Impact of legume species and management on nitrogen fixation at the field scale

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Symbiphyt days

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Improving low-input systems with legumes

Bedoussac et al, 2015
Gaba et al, 2015
Lüscher et al, 2014

- Not a new question! (role of legumes on soil… Virgile, I BC)

- But a renewed agro-climatic background:
  - *Increasing concern about climate change and environment*

    -> requires transformation of cropping system and management practices

- Crop diversification and legumes are a solution for low-input systems
  - *Benefits from N2 fixation and break-crop effect*

    -> requires identification of the drivers of N2 fixation and NUE at different scales (crop / plant community / rotation levels)

Improving low-input systems with legumes

- Different ways to introduce legumes in low input cropping systems
  - *Cash crops / Forages / Service species (cover crops…)*

Cash crops

…

Forages

Service crops

Improving low-input systems with legumes

- Different ways to introduce legumes in low input cropping systems
  - *Cash crops / Forages / Service species (cover crops…)*
  - *Sole crops / Mixed species (intercrops)*

Sole crops

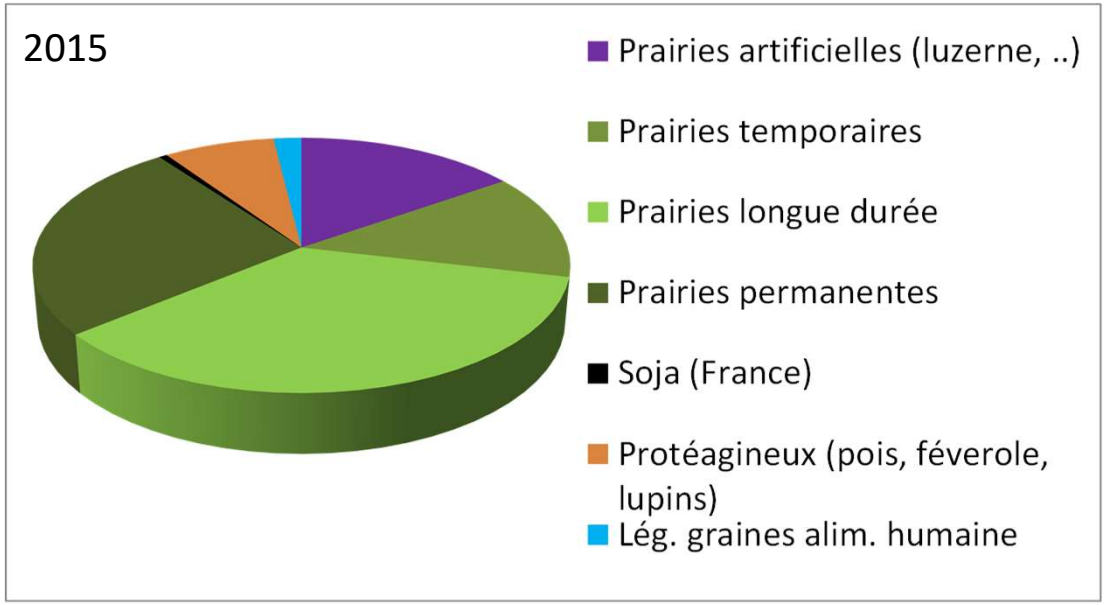
Mixed Species

Overview of current contributions to N inputs

Contribution to fixed N inputs in aroecosystems? **0.52 MT** fixed N in french SAU

Schneider & Huyghe, 2015

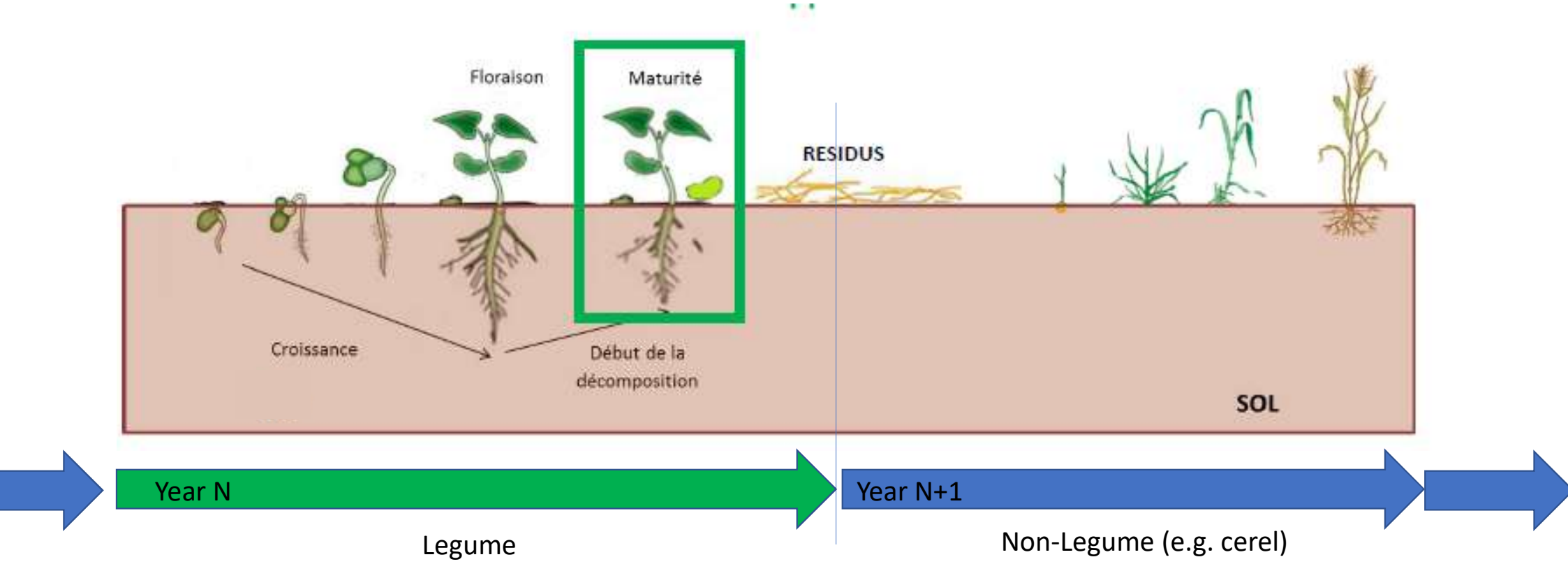
Vertès et al. 2015



- 90% from forage legumes
  - mostly grown in mixtures!
  - Including forages in crop rotations (PA/PT)
- About 10% from grain legumes
  - mostly grown as sole crops
  - But intercropping and cover crops increasing

Legume crop impact on the N cycle (inputs / losses)

Guinet, 2017
Guinet et al, 2019



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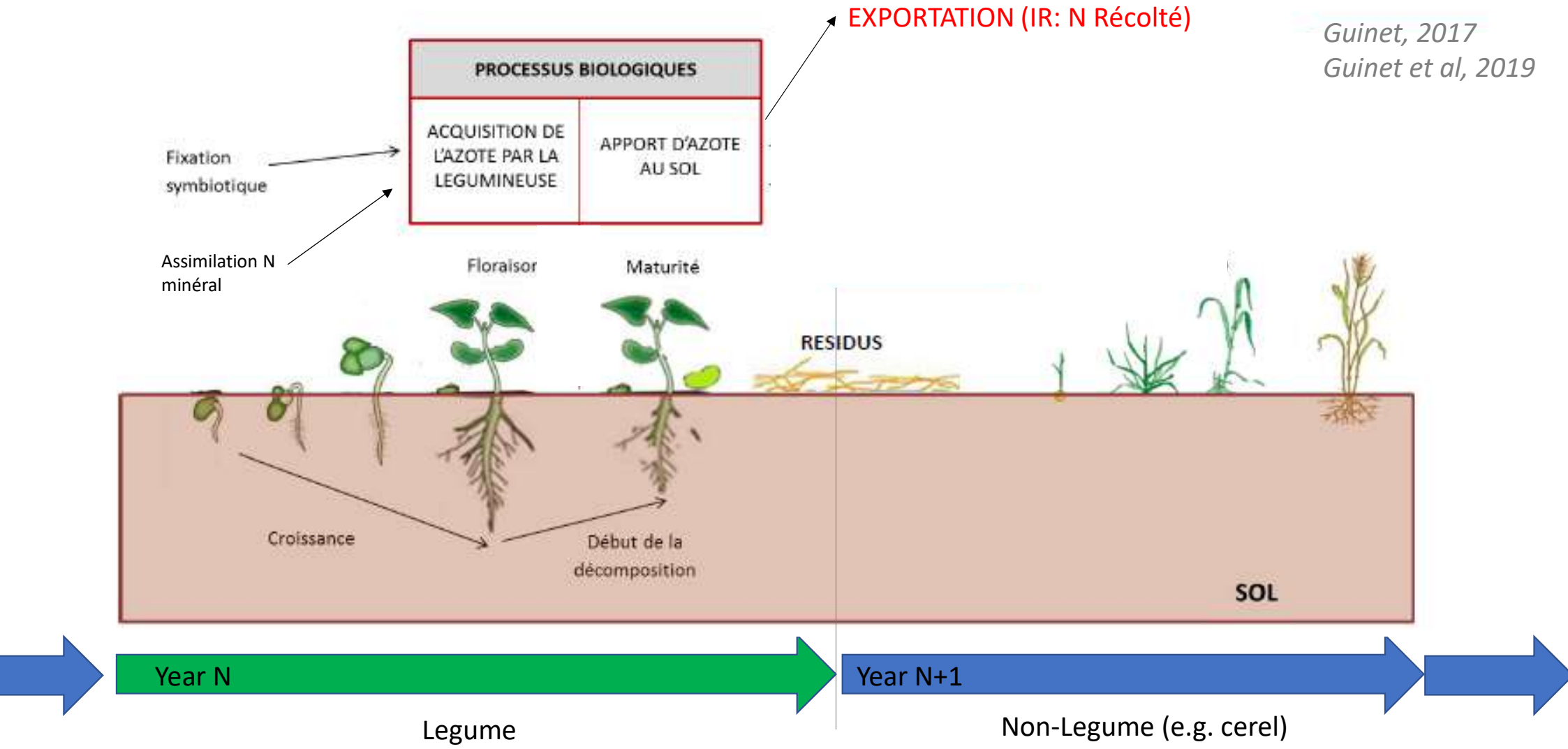

Guinet, 2017
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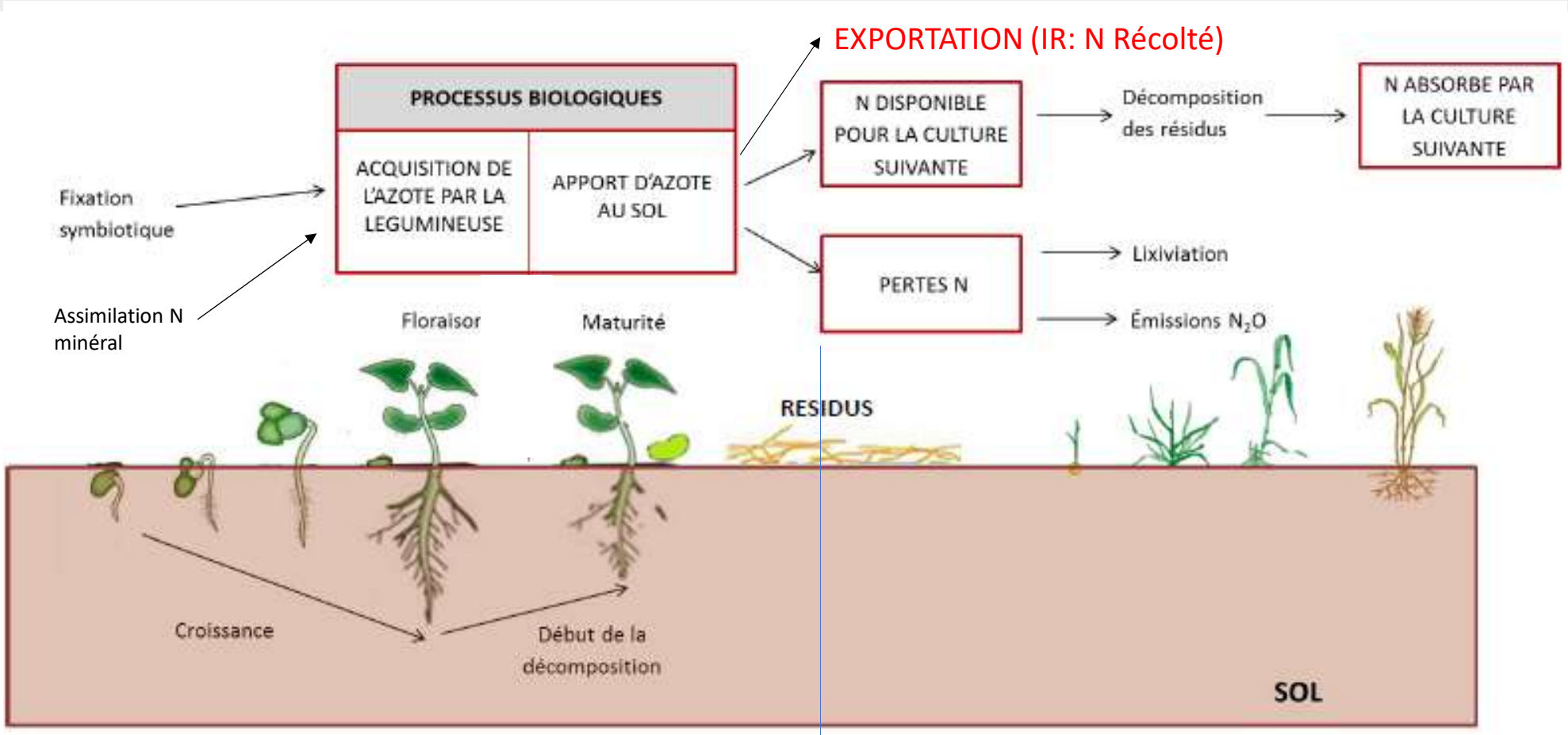


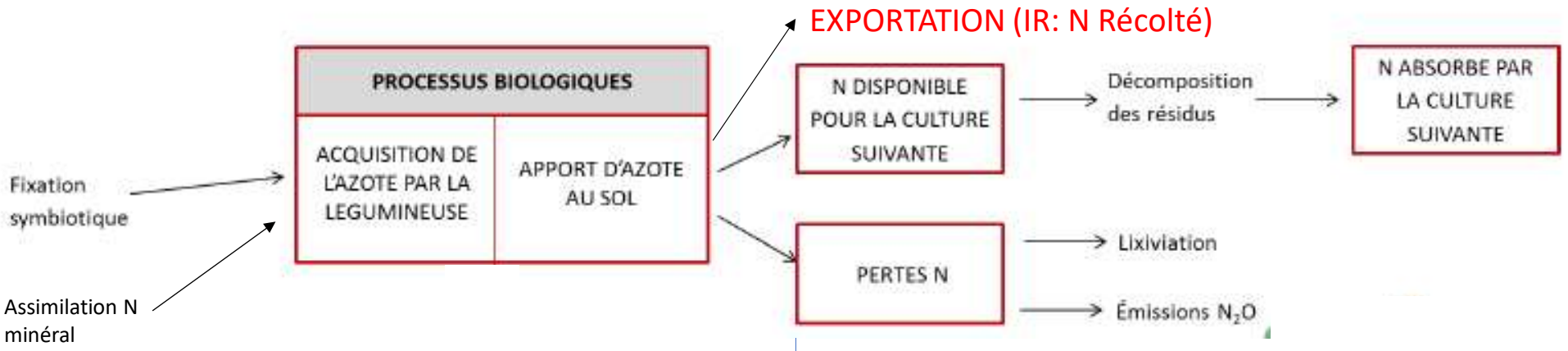
Year N

Legume

Year N+1

Non-Legume (e.g. cerel)

Legume crop impact on the N cycle (inputs / losses)



Legume traits related to **N inputs**

- N fixation (nodulation / symbiosis…)
- N assimilation by roots (root traits / phenology)
- Crop productivity (N demand)

Legume traits related to **N fate**

- Amounts of residual N (HI, …)
- Mineralisation rate of residues (quality, µbial communities…)
- Rhizodeposition

Year N

Legume

Year N+1

Non-Legume (e.g. cereal)

Legume crop impact on the N cycle (inputs / losses)

Guinet, 2017

Comparison of 10 grain legumes on N fixation and N fate

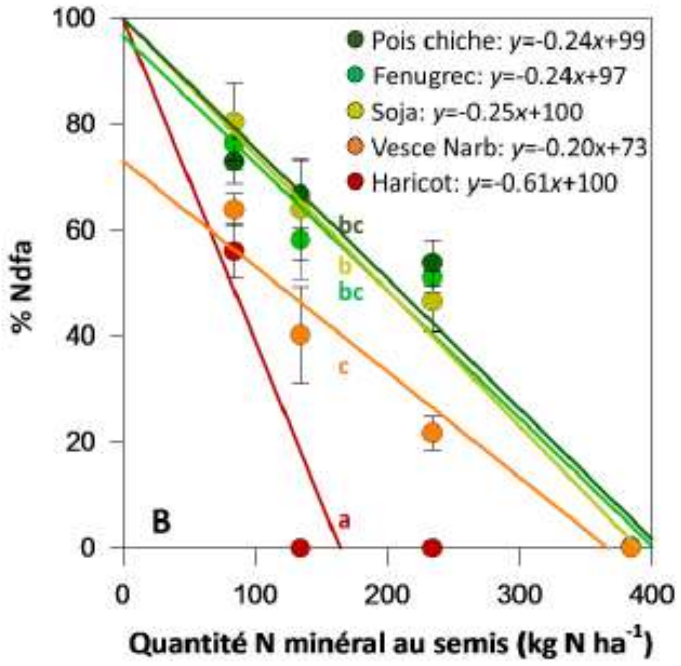
Differential contributions to fixed N inputs

Guinet et al, 2019

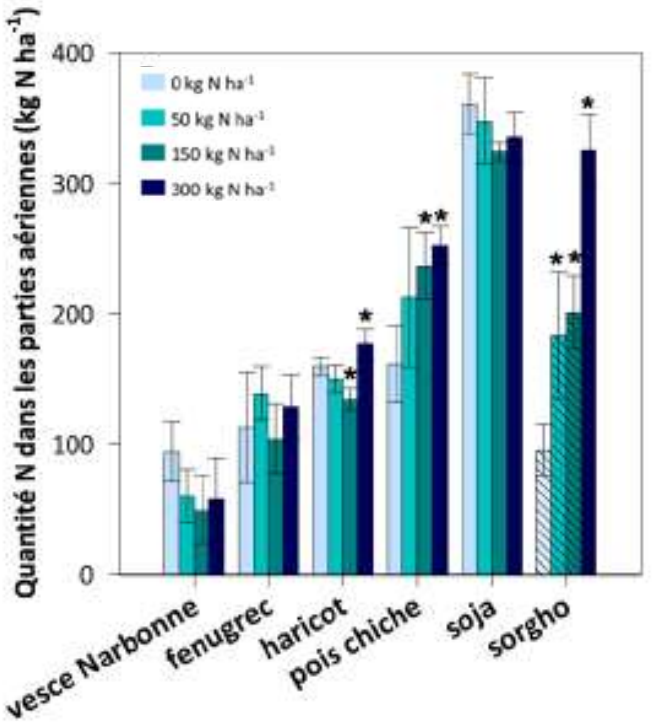
Regarding **fixed N inputs** in sole crops

legumes species largely differ in :

Sensitivity of N fixation to mineral N



Potential DM productivity and crop N demand



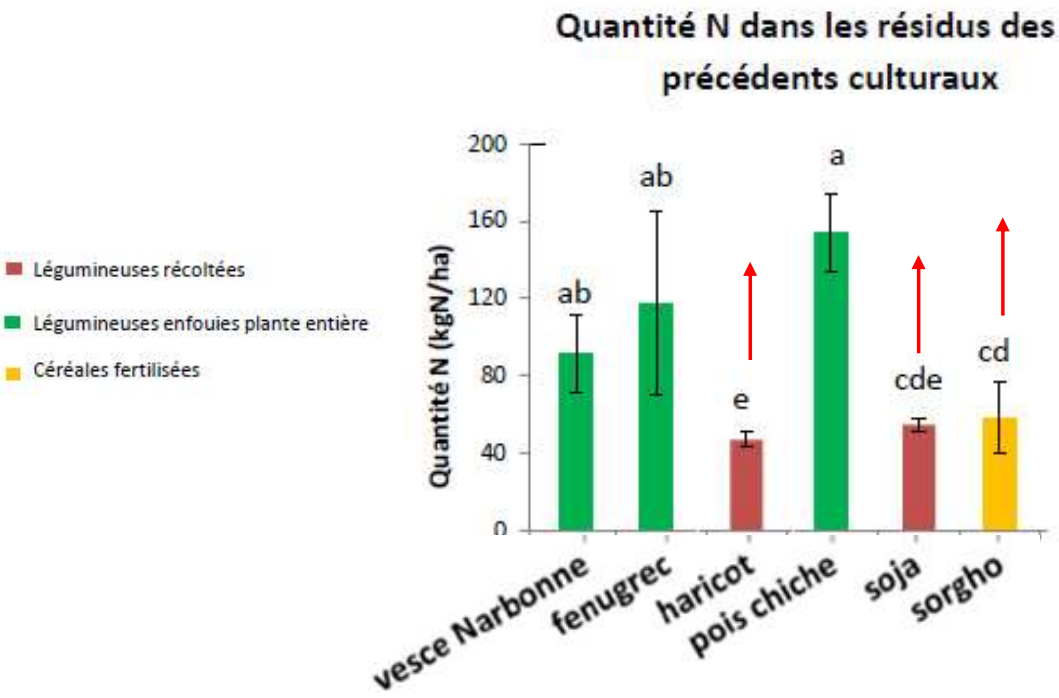
Impact on residual N fate

Regarding **N fate** in sole crops

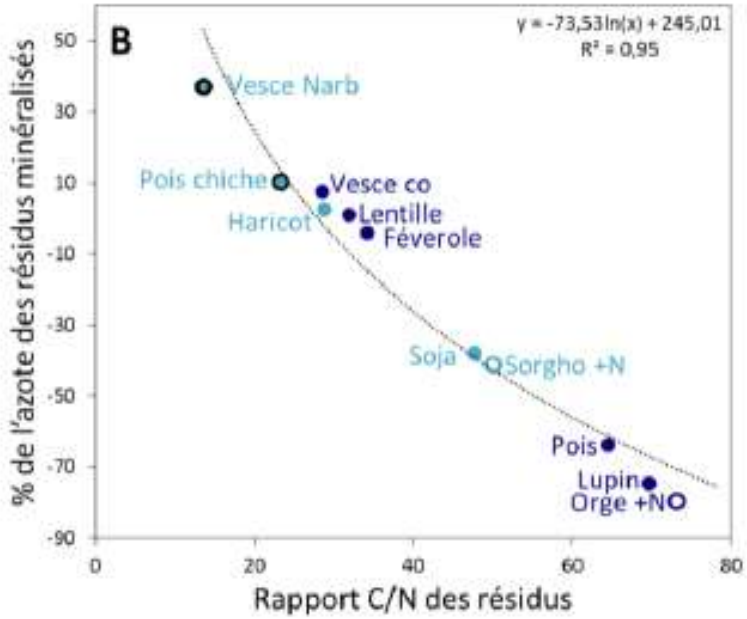
Guinet et al, 2019

legumes species largely differ in :

HI and residual N (above+belowground)



Quality & potential mineralisation of residues



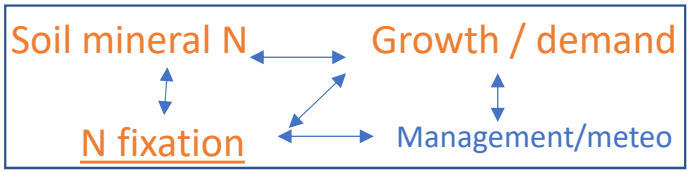
spring

summer

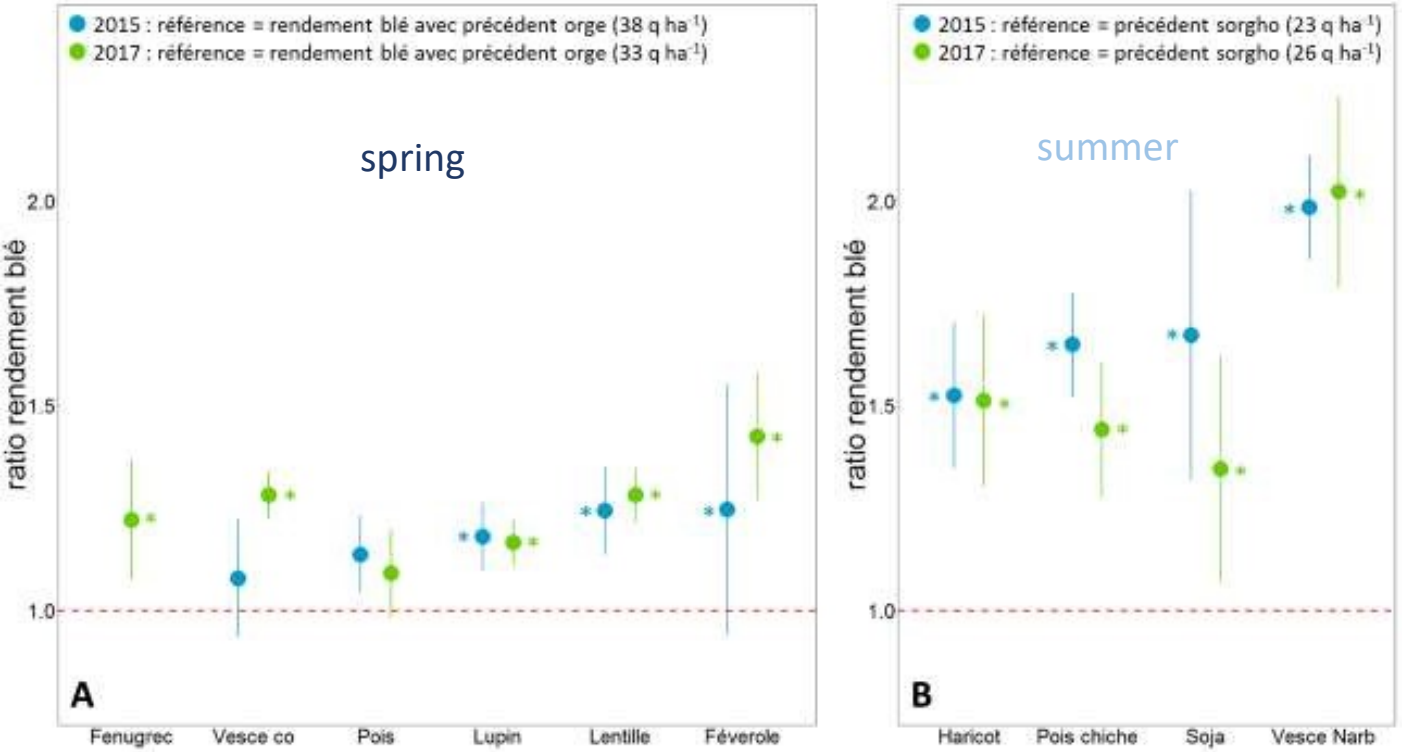
Impact on residual N fate

Regarding **N fate** in sole crops

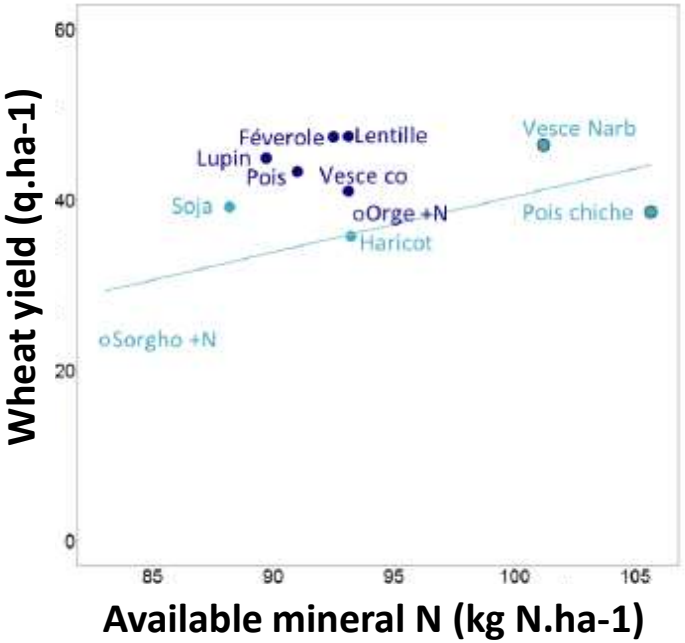
Guinet et al, 2019



Legume legacy effect on the following crop generally positive (ratio > 1), partially related to species



Available N affected via multifactorial effects on available N



Mixing species to maximize the benefits from N fixation?

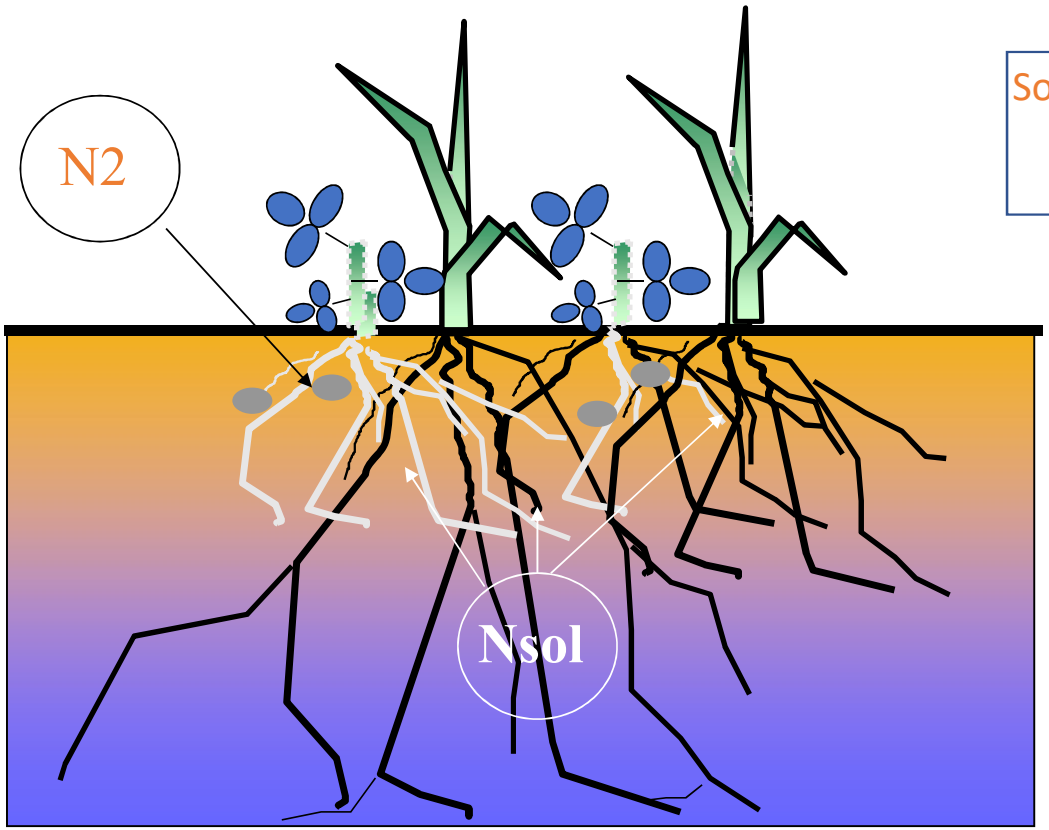
Mixing species to maximize the benefits from N fixation?

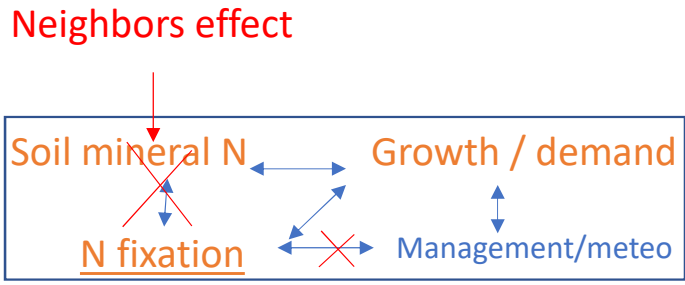
Competition at the community level

-> Niche separation for N:

-Grasses/cereals >> competitors for mineral N

-Legumes able to fix atmospheric N

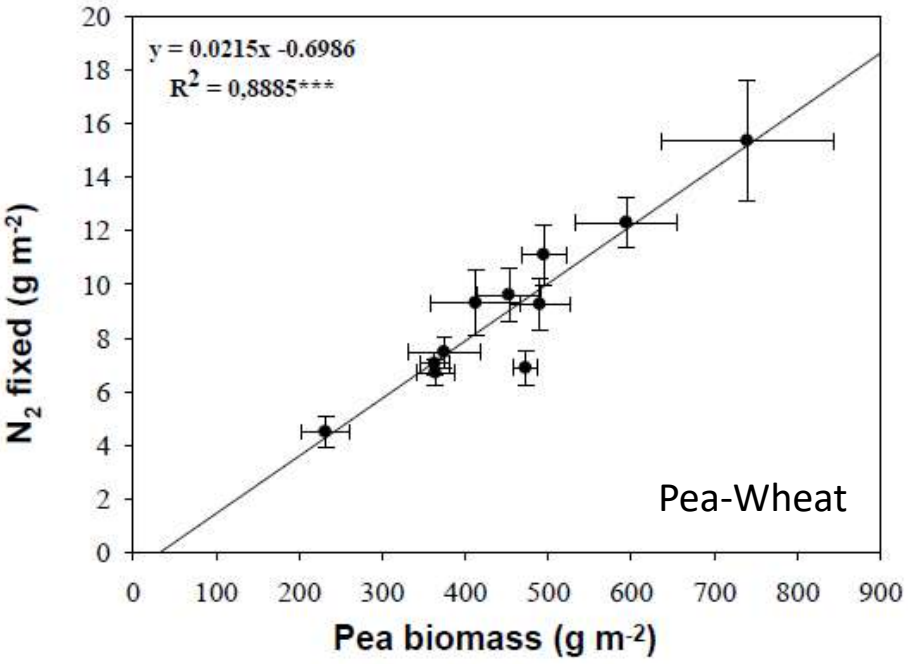




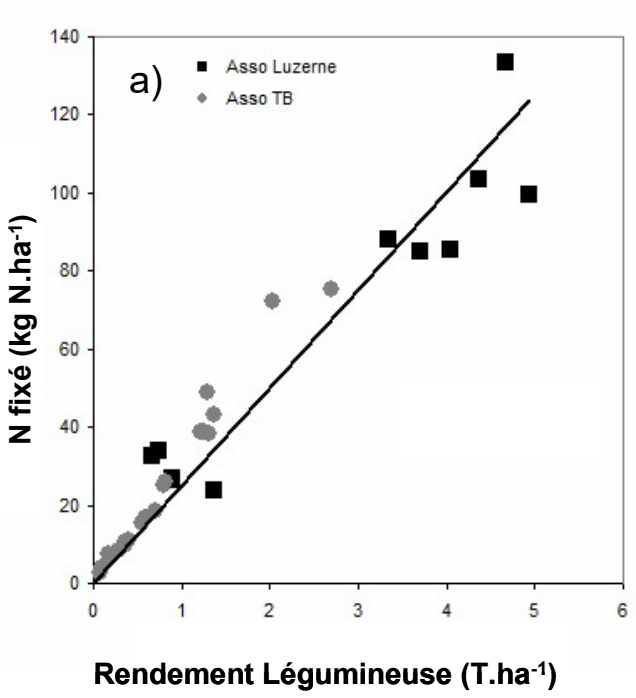
N fixation in mixtures

Hellou et al,
Louarn et al, 2016

Cereal-legume intercop



Mixed Grasslands

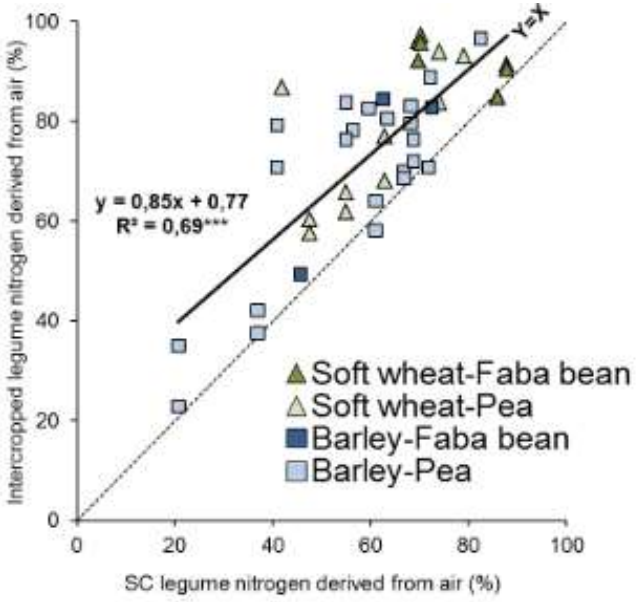


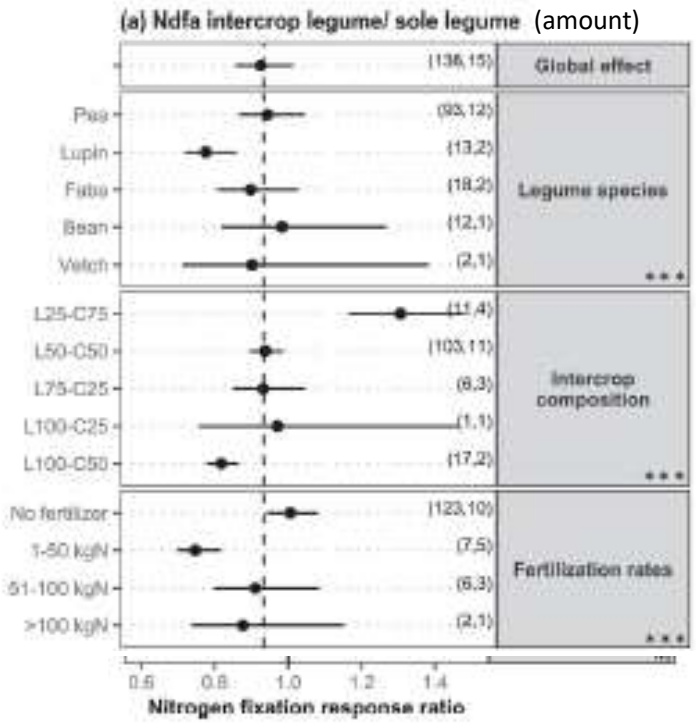
- High Ndfa (>75-80%) -> Fixed N inputs proportional to the partial yield of legumes
- 20-40 kg N.T-1 depending on species and stages

N fixation and supplementary N inputs in mixtures

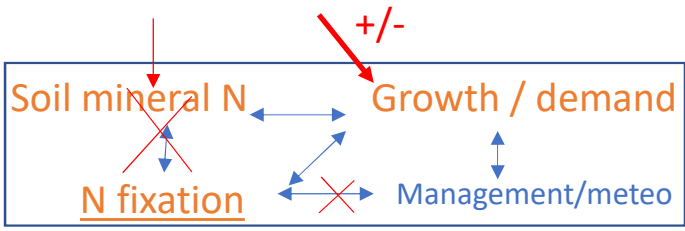
Bedoussac et al, 2015
Rodriguez et al, 2020

Cereal-legume intercop





Neighbors effect

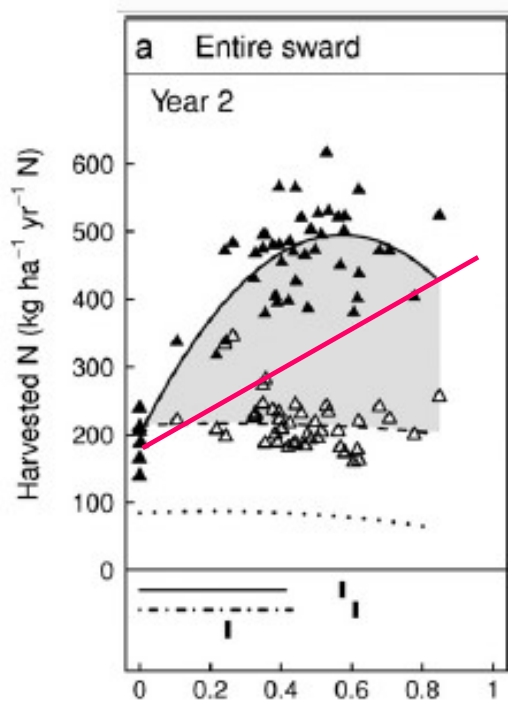


- Generally, mixture advantage compared to sole crops in terms of %Ndfa, not necessarilly on total fixed N
- The relative advantage is higher under **low input** conditions
- The advantage in terms of total N is higher in **balanced mixtures** (moderate ligtht competition favors legume growth)

Yield advantage in mixtures

Increased N input in mixed grasslands

Nyfeler et al 2011
Fox et al 2020

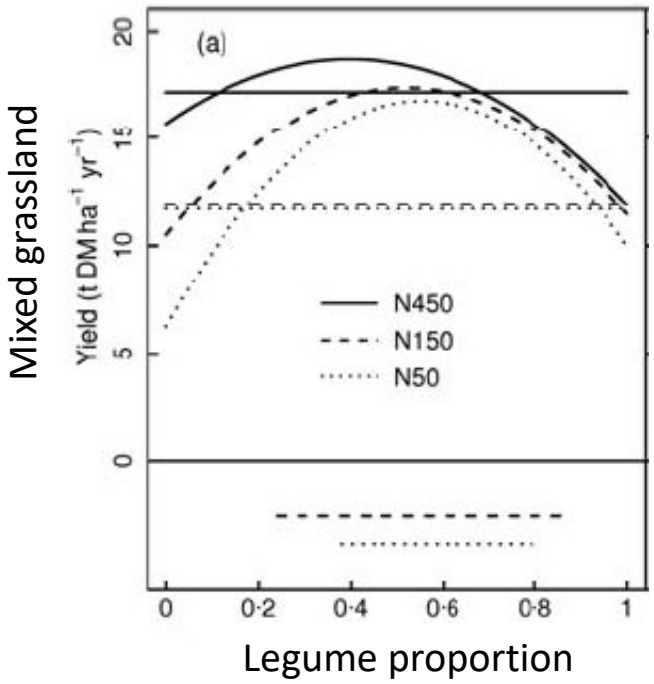


Yield advantage in mixtures

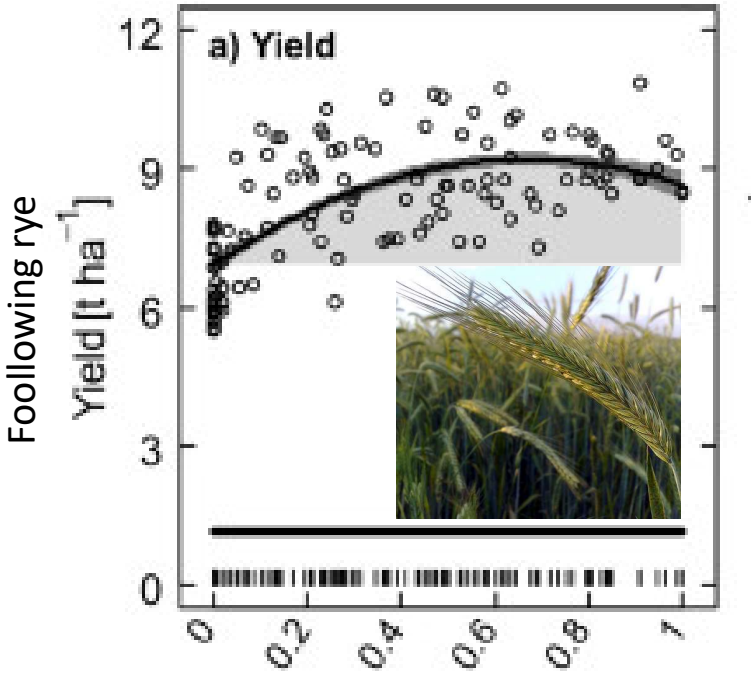
Nyfeler et al 2009
Fox et al 2020

Increased N input in mixed grasslands

Direct effect on **mixture yield** compared to sole crops (Overyielding->ressource use)



Indirect legacy effect on the following crop

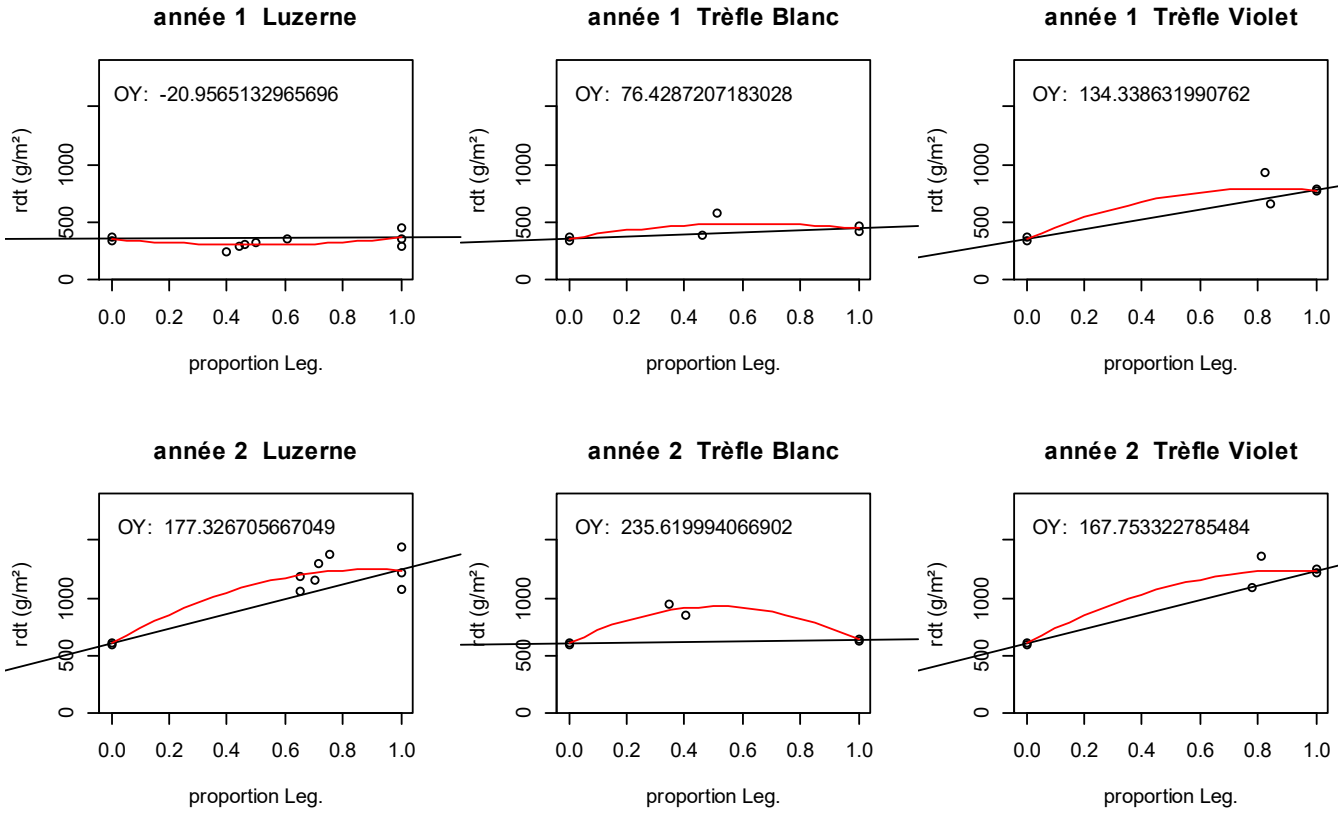


- The relative yield advantage is higher under **low input** conditions
- Strongly dependent on the **proportion of legumes** in the mixture
- Also affects positively the following crop

Yield advantage in mixtures

x

Louarn et al 2015
Louarn et al 2021

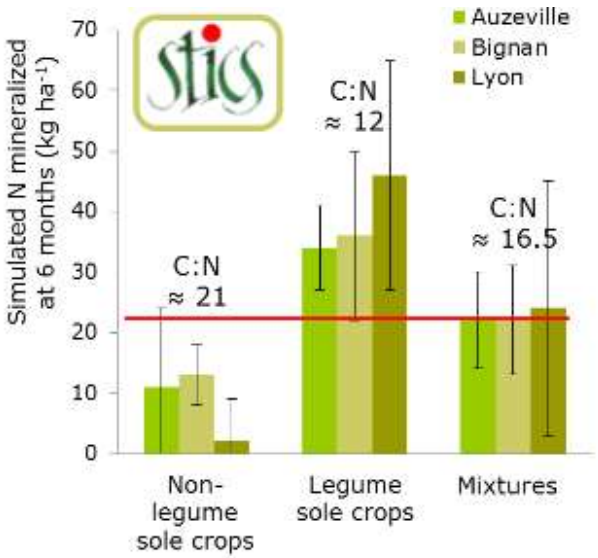


- Effect of legume species on the balance / dynamics of legume proportion
- Potential OY affected by net N transfer from legumes (++ WC)
- The best mixtures depend on species, cultivars, fertilization...!

Control of N losses by mixtures

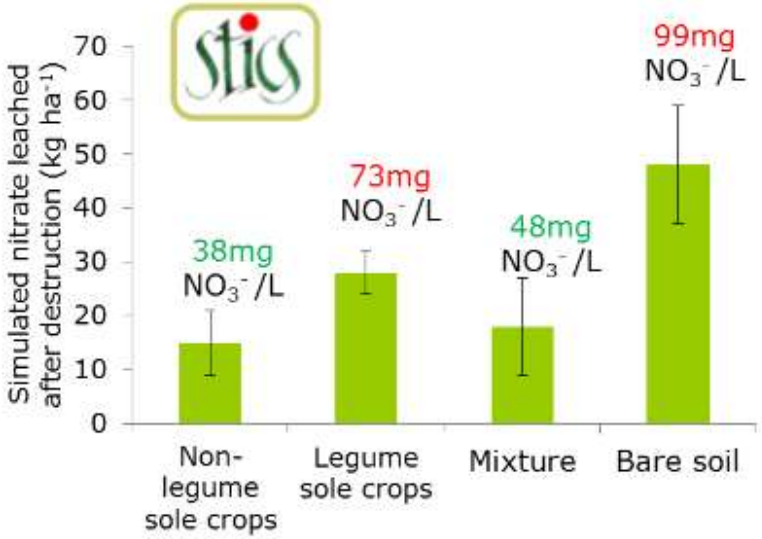
Cover crop mixtures

Tribouillois et al 2015



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

Designing legume-based innovative systems?

- Further work is needed to better take advantage of legume fixation in cropping systems:
    - *Comparative N use between diversification species / systems (cover crops / annuals versus perennial sp.)*
    - *trade-off between services?*
    - *Impact of intercropping and mixtures at the rotation level (pets and diseases? -> delays)*

- A number of factors/levers still need to be adressed:
    - *Species and cultivars adaptations -> Combination of traits? Ideomixes?*
    - *Sowing pratices (densities/patterns/relays…)*
    - *Harvest and post-harvest for grains*

- Rotational position / complementarities between production/services
    - *Living mulch?*

Thank you for your attention!

Acknowledments: Laurent Bedoussac, Maé Guinet, Bernadette Julier