Designing and evaluating arable systems. Cash and cover crop legumes in sole crop and intercrop to improve nitrogen use efficiency

Laurent Bedoussac, Hélène Tribouillois, Daniel Plaza Bonilla, Etienne-Pascal Journet, Eric Justes

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19th NITROGEN WORKSHOP
Efficient use of different sources of nitrogen in agriculture - from theory to practice
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INTRODUCTION

Improving low-input systems with legumes

Bedoussac, L. et al. 2015. Agronomy for Sustainable Development 35, 911-935
Plaza-Bonilla, D. et al. 2015. Agriculture, Ecosystem and Environment 212, 1-12
Tribouillois, H. et al. 2015. Plant and Soil 401, 347-364

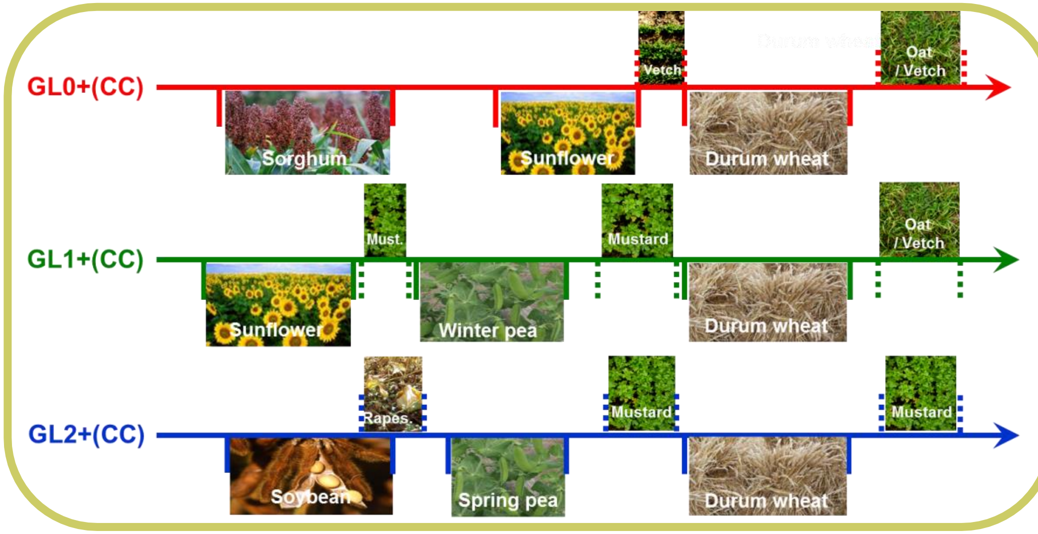
- **Increasing concern about climate change and environment**
  - Requires transformation of cropping systems
- **Crops diversification and legumes are a solution for low-input syst.**
  - Break-crop effects and benefits from N2-fixation
- **Different ways to introduce legumes in low-input cropping syst.**
  - Cash crops and Cover crops
  - Sole crops and Intercrops

- **Objectives : Designing and evaluating low-input cropping systems**
  - Maximizing the benefit from leguminous N2 fixation
  - Reducing environmental impacts
  - Using jointly field experiments and crop modelling
  - Evaluating grain legume intercrops for yield and quality
  - Evaluating cover crops for nitrate capture and green manuring services

1.1) Designing and evaluating cropping systems

From : Plaza-Bonilla, D. et al. 2015. Agriculture, Ecosystem and Environment 212, 1-12

- **Two 6-year field experiments to study the effects of grain legumes**
  - **A three-year rotation**
  - **Six rotations compared**
    - 0, 1 or 2 grain legume
    - With or without cover crop
    - Each crop grown each year
  - **Crop management based on decision rules**

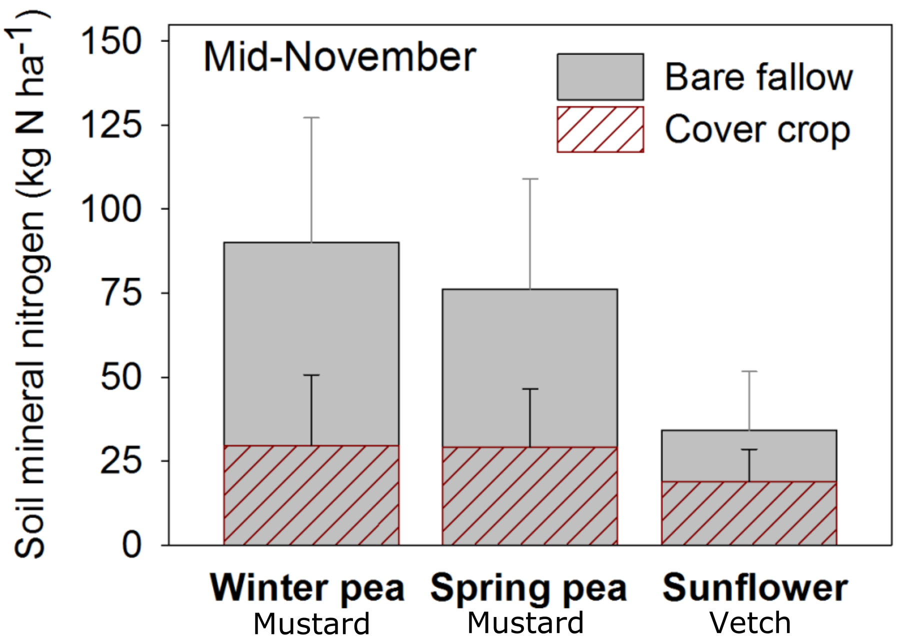


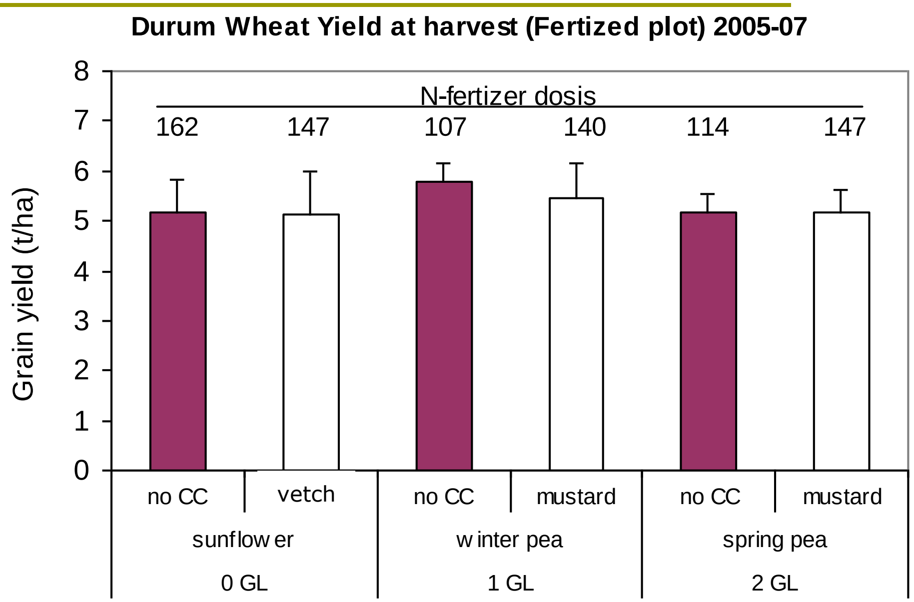
- **Simulations at the rotation time taking into account water and N dynamical budgets**

Soil-Crop Model for legumes and CC
(Brisson et al., 1998; 2020; 2003)

1.2) Effects of legumes and cover crops on wheat yield and soil mineral N

From : Plaza-Bonilla, D. et al. 2015. Agriculture, Ecosystem and Environnement 212, 1-12





Mineral-N in soil at wheat sowing

- Higher soil N availability after pea: +50 kg N/ha
- Significant effect of CC to decrease mineral-N
- Mustard very efficient to uptake soil mineral-N during few weeks

Wheat yield & fertilizer-N doses

- Yield slightly higher after w. pea
- Same yield with and without CC
- N release not always compensate pre-emptive competition for soil N
- Rate of fertilizer-N must be increased to reach the same yield

1.3) Designing and evaluating cropping systems

From : Plaza-Bonilla, D. et al. 2015. Agriculture, Ecosystem and Environment 212, 1-12

- **Grain legume sole cropping not always decrease inputs (except N)**
  - **Sensitivity of pea to pests (aphids, weevils) and diseases (anthracnose)…**
  - **How to chose grain legume cultivars?**

- **Higher N availability after pea must be carefully manage**
  - **To avoid high level of nitrate leaching**
  - **Need to adapt the whole cropping system to valorize N2 fixation**

- **Cover crops are efficient but need to be carefully managed**
  - **To avoid N pre-emptive competition for the succeeding crop**
  - **What about N20 emissions?**
  - **How to chose adapted species?**

2.1) Cover crops for nitrate capture and green manure services

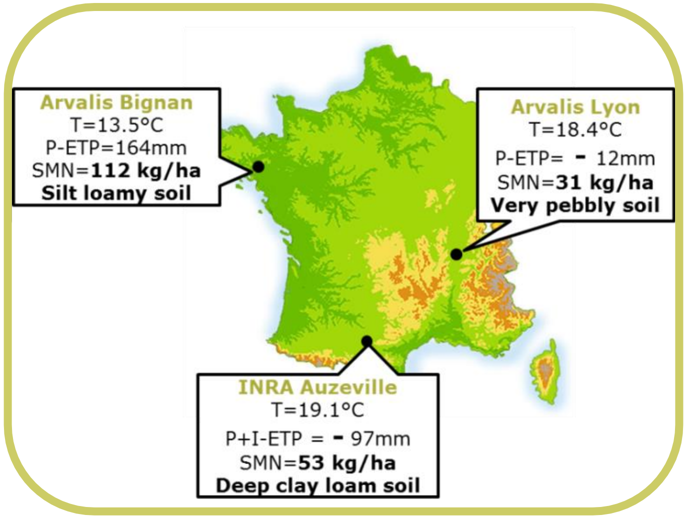
From : Tribouillois, H. et al. 2015. Plant and Soil 401, 347-364

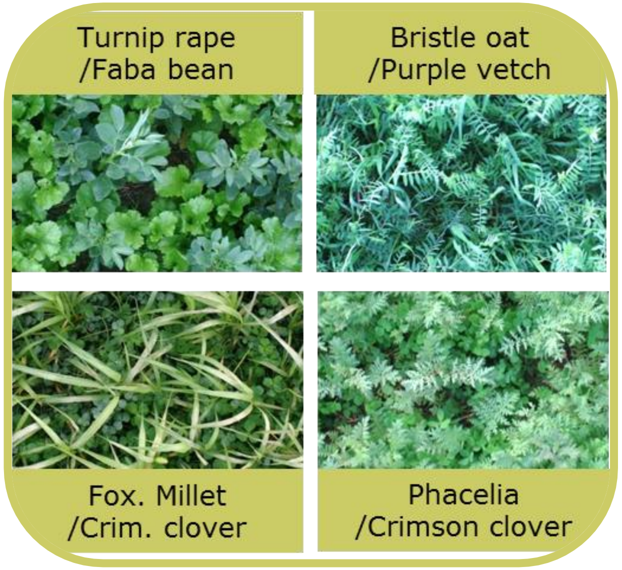
- **A wide range of conditions**
  - **3 sites**
  - **Contrasted pedo-climatic conditions**

- **Mixtures evaluation on 3 sites**
  - **5 fast growing legumes**
    Purple vetch, crimson clover,
    wild lentil, faba bean, forage pea
  - **5 various non-legumes (family, architecture)**
    Turnip rape, foxtail millet, bristle oat,
    Italian ryegrass, phacelia
  - **25 bispecific mixtures**
    (1 leg/1 non-leg ; 50%/50%)

- **Effect of date of destruction on one site for selected mixtures**

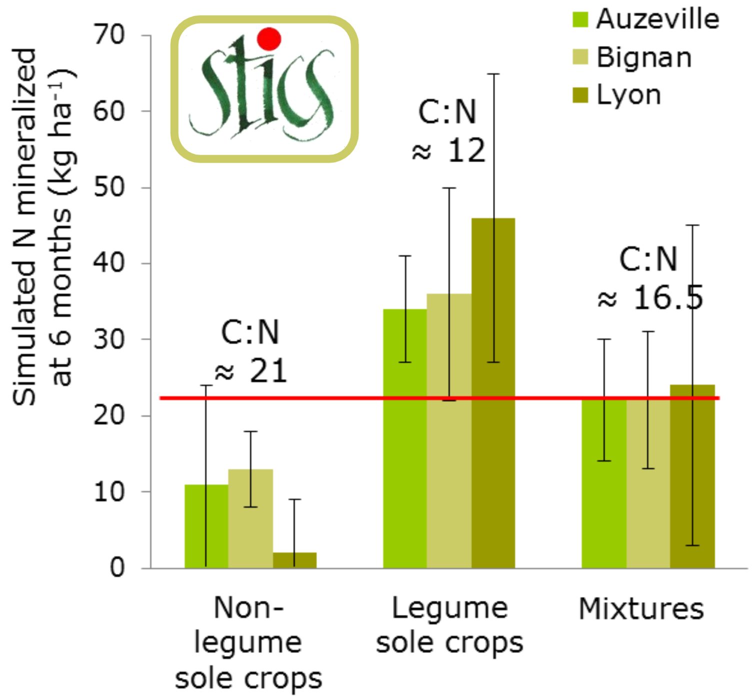
- **N management services assessed with both experiments and models**

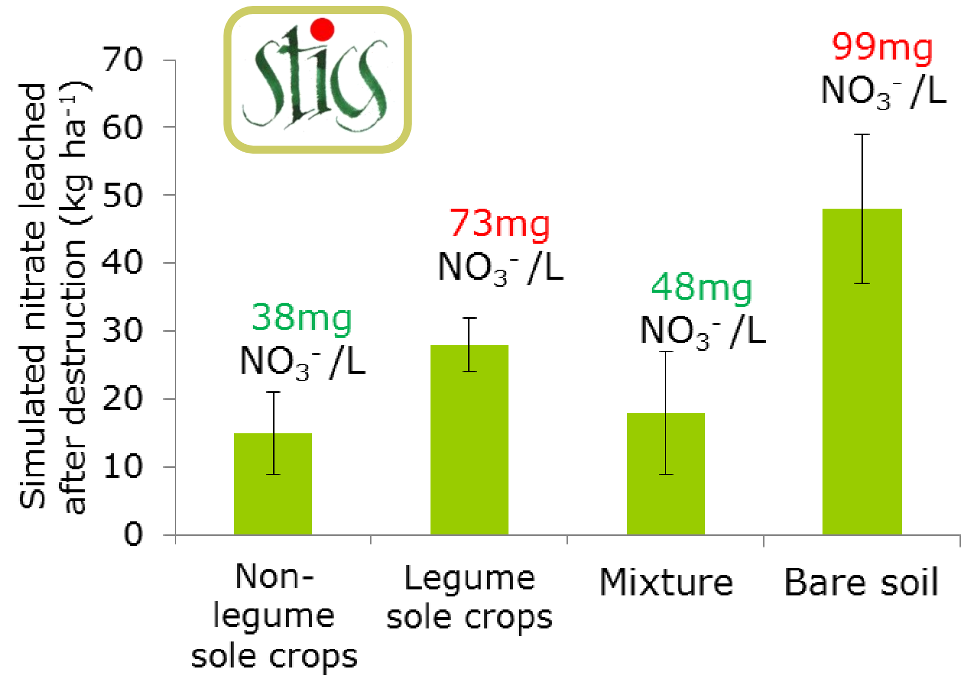




2.2) N mineralization and Nitrate leaching simulation

From : Tribouillois, H. et al. 2015. Plant and Soil 401, 347-364





N mineralization from CC residues

- **N mineralized from residues:** Non-leg. SC < Mix. < Leg. SC
- **C:N ratio:** Leg. SC < Mix. < Non-leg. SC

Nitrate leaching simulation (destruction after autumn)

- **N leached:** Mix.≈Non-leg. SC < Leg. SC
- **[NO3-] in drained water:** Mix.≈Non-leg. SC < Leg. SC < BS

2.3) Cover crops for nitrate capture and green manure services

From : Tribouillois, H. et al. 2015. Plant and Soil 401, 347-364

- **Bispecific cover crop mixtures allowed :**
  - **Catch crop effect ≈ non-legume sole crops**
  - **Green manure effect intermediary**
- **The best mixtures depend on the risk of leaching and pre-emptive competition**
  - **Case 1. Low SMN and low drainage (low risk of NO3- leaching, high risk of pre-emptive competition**
    - **Mixture favoring the green manure effect with a destruction at mid-Autumn**
  - **Case 2. High SMN and very permeable soil (high risk of NO3- leaching)**
    - **Mixture favoring catch crop during winter and late destruction at the end of Winter**
- **Need for a dynamic model for bispecific mixtures CC to help for species assemblage and optimizing CC management**

3.1) GL Intercrops to improve productivity and stability by species complementarity

From : Bedoussac, L. et al. 2015. Agronomy for Sustainable Development 35, 911-935

- **10 years of experiments**
  - **Various pedo-climatic conditions**
  - **Conventional and organic farming**
  - **Experimental station and farm**
  - **Spring and Winter crops**

- **Large range of practices**
  - **Cultivars, Densities, Patterns, N, P…**

- **Different aims :**
  - **Evaluate IC potential advantages**
  - **Analyze IC functioning**

3.2) IC improves yield by complementarity for N Sources (soil mineral N and N2 from air)

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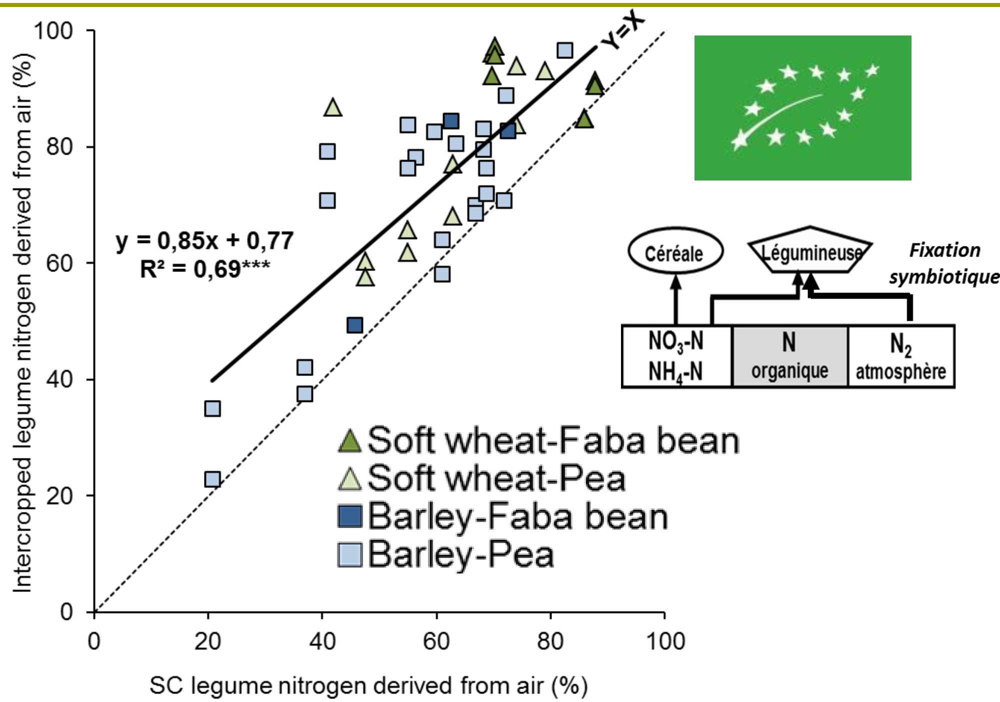

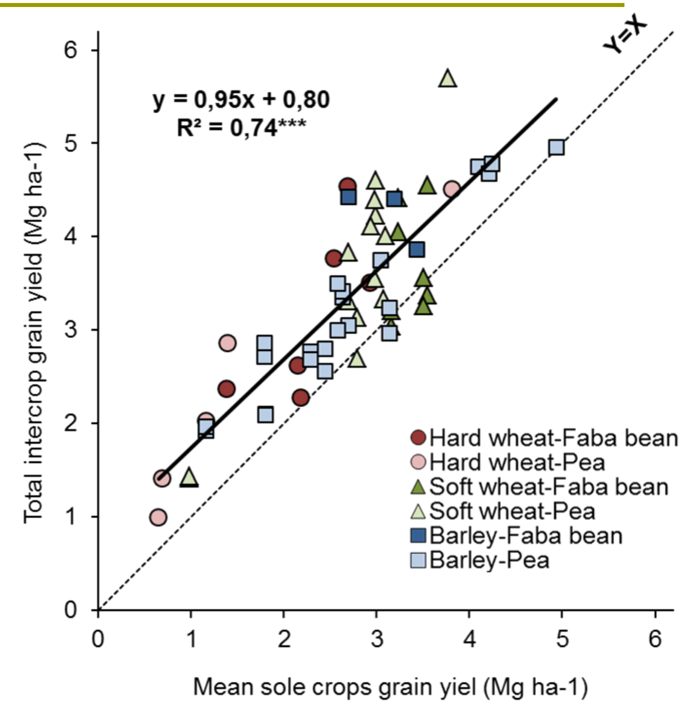

- **Higher legume N2 fixation rate in IC (75% vs. 62%)**
  - **Niche complementarity for N sources & competition for soil N**
  - **Most of soil mineral N available for the cereal**
  - **IC efficiency higher in low N**

- **IC yield higher than the mean SC (3.3 vs 2.7 Mg ha-1)**
  - **Highest efficiency for low N**
- **IC grain yield more stable**
  - **Higher resiliency**
- **Proportion of cereal > 50%**
  - **Cereal more competitive**

3.3) GL Intercrops to improve productivity and stability by species complementarity

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- **Intercropping is an efficient way to improve yield and grain quality**
  - **Competition for similar resources (in time, space or chemical form) is reduced**
  - **Facilitation process (e.g. P) or niche complementarity (e.g. N)**
- **Intercropping advantages mostly observed in low-input conditions**
- **N transfers between species are limited for annual crops**
- **The best mixtures depend on species, cultivars, fertilization…**
  - **Modelling intercropping systems could be helpful to optimize them and to determine varietal characteristics suited to mixtures**





Towards new innovative cropping systems

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- **Further work is needed to better exploit legume advantages and design new cropping systems :**
  - Better use N availability due to grain legume by sowing cover crop to limit nitrate leaching and increase the N efficiency at the rotation level
  - Analyse the potential of intercrops to reduce grain legume pests and diseases damages which are tedious problems in low-input farming and organic farming
- **A number of factors still needs to be optimized before the full potential of intercropping systems can be expressed such as:**
  - Intercrop efficiency according to N availability in dynamics
  - Species and cultivars adaptations
  - Sowing practice (densities and patterns)
  - Harvest and post-harvest for grain IC: adjustment of beating and grain separation
- **The correct rotational position of intercrops need to be analyzed in order to propose relevant solutions…**

Tack för din uppmärksamhet

Designing and evaluating arable systems: cash and cover crop legumes in sole crop and intercrop to improve Nitrogen Use efficiency

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To learn more about this presentation:

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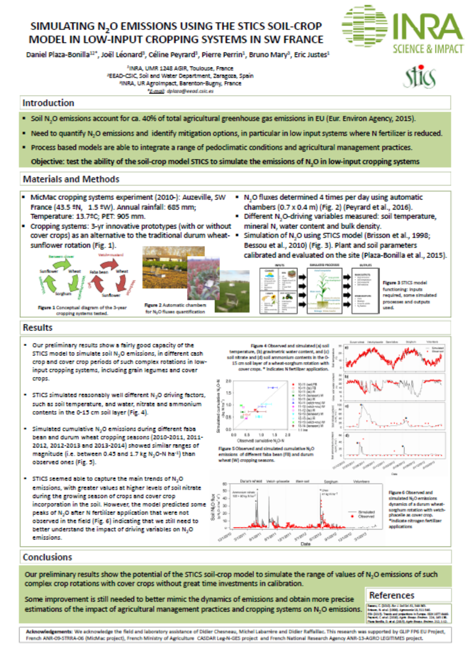

SIMULATING N_2O EMISSIONS USING THE STICS SOIL-CROP MODEL IN LOW-INPUT CROPPING SYSTEMS IN SW FRANCE

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Introduction

- Soil N_2O emissions account for ca. 40% of total agricultural greenhouse gas emissions in EU (Eur. Environ Agency, 2015).
- Need to quantify N_2O emissions and identify mitigation options, in particular in low input systems where N fertilizer is reduced.
- Process based models are able to integrate a range of pedoclimatic conditions and agricultural management practices.

Objective: test the ability of the soil-crop model STICS to simulate the emissions of N_2O in low-input cropping systems

Materials and Methods

- MicMac cropping systems experiment (2010-): Auzeville, SW France (43.5 ºN, 1.5 ºW). Annual rainfall: 685 mm; Temperature: 13.7ºC; PET: 905 mm.
- Cropping systems: 3-yr innovative prototypes (with or without cover crops) as an alternative to the traditional durum wheat-sunflower rotation (Fig. 1).
- N_2O fluxes determined 4 times per day using automatic chambers (0.7 x 0.4 m) (Fig. 2) (Peyrard et al., 2016).
- Different N_2O-driving variables measured: soil temperature, mineral N, water content and bulk density.
- Simulation of N_2O using STICS model (Brisson et al., 1998; Bessou et al., 2010) (Fig. 3). Plant and soil parameters calibrated and evaluated on the site (Plaza-Bonilla et al., 2015).

Figure 1 Conceptual diagram of the 3-year cropping systems tested.

Figure 2 Automatic chambers for N_2O fluxes quantification

Figure 3 STICS model functioning: inputs required, some simulated processes and outputs used.

Results

- Our preliminary results show a fairly good capacity of the STICS model to simulate soil N_2O emissions, in different cash crop and cover crop periods of such complex rotations in low-input cropping systems, including grain legumes and cover crops.
- STICS simulated reasonably well different N_2O driving factors, such as soil temperature, and water, nitrate and ammonium contents in the 0-15 cm soil layer (Fig. 4).
- Simulated cumulative N_2O emissions during different faba bean and durum wheat cropping seasons (2010-2011, 2011-2012, 2012-2013 and 2013-2014) showed similar ranges of magnitude (i.e. between 0.45 and 1.7 kg N_2O-N ha^{-1}) than observed ones (Fig. 5).
- STICS seemed able to capture the main trends of N_2O emissions, with greater values at higher levels of soil nitrate during the growing season of crops and cover crop incorporation in the soil. However, the model predicted some peaks of N_2O after N fertilizer application that were not observed in the field (Fig. 6) indicating that we still need to better understand the impact of driving variables on N_2O emissions.

Figure 4 Observed and simulated (a) soil temperature, (b) gravimetric water content, and (c) soil nitrate and (d) soil ammonium contents in the 0-15 cm soil layer of a wheat-sorghum rotation with cover crops. * Indicates N fertilizer application.

Figure 6 Observed and simulated N_2O emissions dynamics of a durum wheat-sorghum rotation with vetch-phacelie as cover crop. *Indicate nitrogen fertilizer applications

Conclusions

Our preliminary results show the potential of the STICS soil-crop model to simulate the range of values of N_2O emissions of such complex crop rotations with cover crops without great time investments in calibration.

Some improvement is still needed to better mimic the dynamics of emissions and obtain more precise estimations of the impact of agricultural management practices and cropping systems on N_2O emissions.

References

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