Do agricultural practices impact carbon, nitrogen and phosphorus stoichiometry in plants and soils on the long-term?

Fabien Ferchaud, Bruno Mary, Frida Keuper, Alain Mollier, Pascal Denoroy, Christian Morel, Anne Budynek, Sabine Houot, Claire Jouany, Mickael Hedde, et al.

20th Nitrogen WORKSHOP
June 25-27, 2018
Rennes, France

Do agricultural practices impact carbon, nitrogen and phosphorus stoichiometry in plants and soils on the long term?

Fabien FERCHAUD, Bruno MARY, Frida KEUPER, Alain MOLLIER, Pascal DENOROY, Christian MOREL, Anne GALLET-BUDYNEK, Sabine HOUOT, Claire JOUANY, Mickaël HEDDE, Philippe HINSINGER, Christophe JOURDAN, Isabelle BERTRAND

FlexStoechio project

AgroImpact

Introduction

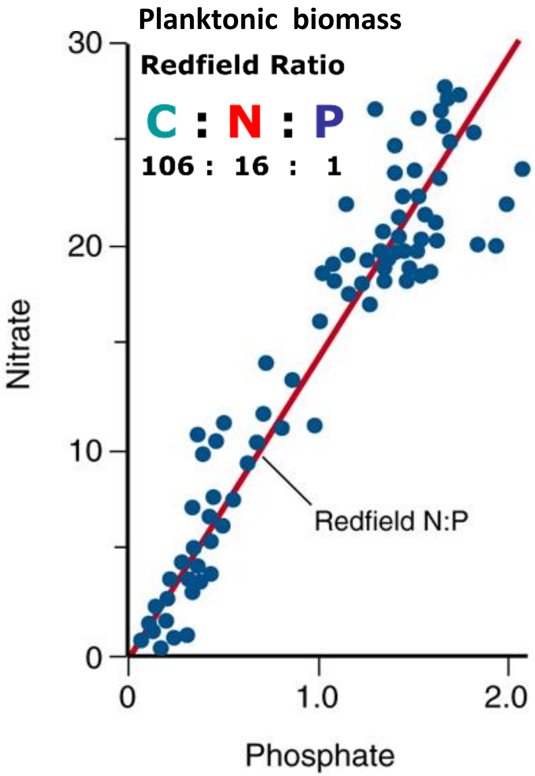
- **Background**

✓ Stoichiometry is the ratio of elements in organisms and environment

✓ Stoichiometry was mainly applied in natural environments

⇒ In terrestrial environments, ratios are rather constraints at the biome level

⇒ In soil, at the global scale, C:N ratios are often more constraints than C:P or N:P ratios (Xu *et al.*, 2013; McGroddy *et al.*, 2014)



However, the effect of agricultural practices on the soil and plant stoichiometry has received less attention

Introduction

- **Stoichiometry : what does it imply?**

✓ Widespread interest in increasing soil carbon stocks (*e.g.* 4 per 1000 initiative) => a possible “hidden cost” due to the need of inorganic nutrients? (Richardson *et al.*, 2014; van Groenigen *et al.*, 2016)

- **Objectives**
  - To evaluate the range of flexibility of C:N:P ratios in soils and plants for various arable cropping systems
  - To quantify the effect of agricultural practices (including long term fertilisation) on these ratios and their evolution
- **Hypothesis**
  - Stoichiometric relationships in soils and plants can be altered by agricultural practices

Methods

- **Collecting long term field experiments data**

✓ 8 long term field experiments comparing different levels of N or P inputs in arable cropping systems and providing data on plants and soils C, N and P contents

✓ Dataset completed by additional analyses when needed

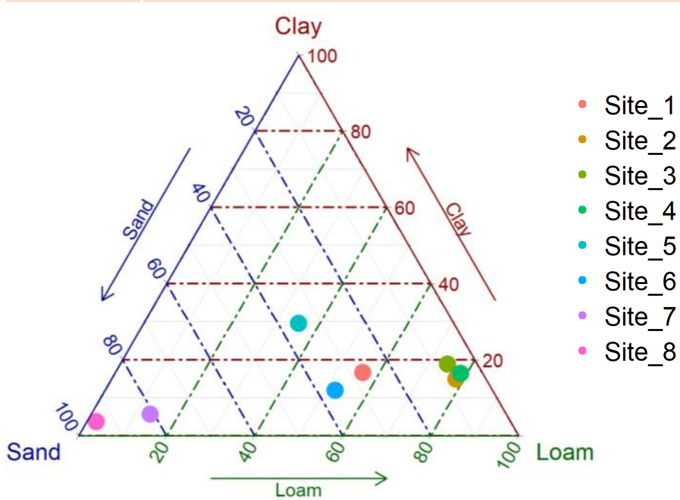
Resulting dataset:

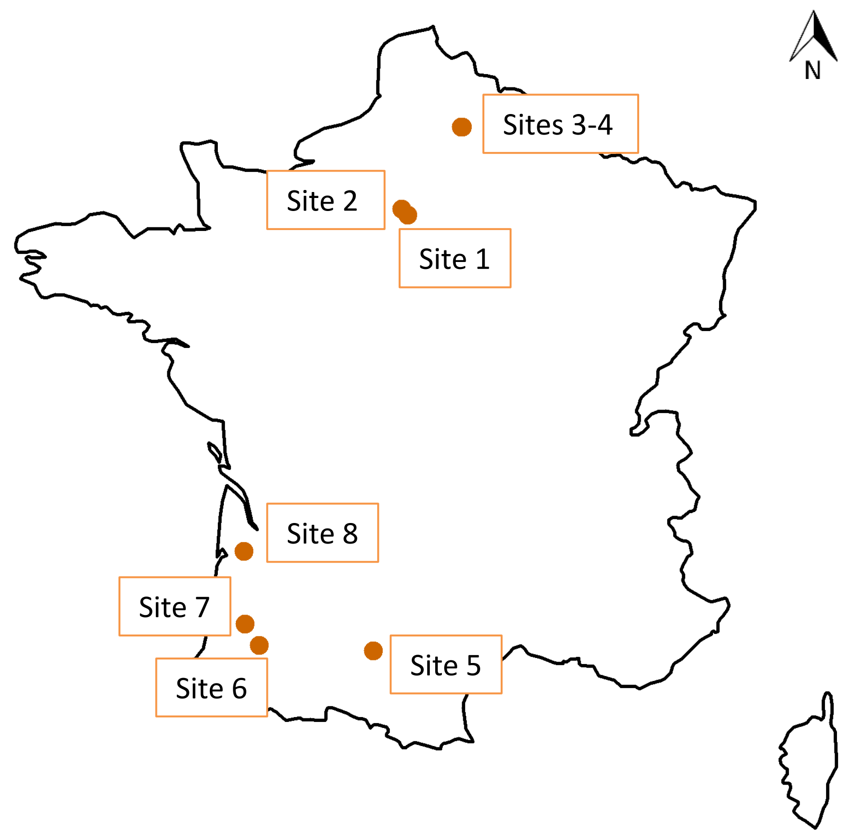
- 7900 plant data: yield, C, N and P content (grains)
- 2600 soil data : organic C, total N and total P content (topsoil)

- **Analyzing C, N, P contents and their stoichiometry in plants and soils in relation to agricultural practices**

The sites and trials

Site	Name and location
1	La Cage (Versailles)
2	SOERE QualiAgro (Feucherolles)
3 4	SOERE ACBB Biomass & Environment (Estrées-Mons)
5	Auzeville (near Toulouse)
6	Mant (near Pau)
7	Tartas - Carcarès Sainte-Croix (near Dax)
8	Pierroton (near Bordeaux)



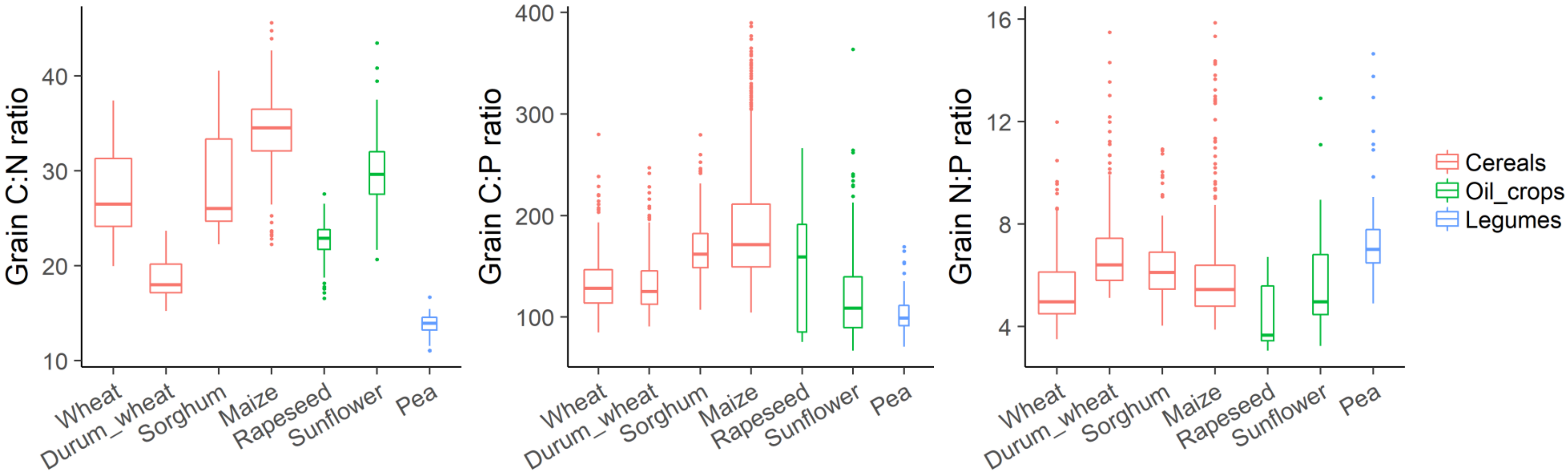


The sites and trials

Site	Name and duration	Tested agricultural practices
1	La Cage 1998-2014 (16 years)	4 arable cropping systems: conventional, low input, conservation agriculture, organic farming
2	SOERE QualiAgro 1998-2013 (15 years)	Organic waste products (4 types) * N fertilisation (2 rates) Wheat-maize rotation
3	SOERE ACBB 2009-2015 (6 years)	4 treatments: conventional, reduced tillage, crop residue removal, reduced N fertilisation Arable cropping system
4	Biomass & Environment 2006-2016 (10 years)	Crop type (perennials vs annuals) * N fertilisation (2 rates)
5	Auzeville 1969-2017 (48 years)	P fertilization (superphosphate): 0, 11, 22 and 33 kg P ha^{-1} yr^{-1} Arable cropping system
6	Mant 1975-1992 (17 years)	P fertilization (superphosphate): 0, 27, 79 kg P ha^{-1} yr^{-1} Continuous irrigated maize
7	Tartas 1972-2004 (32 years)	P fertilization (superphosphate): 0, 44, 96 kg P ha^{-1} yr^{-1} Continuous irrigated maize
8	Pierroton 1995-2015 (20 years)	P fertilization (superphosphate): 10, 15, 20, 40, 80 kg P ha^{-1} yr^{-1} Continuous irrigated maize

C, N and P relationships in plants (grains)

- **Ranges of C:N, C:P and N:P ratio observed by species**



- Large variability particularly for **C:P** and **N:P** ratios
- Mainly due to N and P variations (C ~ constant)
- Strong differences between species

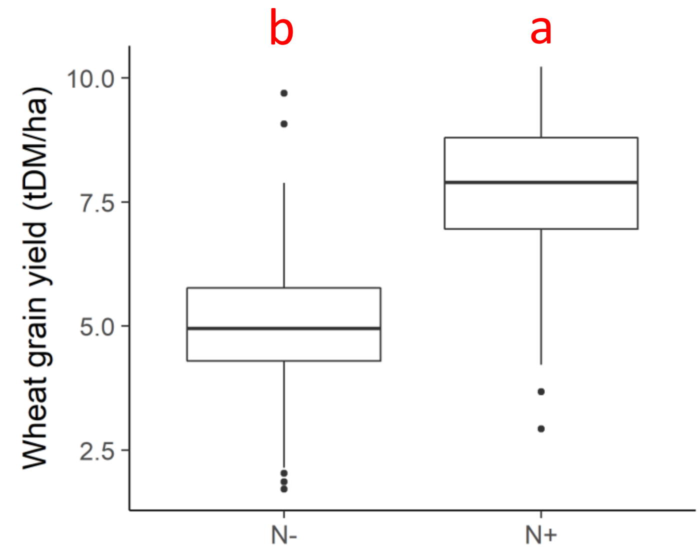
⇒ *We focused on main crops (**wheat in N trials, maize in P trials**) to analyse the effects of agricultural practices*

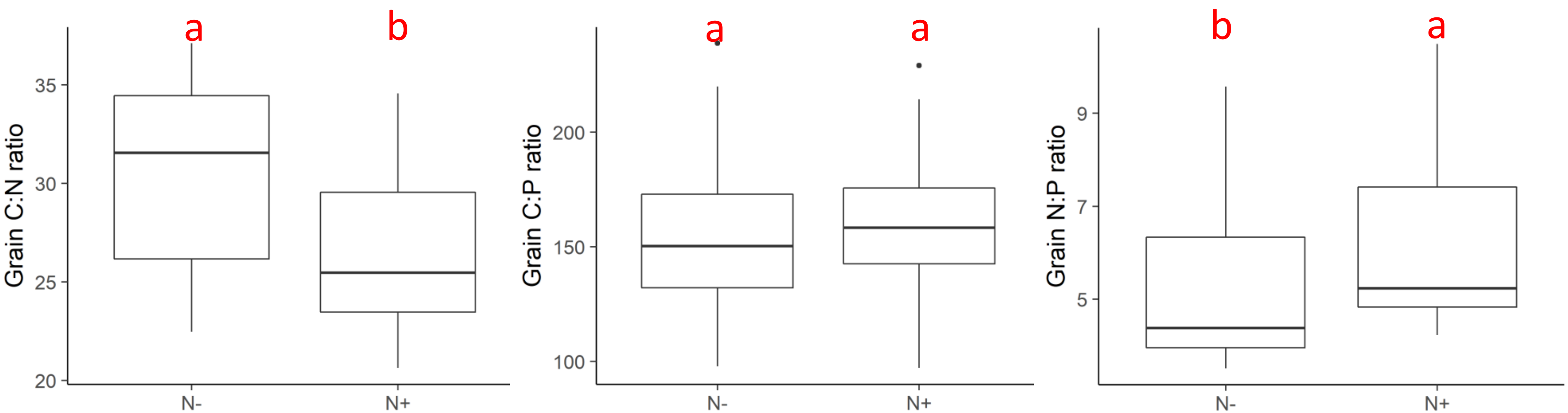
Impact of N fertilisation on yield and ratios

<u>N fertilisation on wheat:</u>

- ✓ increased **yield** (++)
- ✓ decreased **C:N** ratio
- ✓ Increased **N:P** ratio

- No significant effect on **C:P** ratio





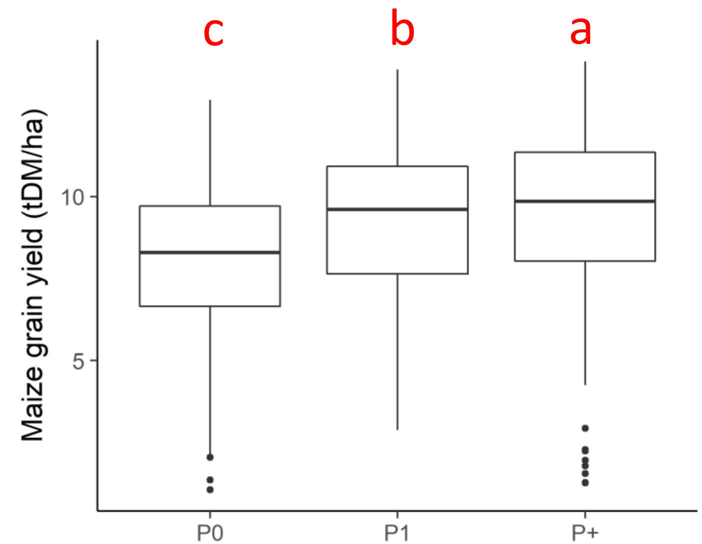
Different letters: $p < 0.05$

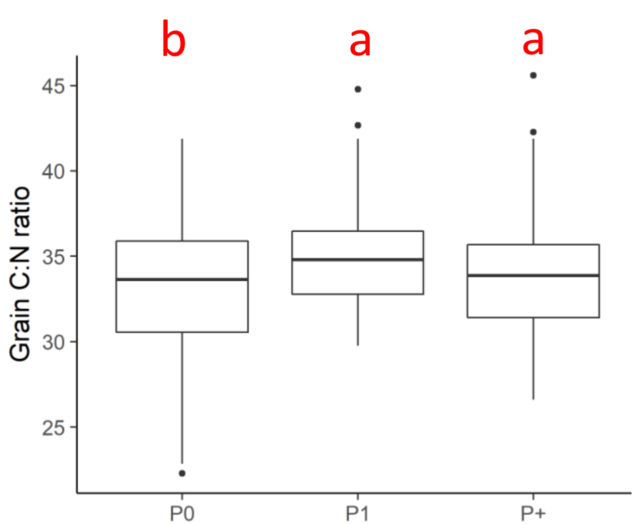
Impact of P fertilisation on yield and ratios

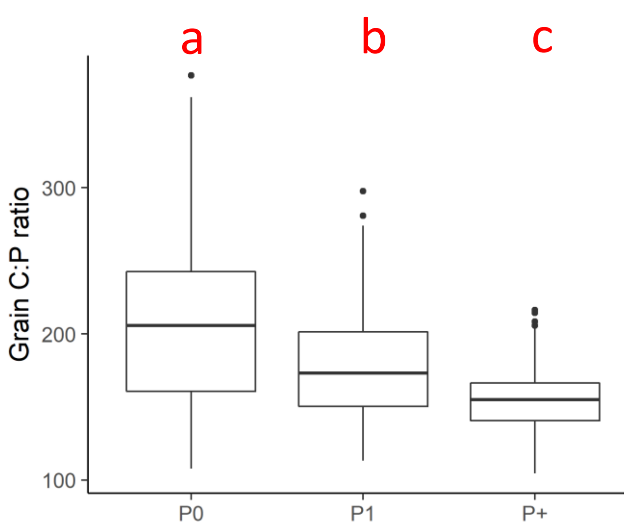
<u>P fertilisation on maize:</u>

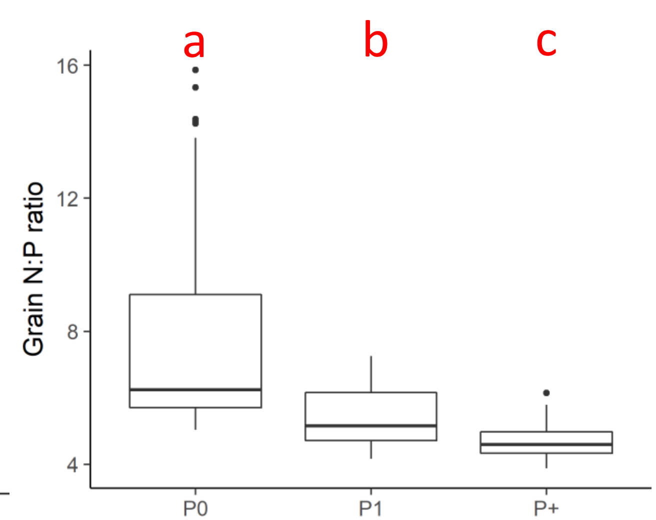
✓ increased **yield** (+)
✓ decreased **C:P** and **N:P** ratios

- Lower **C:N** ratios in P0



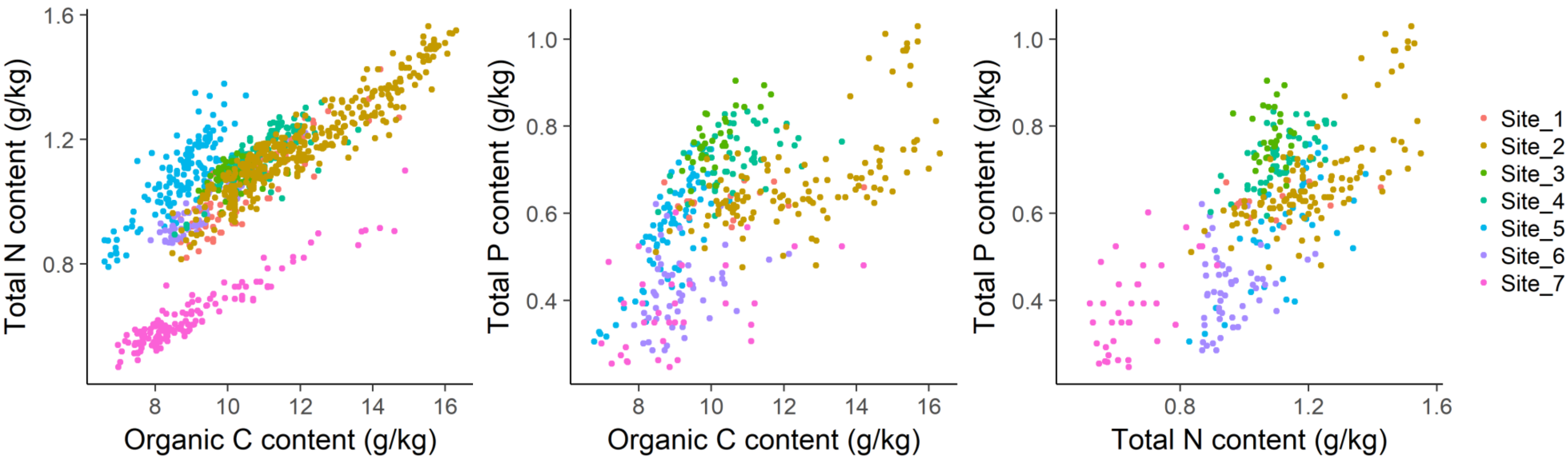






Different letters: $p < 0.05$

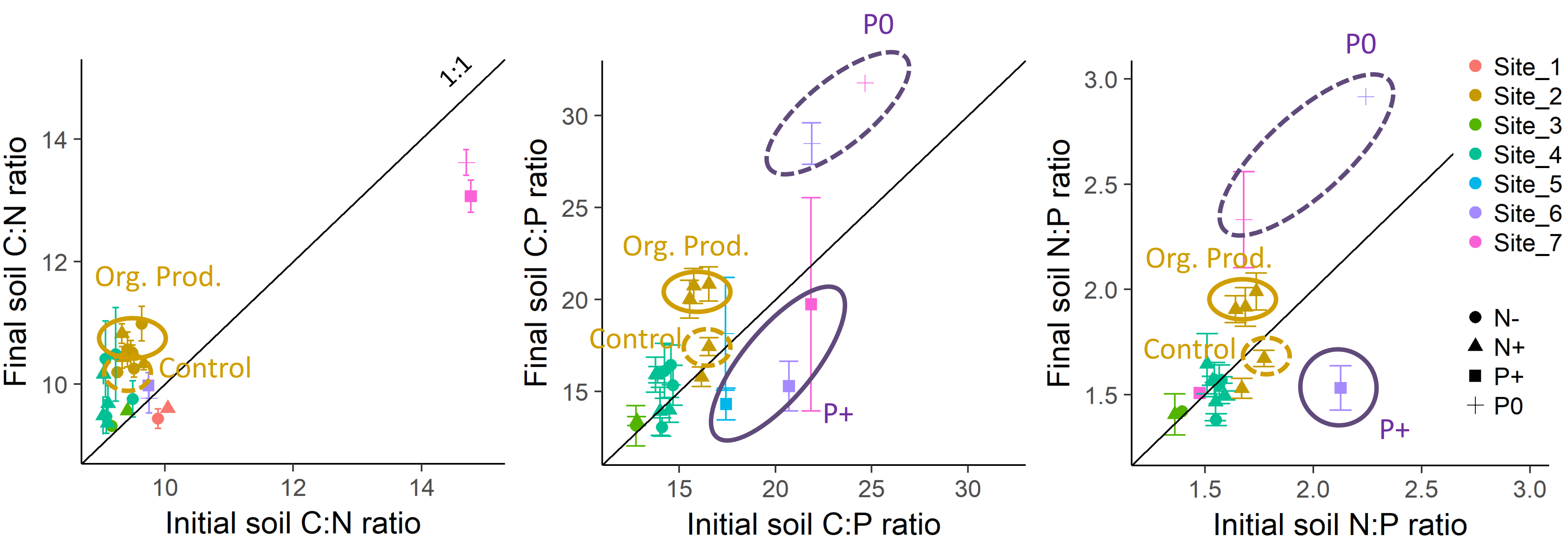
Relationships between C, N and P contents



- C, N and P contents in soils were closely linked
- At the site level, relationship between C and N was more constraint than between C and P or N and P
- A strong site effect was observed

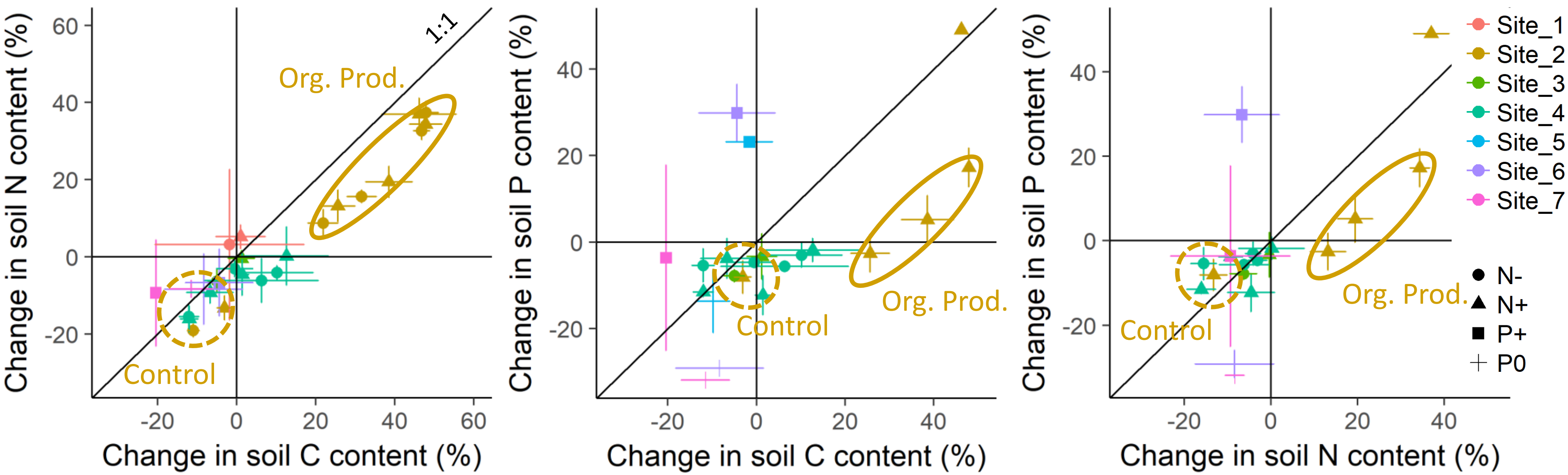
⇒ *necessity to focus on **temporal changes** in contents or ratios to evaluate impacts of agricultural practices*

Temporal evolution of ratios in soil



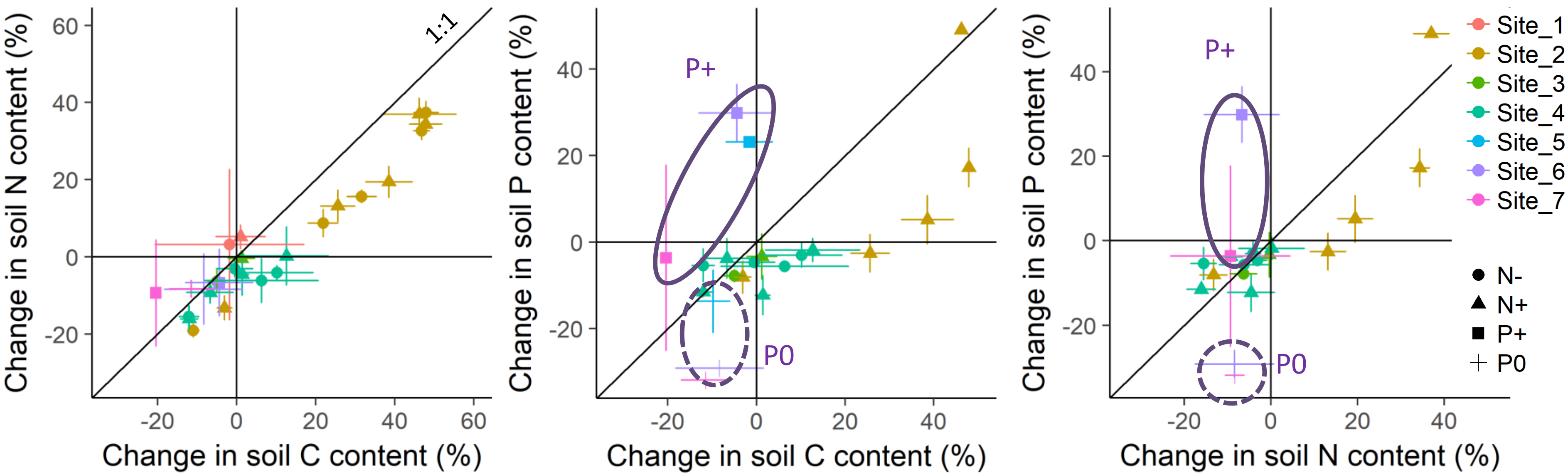
- **C:N** ratio evolution was site specific and not influenced by treatments, excepted the input of organic waste products
- **C:P** and **N:P** ratios evolution was influenced by P inputs and organic waste products

Changes in soil C, N and P contents



- Organic products changed C:N ratio by increasing more rapidly C than N content in soil
- Organic products also increased more rapidly C and N than P contents (except for one type of product)

Changes in soil C, N and P contents



- Organic fertilisers changed C:N ratio by increasing more rapidly C than N content in soil
- Organic products also increased more rapidly C and N than P contents (except for one type of product)
- P inputs changed C:P and N:P ratios mainly by changing P content

Effects of practices on C, N and P in soil

- **Summary**

	N+ *vs* N-	P+ *vs* P-	Organic waste prod. *vs* mineral fert.
C content	↑ (2 sites /4)	↑ (1 site /4)	↑↑
N content	↑ (2 sites /4)	↑ (1 site /4)	↑↑
P content	NS	↑ (4 sites /4)	↑↑ or ↑ or =
C:N	NS	NS	↑ or =
C:P	NS	↓ (4 sites /4)	↑ or ↓
N:P	NS	↓ (4 sites /4)	↑ or ↓

*Results from ANOVAs: Treatments * Years*

Conclusion and prospects

- Long term **N and P fertilisation** treatments induced **differences in crop grain yields and in ratios** (mainly C:N and N:P for N fertilisation ; C:P and N:P for P fertilisation)
- Long term **P fertilisation** treatments induced **strong differences in C:P and N:P ratios in soil**, mainly due to variation in P content
- **C:N stoichiometry in soil was more constraint** and not affected by N and P inputs (except when organic products were applied)
- However, **significant changes in C:N ratio with time** were observed in several sites

<u>Prospects:</u>

- To analyse changes in contents and ratios in soil in relation with N and P budgets (inputs – exports) and with C inputs

Thank you for your attention

We thank the INRA Division Environment and Agronomy for funding this project.

We thank the students involved in this work:
Jocelyn Carré and Emilie Swaenepoel