



Dynamic of organic phosphorus in the plough soil layer of three contrasting long-term field experiments

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► To cite this version:

Pablo Raguet, Alain Mollier, Noura Ziadi, Sabine Houot, Denis Montenach, et al.. Dynamic of organic phosphorus in the plough soil layer of three contrasting long-term field experiments. Canadian Society of Soil Science – Alberta Soil Science Workshop, May 2022, Edmonton, Canada. hal-03719741

HAL Id: hal-03719741

<https://hal.inrae.fr/hal-03719741v1>

Submitted on 11 Jul 2022

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Dynamic of organic phosphorus in the plough soil layer of three contrasting long-term field experiments

PhD contract founded by l'Agence Nationale de la Recherche (France) : n° ANR-10-IDEX-03-02
Initiative d'Excellence, Université de Bordeaux, cotutelle with Laval university

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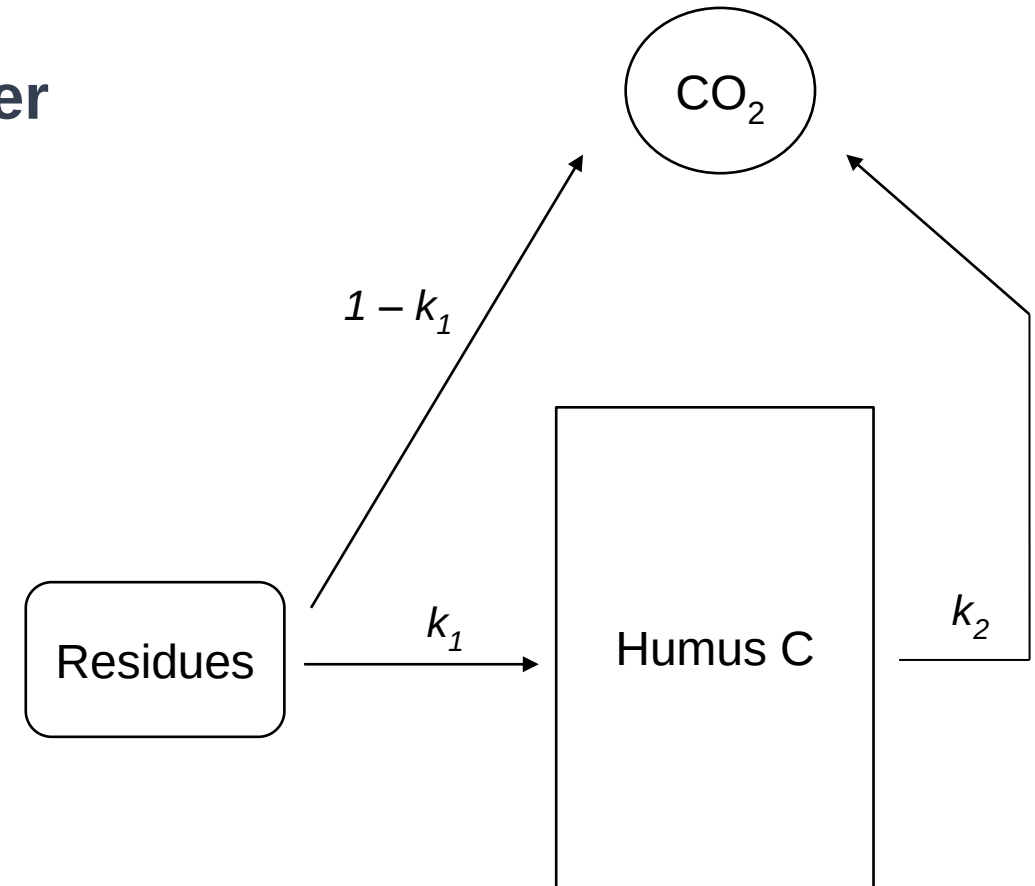


Agriculture and
Agri-Food Canada



Cropped soils over decades, ploughed layer

- ▶ Soil Organic Phosphorus (SOP): $\approx 30\%$ of total phosphorus (P)
- ▶ Few long-term studies in field conditions on SOP dynamics
- ▶ **No information on SOP gross mineralization**
- ▶ Extensive literature on soil organic carbon speciation, dynamic and modeling
([Andriulo et al 1999](#), [Clivot et al 2019](#), [Hénin and Dupuis 1945](#))
- ➔ **model adaptation to SOP:**
 - Annual time step
 - Simulation over decades
 - Cropped field conditions

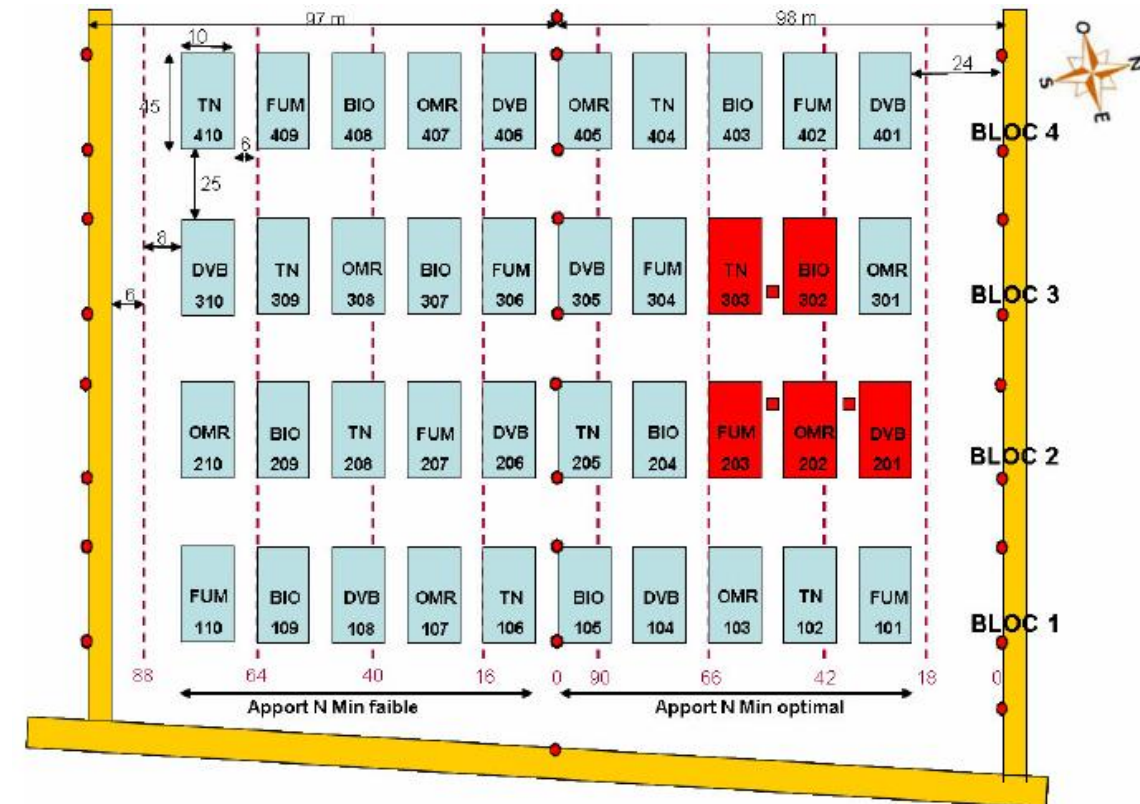


Conceptual diagram of the Hénin-Dupuis model in Andriulo et al 1999: consider two C pools. k_1 = humification rate of crop residues, k_2 = mineralization rate of soil organic matter

Study aims

- ▶ **Quantification of SOP annual gross mineralization rate**
 - Modeling on time series data
 - Over several decades
 - 3 long-term field experiments (4 replicates per treatments)
 - Different field conditions

- ▶ **Assessment of fertilization practices effects on SOP gross mineralization**
 - Organic waste products fertilization (OWP)
 - Mineral fertilization



Qualiagro field map

Long-term field experiments

S2

Oceanic ; luvisol; corn-wheat;

18 years; 7 soil samplings; pH = 7.1

Treatments and P inputs (kg P ha⁻¹ an⁻¹):

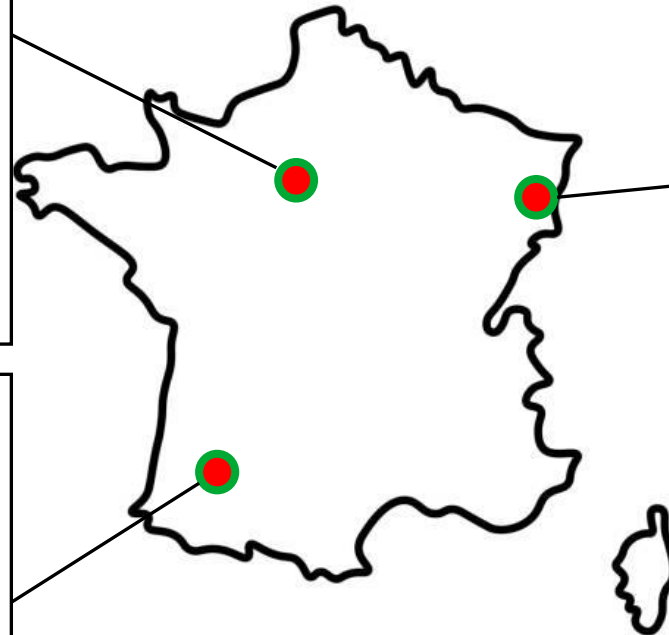
- Control (5)
- Municipal solid waste (24)
- Farm yard manure (28)
- Biowaste (44)
- Green waste and sewage sludge (106)

S1

Oceanic ; sandy soil ; maize monoculture

17 years ; 4 soil samplings; pH = 7.3

P inputs as tripe superphosphate :
0, 27, and 76 kg P ha⁻¹ yr⁻¹



FRANCE

S3

Continental; eutric brunisol;

corn-wheat-sugar beet-barley ;

14 years; 6 soil samplings; pH = 8.3

Treatments and P inputs (kg P ha⁻¹ an⁻¹):

- Control (8)
- Farm yard manure (21)
- Composted farm yard manure (21)
- Biowaste (17)
- Urban sewage sludge (36)
- Green waste and sewage sludge (45)

Sampling and measures

► Soils and Organic waste product

→ **TotP**: HF extraction ([AFNOR 1999](#))

→ **Organic P**:
[Saunders and Williams \(1955\)](#)

► Crops

→ Annual yield

→ P concentration in grains

→ Aboveground residues biomass
(S2, S3 and some years in S1)

→ P concentration in aboveground residues

	Cumulated sum total P applied (kg P ha ⁻¹)		Cumulated sum organic P applied (kg P ha ⁻¹)		C_{org}/P_{org}	N_{org}/P_{org}
	S2	S3	S2	S3		
BIO	834	327	58	17	725 ±142	59 ±11
FYM	714	362	257	114	174 ±57	11 ±2
FYMC		373		114	133 ±37	10 ±2
MSW	436		39		1012 ±313	55 ±11
SLU		588		92	73 ±9	12 ±1
GWS	2020	715	323	107	134 ±51	12 ±3

Model description

- ▶ SOP dynamic = balance between:
 - 1) **P incorporation** to SOP
 - 2) **SOP mineralization**
 → Annual time step
- ▶ Products P inputs the year following fertilization:
 - PO_4^- (decomposition)
 - SOP (incorporation)
- ▶ Derivative equation:

$$\Delta \text{SOP} = \sum (P_i \times h_i) - K \times \text{SOP}$$

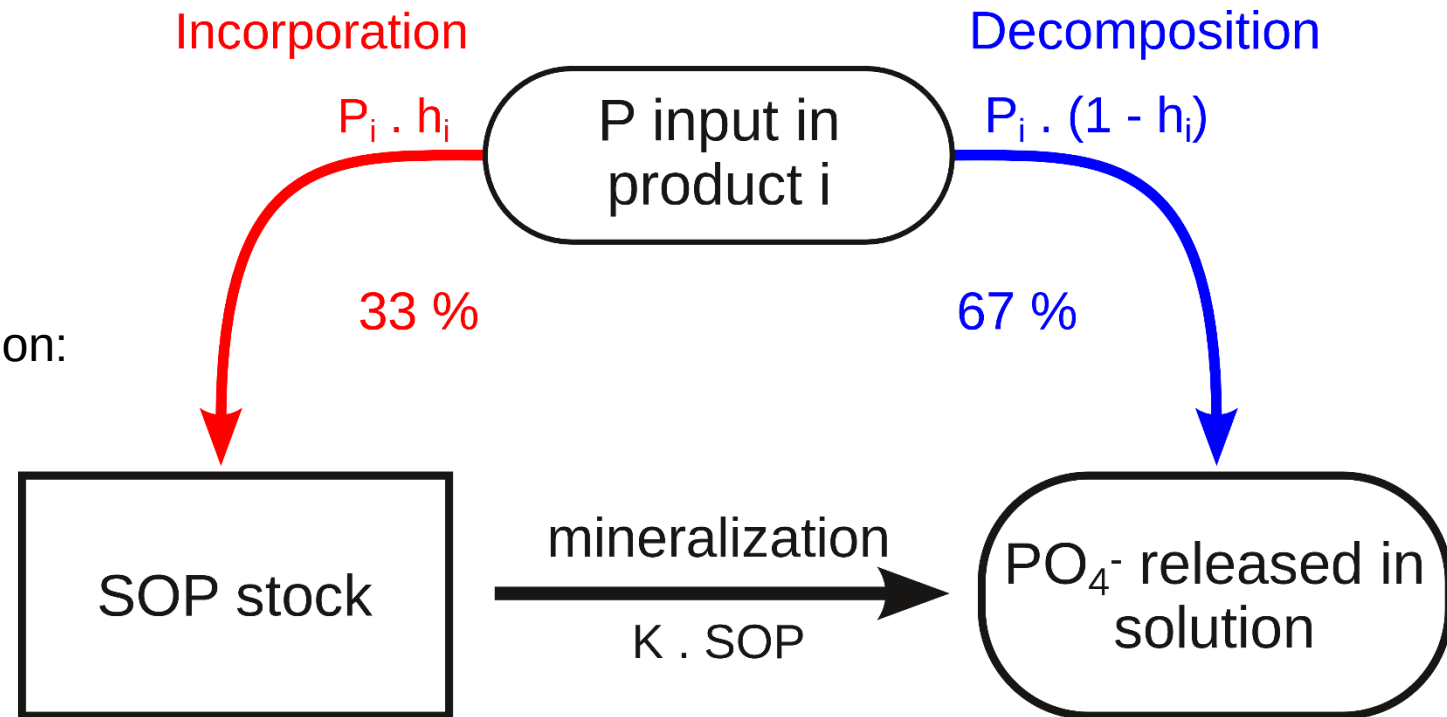
with :

i: P input source (3 types of crop residues, OWP)

P_i ($\text{kg ha}^{-1} \text{ y}^{-1}$): amount of organic P input within *i*

h_i: incorporation coefficient of *P_i* to SOP during 1 year

K (y^{-1}): gross mineralization coefficient of SOP



Conceptual diagram of the model

Model calculation

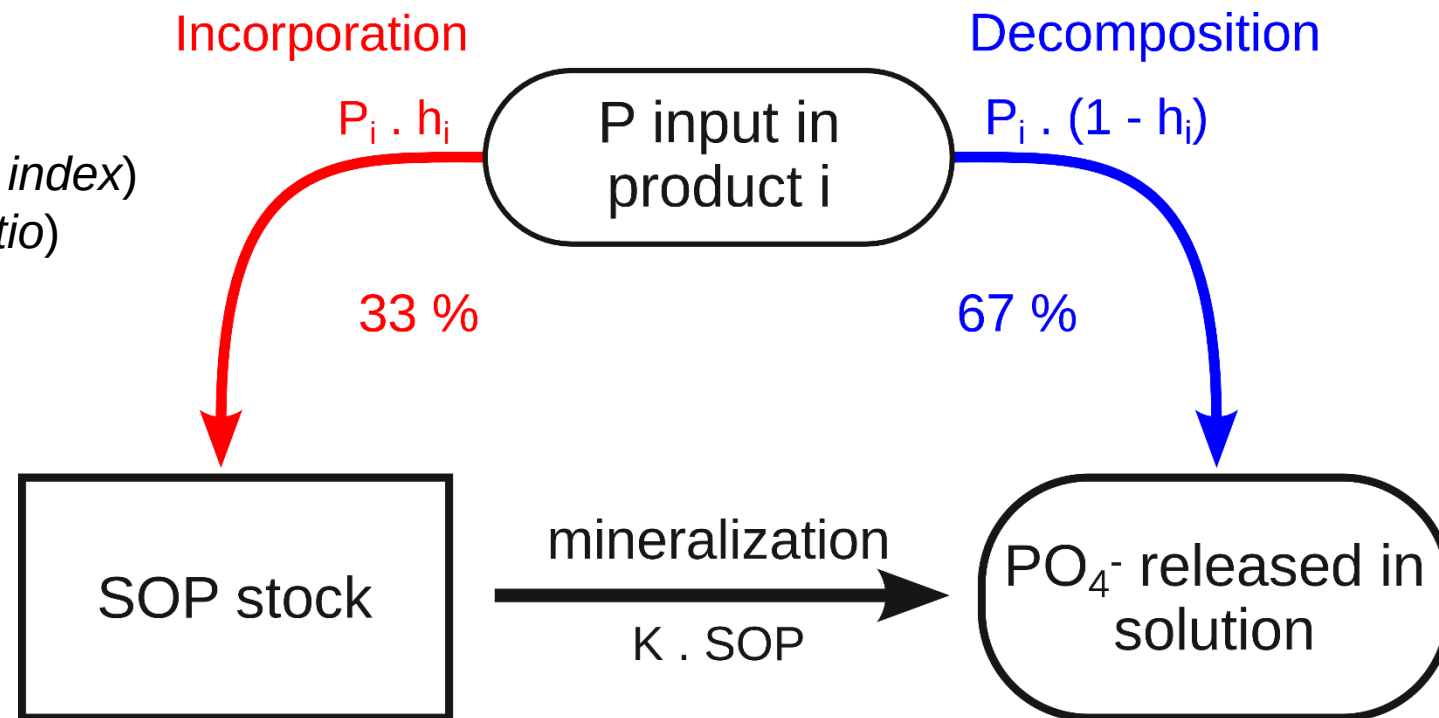
► Known parameters:

- **P_i** : measured in OWP and calculated for:
 - S1 aboveground residues (*use P harvest index*)
 - Belowground residues (*use root-shoot ratio*)
 - Harvest losses (*≈ 3% P exported*)
- **h_i** (*based on published values*)
- SOP stock

► Unknown parameter: **K**

- Optimized (reduce the sum of square)

- gross annual rate of mineralization = **K x SOP** (kg P ha⁻¹ y⁻¹)



Conceptual diagram of the model

Other calculation

- Net SOP stock variation evaluated with **linear regression**

Sites main characteristics

	S1	S2	S3
Mean annual yield (t ha ⁻¹ y ⁻¹)	8.3 ±2.0 a	8.2 ±1.3 a	9.1 ±3.9 b
Mean annual P exportation (kg P ha ⁻¹ y ⁻¹)	26.5 ±6.5 b	23.5 ±7.2 a	22.5 ±8.5 a
Mean annual organic P applied in OWP incorporated to SOP (kg P ha ⁻¹ y ⁻¹) <i>include years without fertilization</i>		6.6 ±11	4.7 ±6.5
Mean annual P return in crop residues incorporated to SOP (kg P ha ⁻¹ y ⁻¹)	2.5 ±0.7	3.2 ±1.5	4.0 ±2.5
Initial total P stock (kg P ha ⁻¹)	1508 ±116	2440 ±155	4296 ±142
Initial SOP stock (kg P ha ⁻¹)	446 ±43	595 ±127	1145 ±108

SOP stocks variation between sites and treatments

► Variations (= slope) ($\text{kg P ha}^{-1} \text{ y}^{-1}$):

→ S1: -0.04 ± 1.06

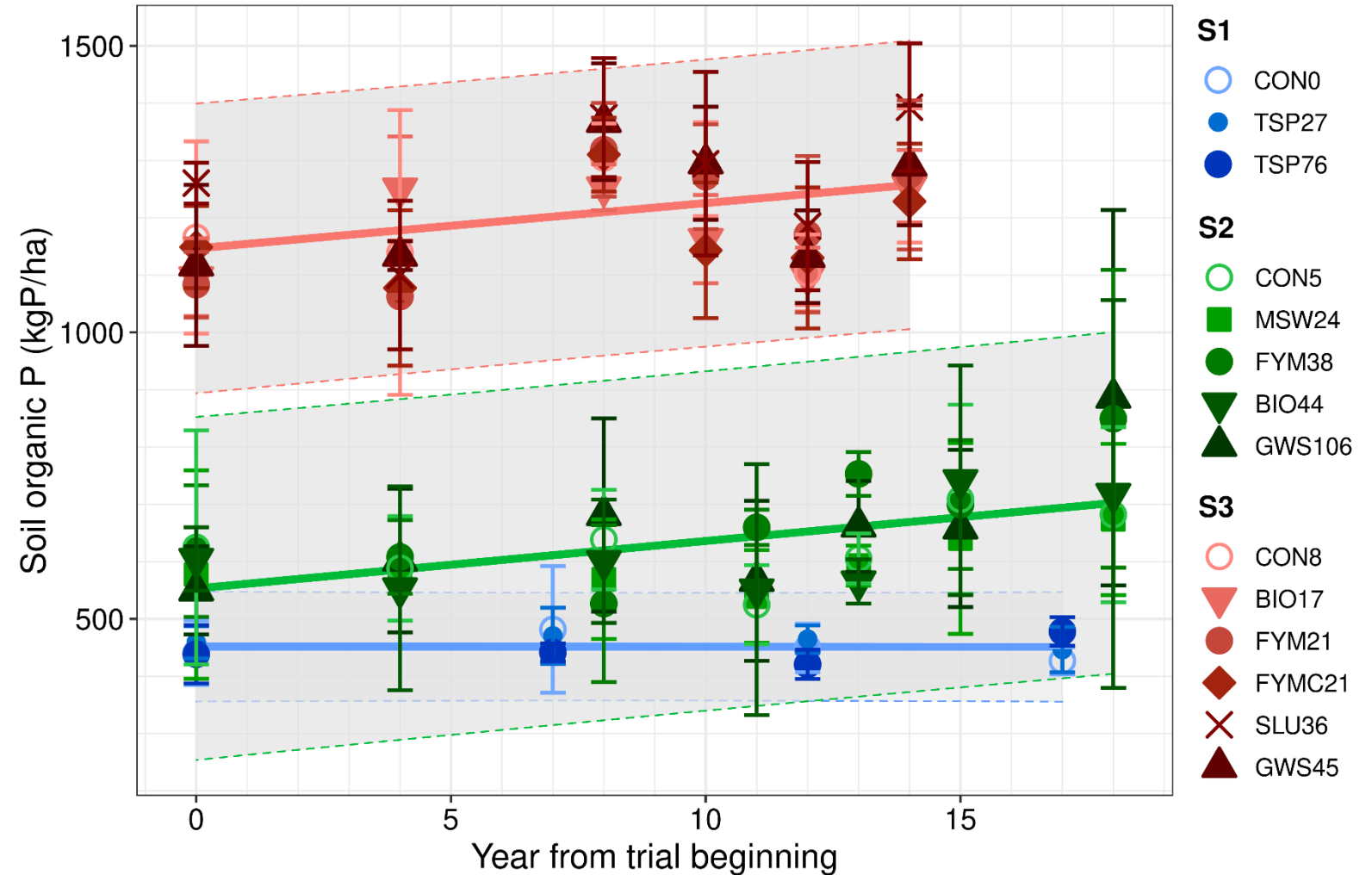
→ S2: 8.3 ± 2.2

→ S3: 7.9 ± 2.2

► Significant site effect on slope and initial SOP stock

► In all sites:

→ no significant difference between treatments



Measured SOP and each site linear regression on SOP stocks in the ploughed soil layer as affected by P fertilization along all three sites.

Model results

- ▶ Gross mineralization coefficient:
 - **Significant differences between treatments in S2**
(*P*-value = 0.02)
 - highest coefficient for manure and green waste + sludge
 - OWP with highest P incorporation to SOP
- ▶ In S1 and S2, **release of PO_4^-** from residues + OWP decomposition over 1 year is **greater than annual rate of SOP gross mineralization**

	S1	S2	S3
K (y^{-1})	0.0046 $\pm$ 0.0038	0.017 $\pm$ 0.016 *	0.0047 $\pm$ 0.0049
Residence time (y)	217	59	213
Gross mineralization (kg P ha $^{-1}$ y $^{-1}$)	2.1 $\pm$ 1.7	10.8 $\pm$ 10.1	5.7 $\pm$ 5.8
Crop residues + OWP PO_4^- release (kg P ha $^{-1}$ y $^{-1}$)	12.5 $\pm$ 3.6	10.6 $\pm$ 4.2	9.4 $\pm$ 4.3
P incorporation to SOP (kg P ha $^{-1}$ y $^{-1}$)	2.5 $\pm$ 0.7	9.8 $\pm$ 11.8	8.7 $\pm$ 6.9

OWP fertilization and SOP mineralization

- 1) P in OWP is mainly as **inorganic P form** ($\approx 80\%$)
 - High difference in P applied as OWP due to **$C_{org}:N_{tot}:P_{org}$ stoichiometry** and **reasoning based on C or N**
 - Organic P amounts applied in OWP are **much smaller** than SOP stock → small impact
- 2) SOP annual gross mineralization rate is **not affected** by fertilization treatment
- 3) **PO_4^- released by P inputs decomposition** $\geq$ SOP gross mineralization

Further research needed

- ▶ Study more long-term field experiments to highlights SOP mineralization drivers
- ▶ Look at OWP and soil P speciation to investigate a SOP mineralization driver
- ▶ Compare SOP mineralization and PO_4^- diffusion at solid-to-solution interface
 - Quantify SOP mineralization contribution to plant nutrition



Thanks for listening



Thanks to

The QualiAgro and PROspective field experiments form part of the SOERE-PRO (network of long-term experiments dedicated to the study of impacts of organic waste product recycling) integrated as a service of the “Investment for future” infrastructure AnaEE-France, overseen by the French National Research Agency (ANR-11-INBS-0001). The QualiAgro experiment was founded and is still supported by INRAE and Veolia R&I.

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Supplementary

	Total P concentration (g P kg ⁻¹)	Organic P (%)	C/P	N/P
BIO	4.7 ±1.4	7	51 ±10	4.1 ±0.8
FYM	6.0 ±1.4	36	62 ±20	4.0 ±0.9
FYMC	7.8 ±1.6	36	48 ±13	3.5 ±0.9
MSW	3.6 ±0.7	9	91 ±28	4.9 ±1.0
SLU	30 ±2	17	12 ±2	2.0 ±0.3
GWS	14 ±4	16	21 ±8	1.9 ±0.5