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Multiannual dynamics of P-ions in solution in two French cropped soils after repeated applications of organic wastes products

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Introduction

- Organic waste products (OWP) represent significant phosphorus (P) sources in France, but their P availability to plants is rather unknown when applied according regulations to cropped fields.
- Dissolved P-ions in soils are of crucial importance since they are the forms absorbed by plant roots.
- After spreading OWP, a part of their total-P is released into the soil solution as orthophosphate ions ($H_2PO_4^-$, HPO_4^{2-}), denoted by P-ions, which modifies equilibrium at the solid-to-solution interface.

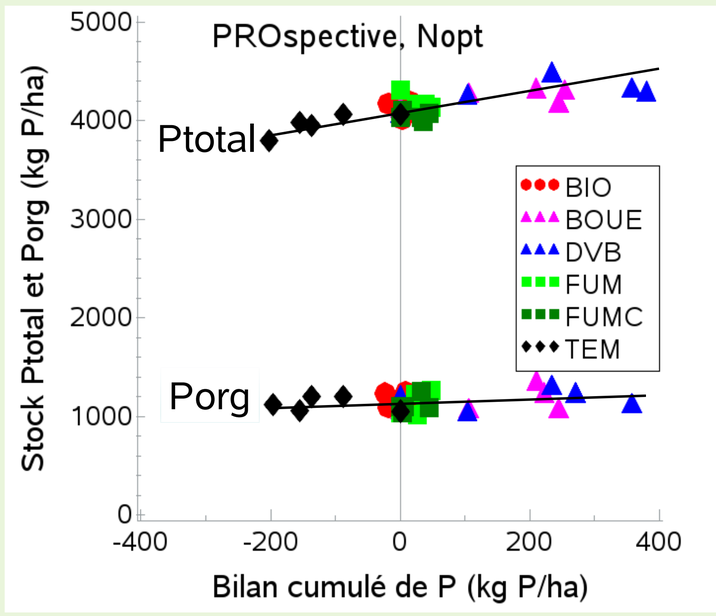
Objective

TO ASSESS THE IMPACT OF REPEATED APPLICATIONS OF DIFFERENT OWP ON THE MULTIANNUAL DYNAMICS OF P-IONS IN SOLUTION WITH CUMULATED P BUDGET (APPLIED P MINUS P EXPORTS)

Material and methods

- The two oldest French field experiments on OWP were analyzed. **Qualiagro** (INRA-Veolia) is on a neutral Glossic Luvisol with silt loam texture. **PROspective** (INRA-Colmar) is on a deep Calcaric Cambisol (11% $CaCO_3$, pH = 8.2).
- In each, there is a control treatment (**TEM**) that does not receive P.
- In both, there are a dairy cow manure (**FUM**), a co-compost of green waste and urban sludge (**DVB**), and a bio-waste compost (**BIOD**).
- A residual household waste compost (**OMR**) is also applied in Qualiagro. The urban sludge (**BOUE**) used to produce DVB and the composted **FUM** (**FUMC**) are also studied in PROspective experiment.
- The OWP were applied every two years as 4 t C ha^{-1} in Qualiagro (1998, 2000, 2002, 2004, 2006, 2007, 2009, 2011, 2013) and 170 kg N_OWP ha^{-1} in PROspective (2000, 2002, 2004, 2006, 2008, 2010, 2012, 2014). Treatments were repeated 4 times.
- Crop successions are representative of regional rotations, i.e. grain corn and winter wheat in QualiAgro, and grain corn, winter wheat, sugar beet and malting spring barley in PROspective. Crop yield and its P content of each experimental plot were yearly measured. All OWP were analyzed for their chemical composition.
- Soils from the plowed layer were sampled every two years, air dried, ground, sieved (2 mm) and stored before analysis.
- P-ions concentration (*C*p) in solution (solubility), and soil-solution transfer of P-ions by diffusion were both determined coupling sorption and isotopic dilution studies.
- Organic P content was determined by the Saunder and Williams' method (PH_2SO_4calcinated – PH_2SO_4 uncalcinated)
- The total P content of the soils was obtained by dissolving with concentrated hydrofluoric and perchloric acids concentrated according to standard NF X 31-147.

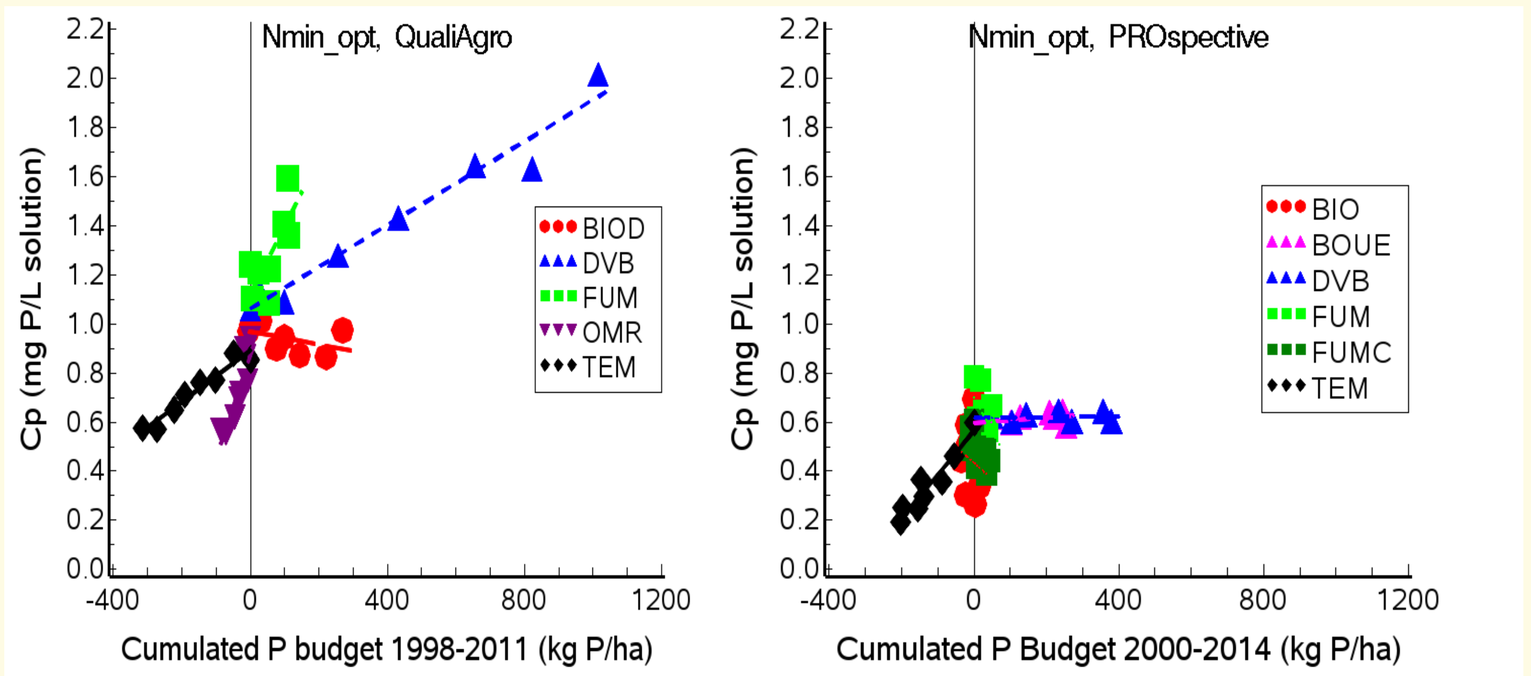
Results



1. In both field experiments (only PRO'spective is shown in figure in front), cumulative P budget depended on OWP dose, duration of field experiment, and OWP type in relation with its P content, C/P and N/P ratio.
2. The full P budget is found by strong HF and $HClO_3$ acids within the first 35 cm of soil in both trials. A few percents are located just below the « theoritical » depth of ploughed layer.
3. Soil organic P content keeps constant in QualiAgro (y= 589 + 0.02x, r^2=0.01, 24 obs) and slightly changes with P budget in PRO'spective (y= 1140+0.23x, r^2=0.09, 30 obs).

Multiannual dynamics of P-ions concentration (*C*p) in solution with cumulated P budget (Figure below)

- The initial *C*p is 1.04 and 0.69 mg P L^{-1} at Qualiagro and PROspective, respectively.
- The *C*p decrease (slope) is faster with negative P budget in **TEM**-PROspective than in **TEM**-Qualiagro (1.8 and 1.1 (µg P L^{-1}) (kg P ha^{-1}) $^{-1}$, respectively) in relation with different capacities of soils to buffer P-ions in solution by diffusion.
- The multiannual *C*p dynamics with P budget differed across OWP in relation with combined effects of solubility of P species in OWP, diffusive P-ions transfer at the solid-to-solution interface, and physical-chemical soil properties.
- In **QualiAgro**, Cp increased proportionally to P budget applying **DVB** as an extention of the slope of **TEM:** the solubility product of P in **DVB** is greater than the one in soil.
- On the other hand in **PROspective**, Cp remains constant whatever the cumulative balance of P with **DVB:** the solubility product of P in **DVB** and soil are similar**.**
- The presence of P forms with sparingly water-soluble content (amorphous phosphate calcium, apatite), such as in **BIOD**, explains the drastic decrease in *C*p in the calcareous soil even if the P budget is balanced. In this soil, the solubility product of P in **BIOD** likely controlled *C*p.



Conclusions

- **Variations of total P in soils match to cumulated P budget. So, P cycle is completely looped (no significant P loss by runoff and leaching)**
- **Multiannual dynamics of soil solution P-ions concentration (Cp) (and also Olsen-P, data not shown) depended on soil types and OWP types.**
- **Additional analysis are required on the speciation of P in OWP and its chemical composition.**

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