | **a** | 62.4 | 31.5 | 93.9 | 44.7 | 98.3 | **b** |
| | Bare fallow | 1.23 | **ab** | 1.29 | **a** | 53.5 | 31.2 | 84.8 | 40.4 | 87.7 | **b** |
| Year | | * | | * | | * | * | NS | NS | * | |
| Treatment | | * | | * | | NS | NS | NS | NS | * | |



# *Results: Nitrate leaching*

- **Lower drainage in CC plots than in fallow.**
- **80% of drainage in periods with CCs.**
- Vetch: more N in soil without increase in leached $NO_3^-$.
- Barley: Immediate reduction in leached $NO_3^-$ (no BNF & larger development).




Gabriel et al., 2012

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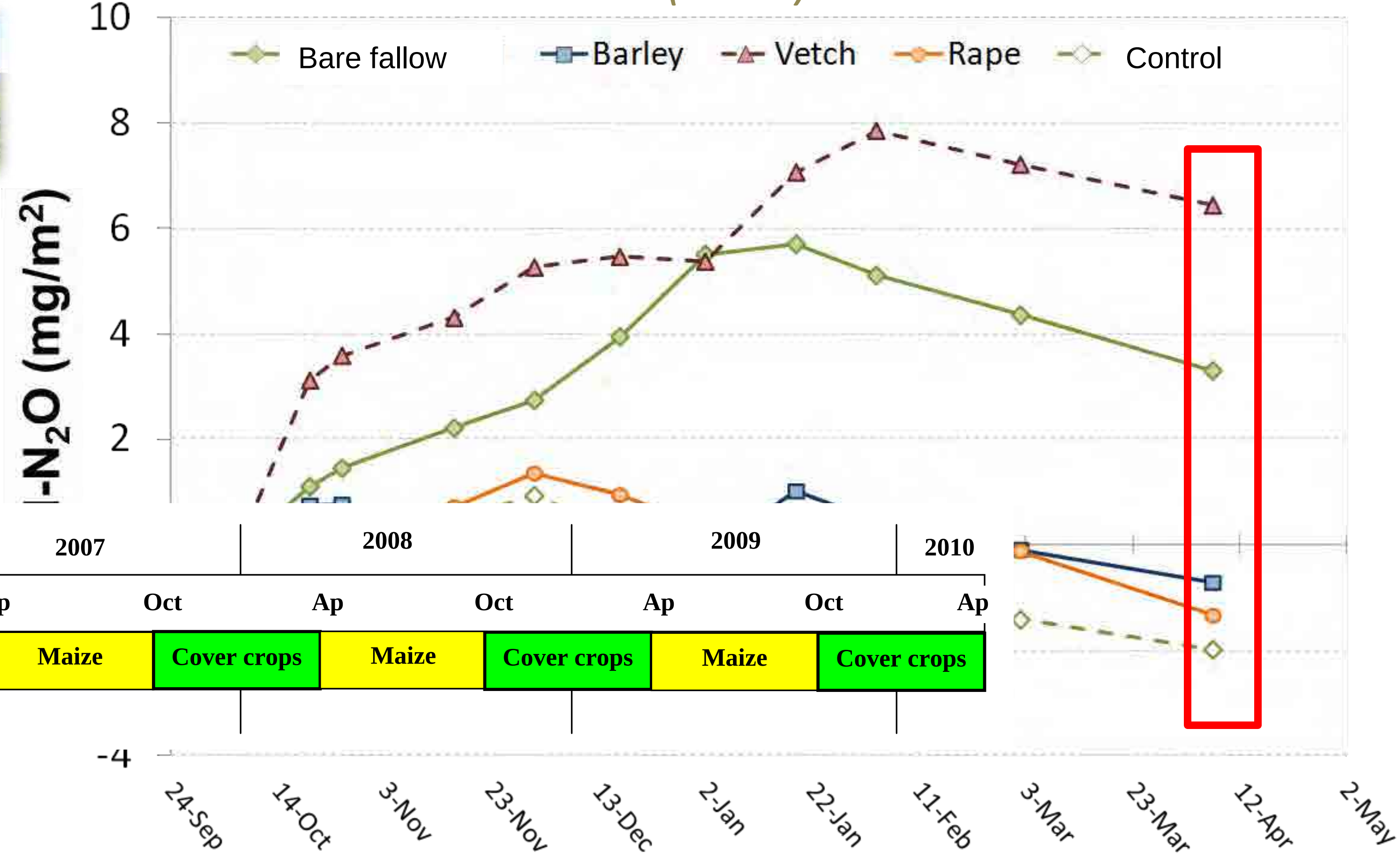
# ***Results: $N_2O$ emissions***

*Cumulative $N_2O$ intercrop period (2010)*



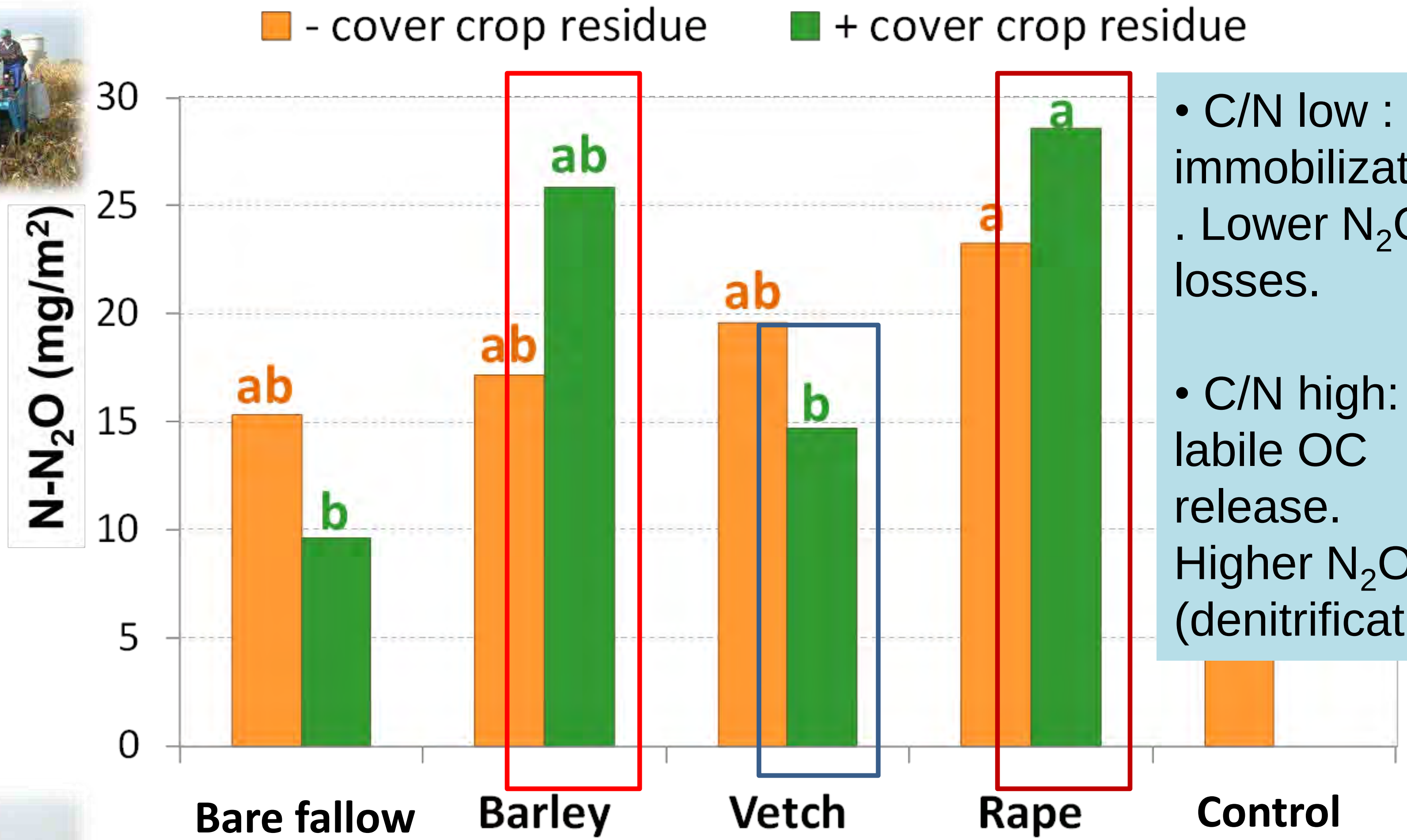

VT > BF > RP ≈ BA >C

Sanz-Cobena et al., 2014



# Results: $N_2O$ emissions

*Cumulative $N_2O$ crop period*




- C/N low : N immobilization. Lower $N_2O$ losses.
- C/N high: labile OC release. Higher $N_2O$ (denitrification)

Low emissions (IPCC): denitrification + leaching + N uptake by crop



# Conclusions

1. Replacing fallow by CCs in the intercrop period reduced N leaching without significantly decreasing maize yield.
2. Most of $NO_3^-$ losses (e.g. 80%) occurred in the CCs period although $NO_3^-$ concentrations fluctuated within the experimental period.
3. CCs reduced N leached, recirculated N and increased the N available in the upper soil layers.
4. Ba showed the highest efficiency as CC, reducing leaching and $NO_3^-$ concentration. However, Vt increased the N content in upper soil layers.
5. Vt highest $N_2O$ emission (75% >Control) in the intercrop period.
6. Fertilization of maize increased $N_2O$ losses in all cases.
7. Only the incorporation of Rp and Ba residues increased $N_2O$ emission (40 y 17%).
8. Total $N_2O$ $<$ than expected in fertilized crops (0.09 EF$<$ $IPCC_{2007}$ EF=1.00).



# Remarks for modelling

- CCs in the intercrop period:
  - Effect of legumes over N2O losses
  - Effect of CC type over water balance (drainage)
- CCs as green manures:
  - N mineralization rates
  - Effect of CC types
  - N2O uptake

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# Thanks for your attention!

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AGRISOST

Special thanks to: J.L. Gabriel; S. García Marco; A. Vallejo; M. Quemada