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INRA SCIENCE & IMPACT

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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

ISPA

AGIR AGroécologie - Innovations - TeRritoires

EcoSys

PCO & SOIS

Introduction

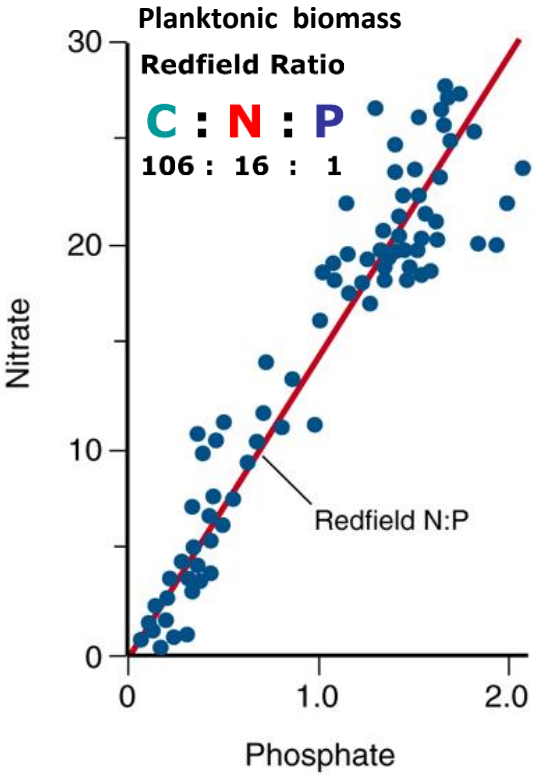
- **Background**

✓ 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

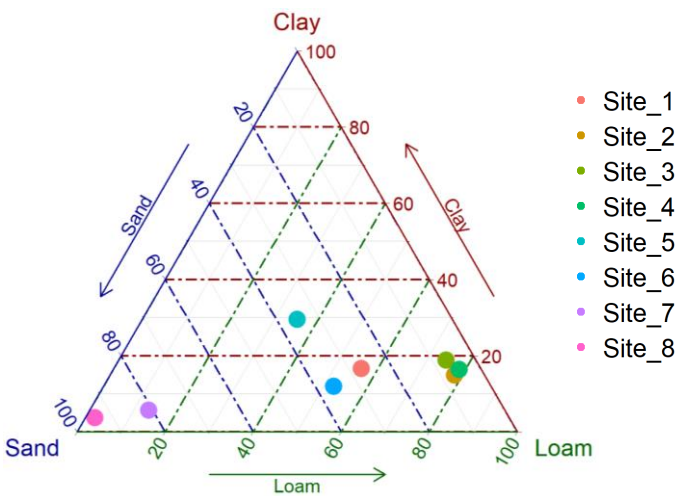
Resulting dataset:

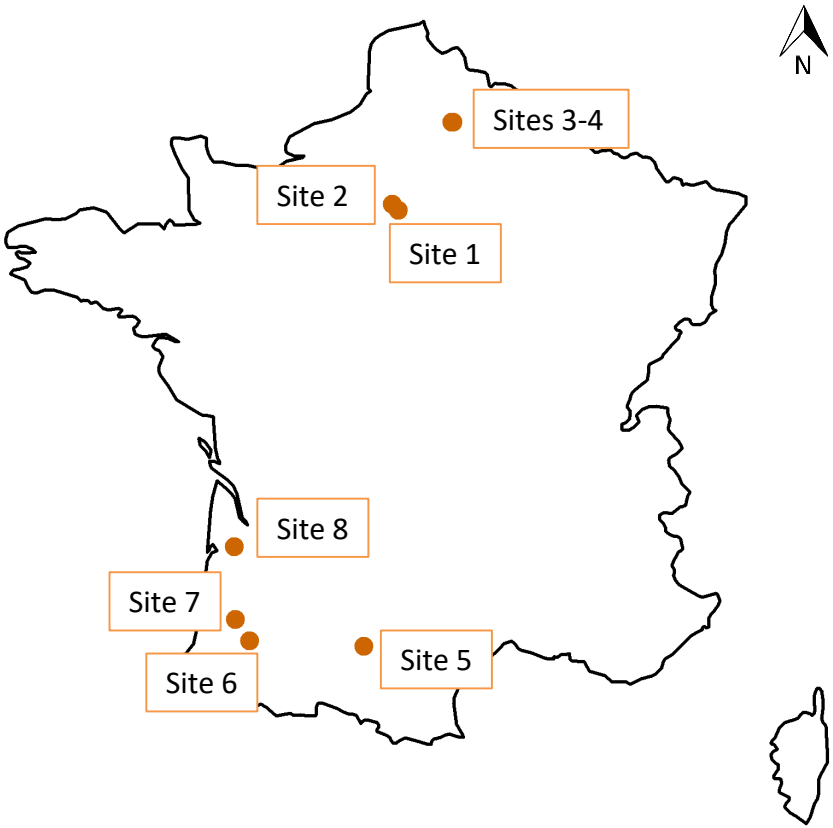
- 7900 plant data: yield, C, N and P content (grains)
- 2600 soil data : organic C, total N and total P content (topsoil)

- **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)



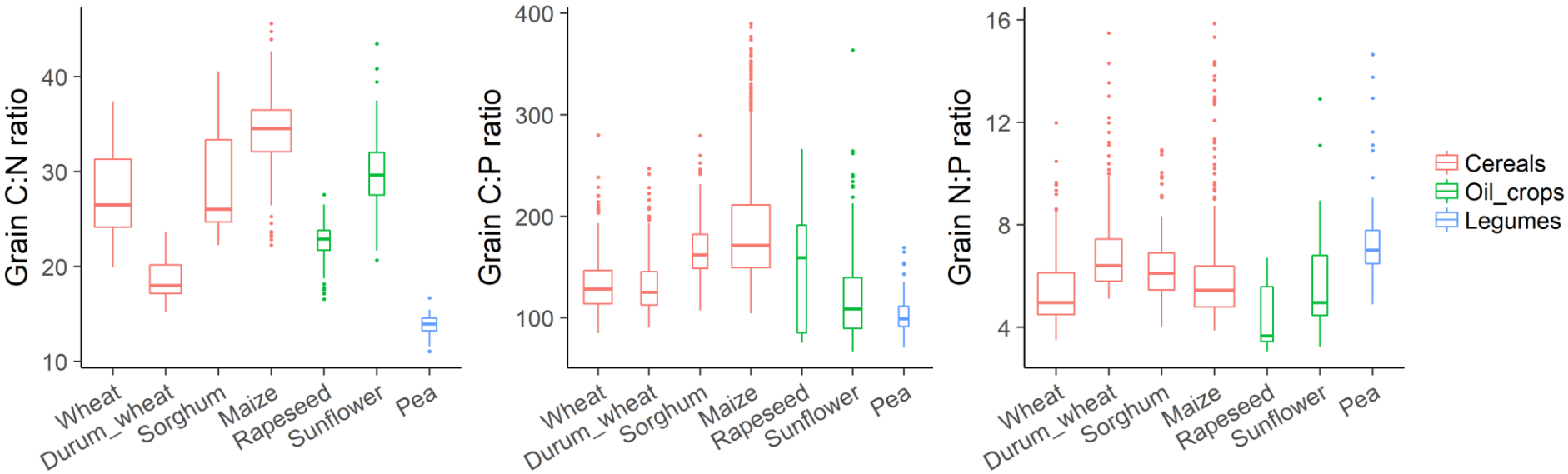


The sites and trials

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

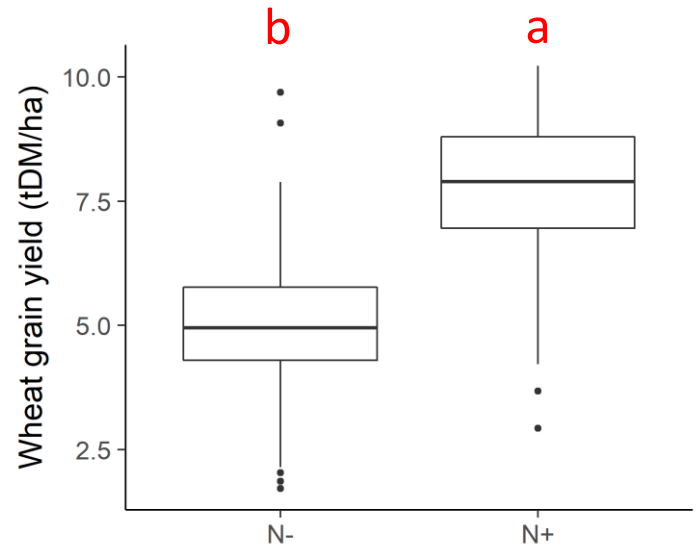
⇒ *We focused on main crops (**wheat in N trials, maize in P trials**) to analyse the effects of agricultural practices*

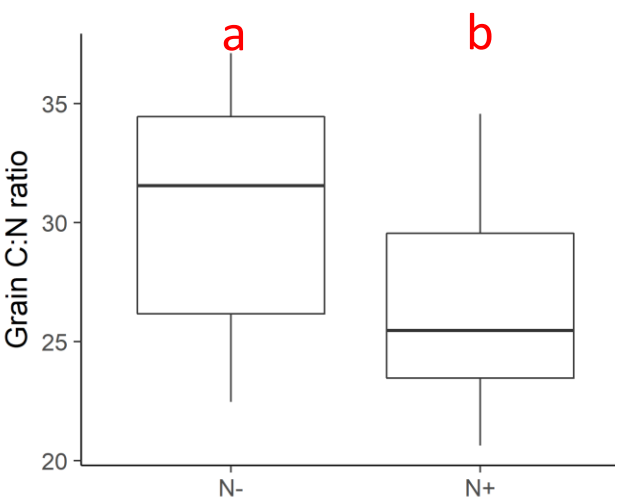
Impact of N fertilisation on yield and ratios

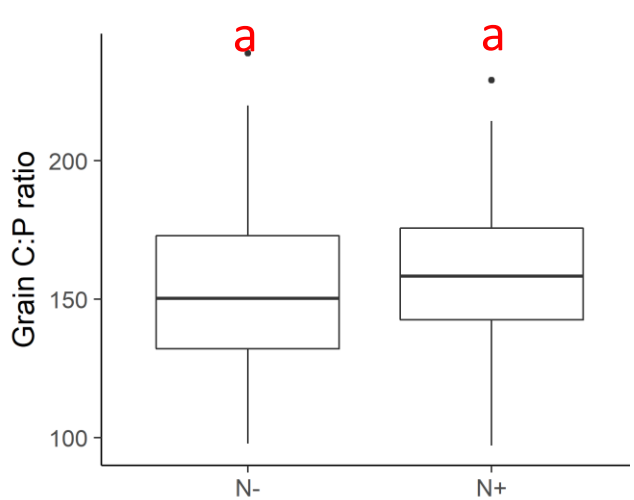
N fertilisation on wheat:

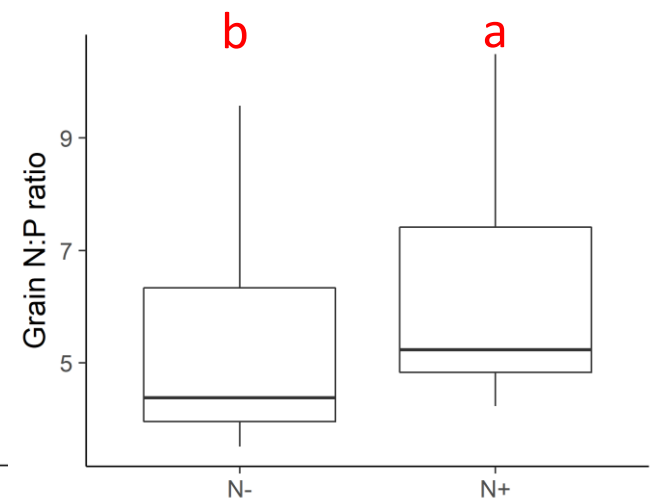
- ✓ increased **yield** (++)
- ✓ decreased **C:N** ratio
- ✓ Increased **N:P** ratio

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









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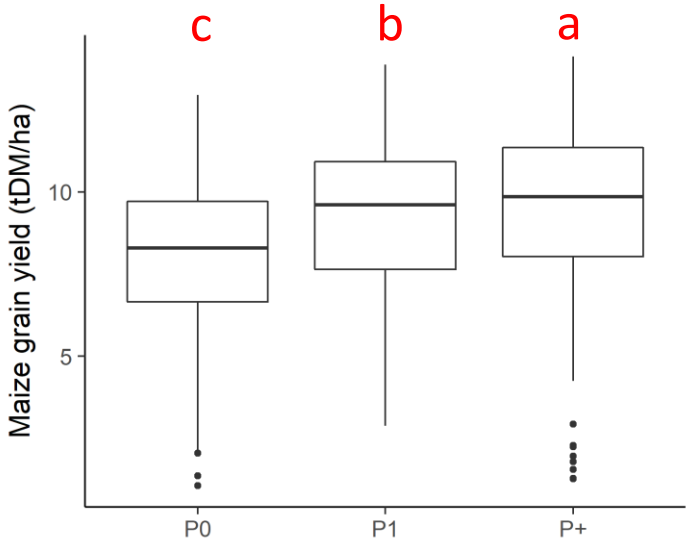
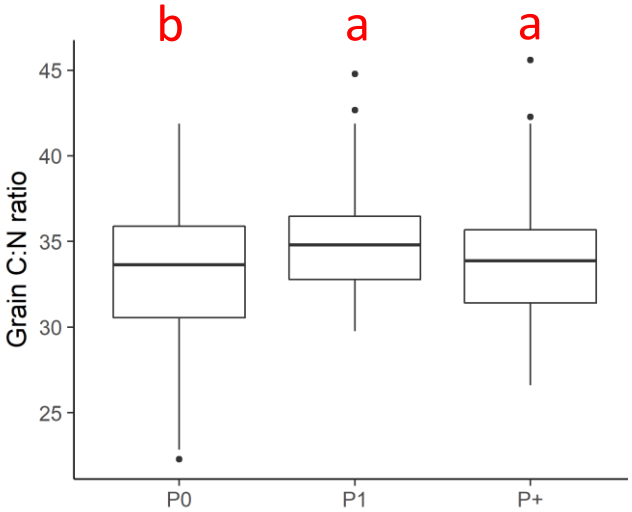
Impact of P fertilisation on yield and ratios

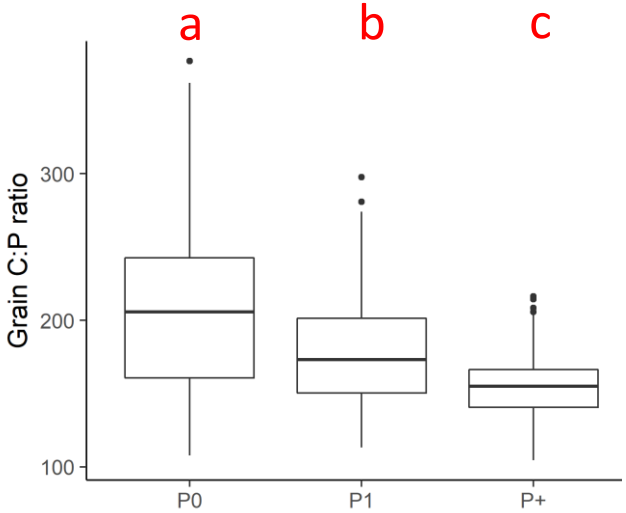
P fertilisation on maize:

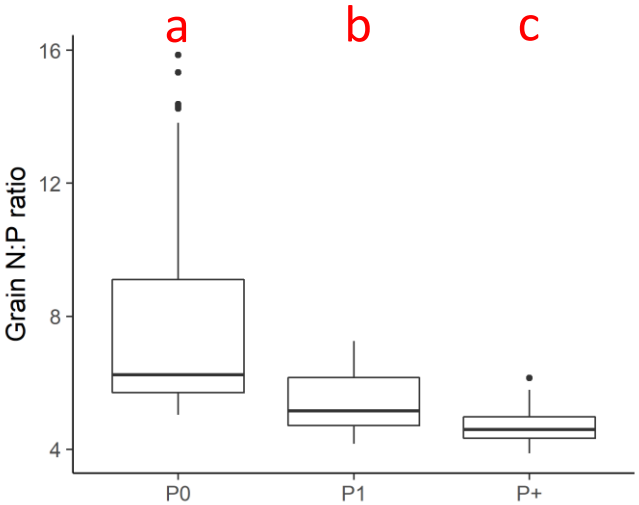
- ✓ increased **yield** (+)
- ✓ decreased **C:P** and **N:P** ratios

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









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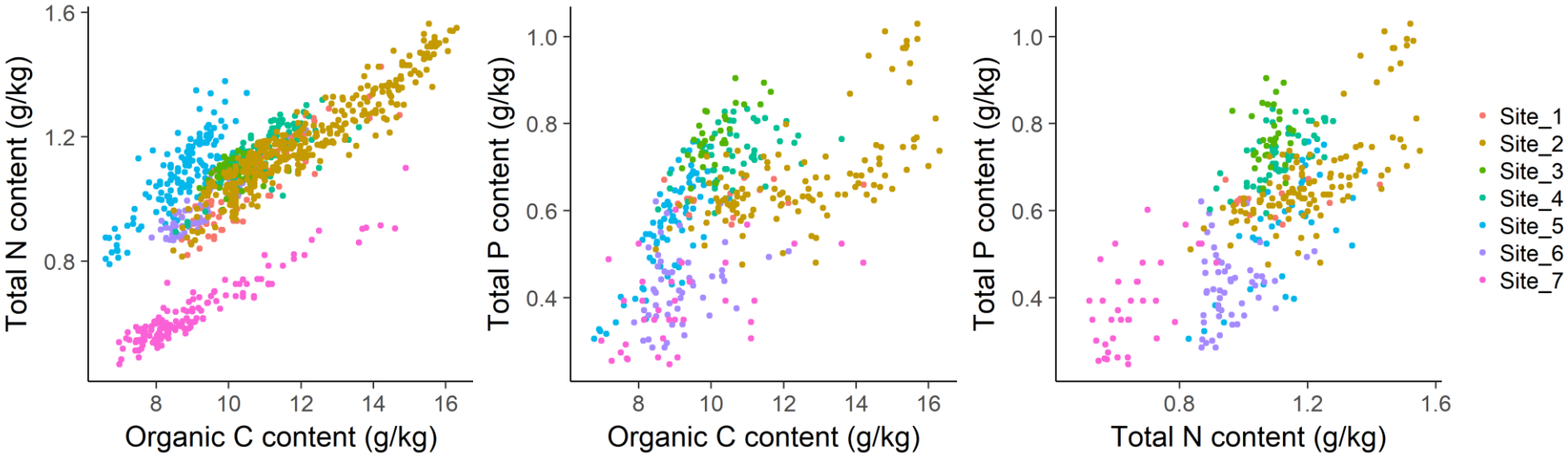
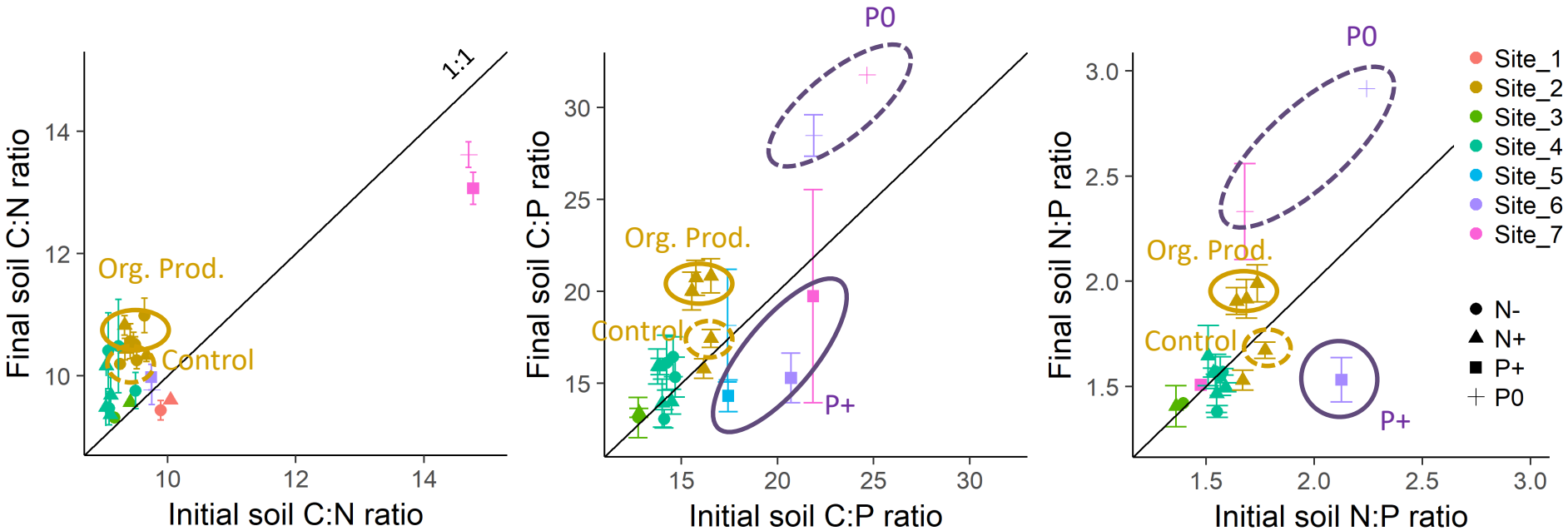
Relationships between C, N and P contents



- 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

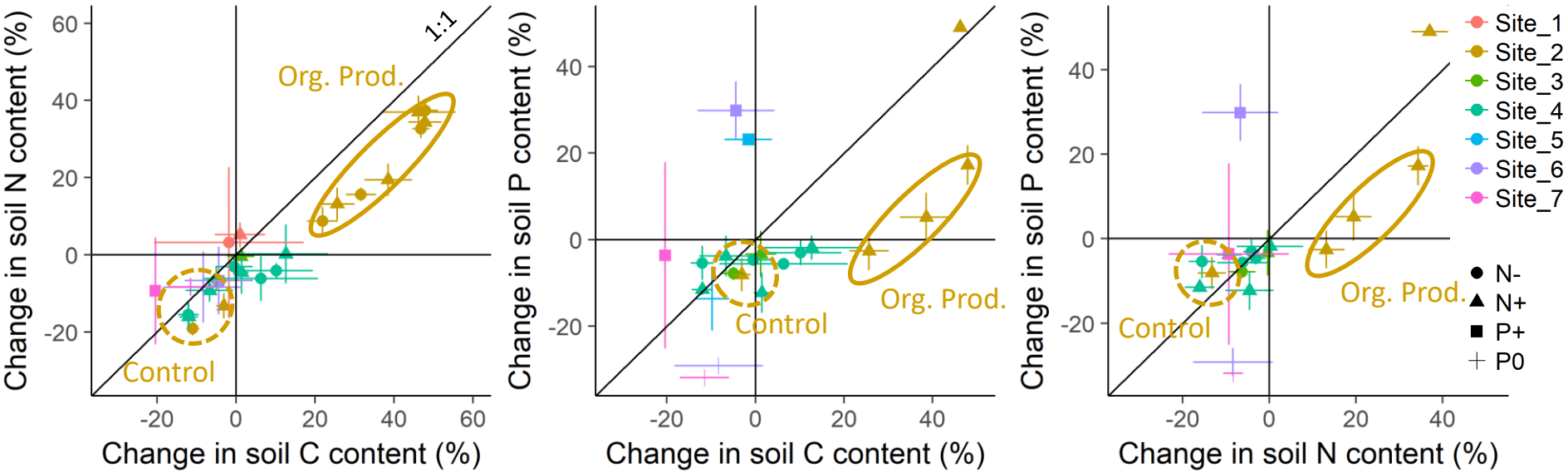
⇒ *necessity to focus on **temporal changes** in contents or ratios to evaluate impacts of agricultural practices*

Temporal evolution of ratios in soil



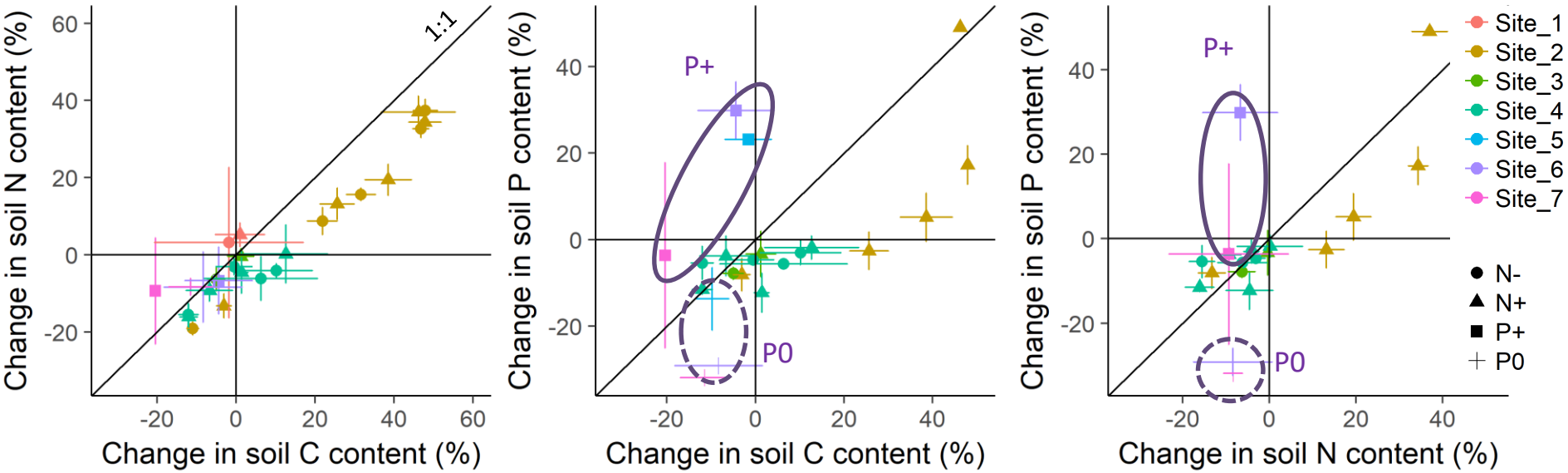
- **C:N** ratio evolution was site specific and not influenced by treatments, excepted the input of organic waste products
- **C:P** and **N:P** ratios evolution was influenced by P inputs and organic waste products

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

Prospects:

- 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

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