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Could soil available phosphorus (P) limit the production of organic agriculture in the context of a large expansion?

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Background

◈ Organic agriculture is often presented as a desirable option to current food production systems.

◈ Question: Could organic farming feed the world?

◈ Studies[(2,3)] have shown that it would be possible to convert up to 60% of agricultural areas to organic agriculture while producing enough food to feed the world. This would be possible under some conditions that include:

- Reducing livestock density by 80%
- Reducing food waste
- Reducing average caloric intake per capita

But none of these studies have taken into account crop response to soil available phosphorus (P) ...

◈ Current agricultural systems are highly dependant on the use of mineral P fertlizers

◈ The expansion of organic agriculture may increase the competition for accessing organic fertilizers such as manure

◈ Repeated negative soil P budgets will trigger a decrease in soil available P, which could in turn limit food production

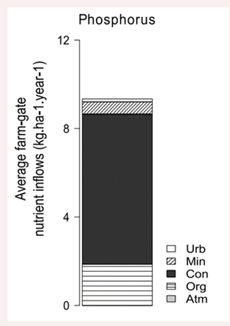

Figure 1 - Average farm-gate P inflows for 63 French organic farms[(1)]. Con refers to P from conventional farming, Min to P from mineral ressources, Urb to P from urban sources and Org to P from organic farming

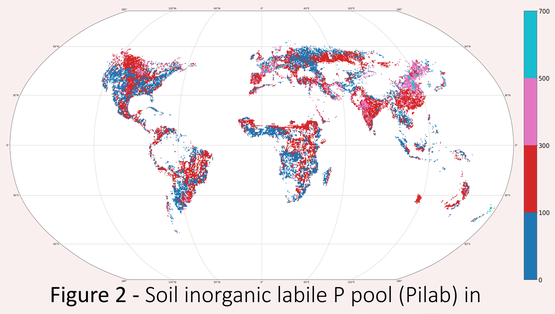

Figure 2 - Soil inorganic labile P pool (Pilab) in cropland soils at year 2017(kgP/ha)[(4)]

Objective: Assess where, when and to what extent soil available P could limit the production of organic agriculture in the context of a large expansion.

Hypothesis: Soil available P will limit food production, especially where current soil available P stocks are low.

Method

◈ Scope
- World scale with a 5 arc min resolution (10km x 10km)
- Run for 100 years at a yearly resolution
- Total agricultural areas per gridcell is kept unchanged at current levels

◈ Combine two models

Crop response to soil available P

GOANIM_N[(2)]_P

Linear optimization model that simulates the expansion of organic agriculture by considering N and P flows between cropland, grassland and livestock systems

GPASOIL v1.1[(4)]

Mecanistic model that simulates soil P dynamics following soil P inputs/outputs

◈ Test different scenarios

Production side	Demand side
Share of organic agriculture (25% - 60% - 100%)	Recycle sludge and household organic waste
Limit soil erosion to reduce soil P losses	Reduce food waste
Grassland response to soil available P	Reduce average caloric intake per capita

Figure 3 - Pairing two models: GOANIM_NP and GPASOIL-v1.1

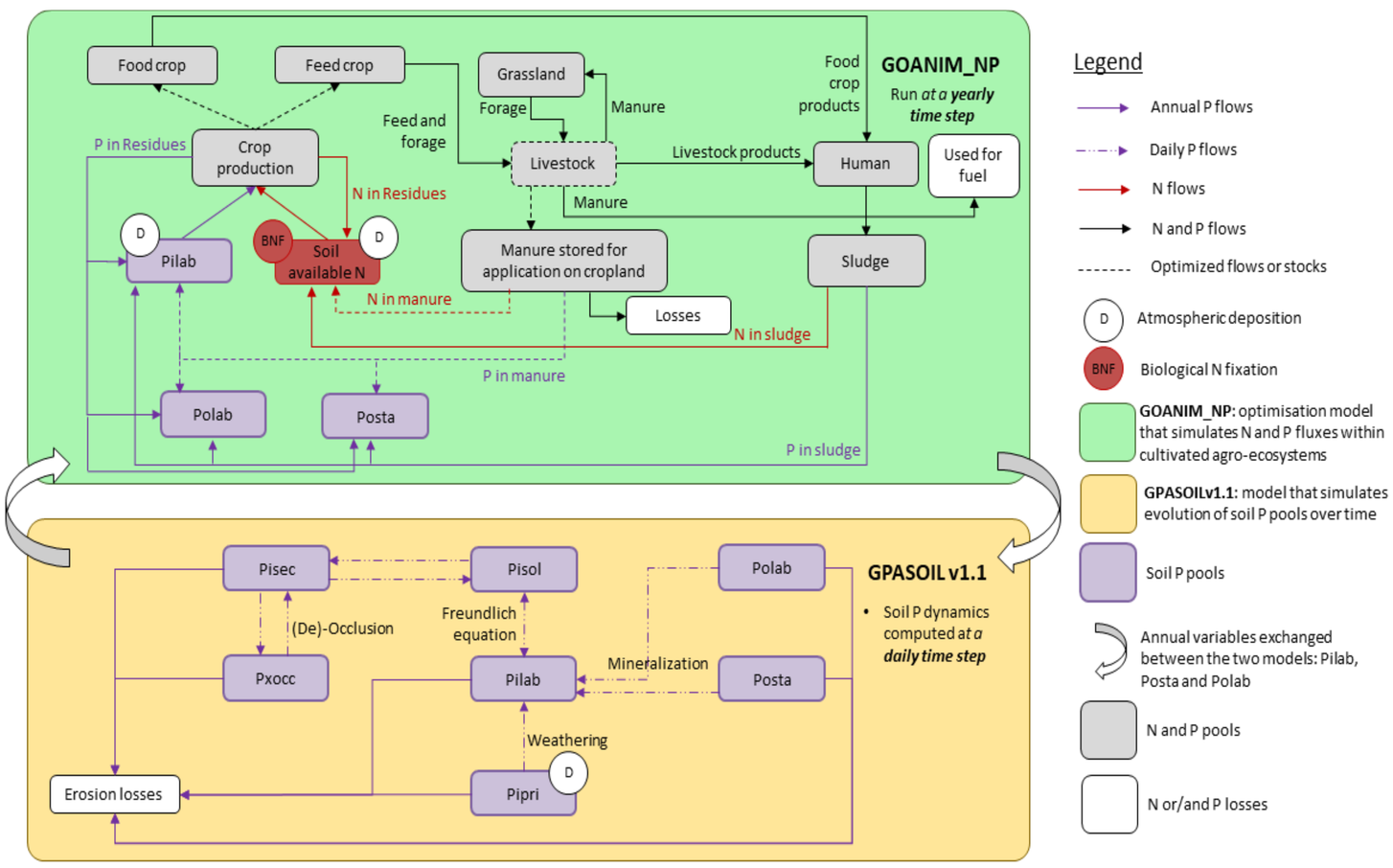

Illustration with one gridcell

Input data

Crop

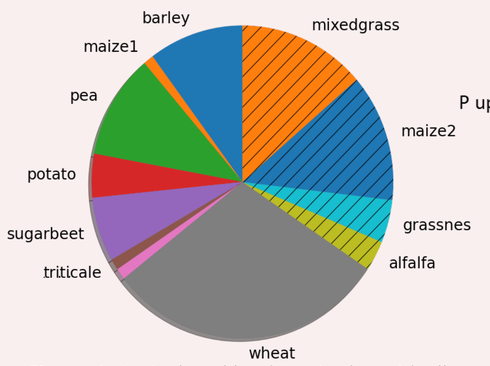

Figure 4- Agricultural land use in the gridcell considered (ha)

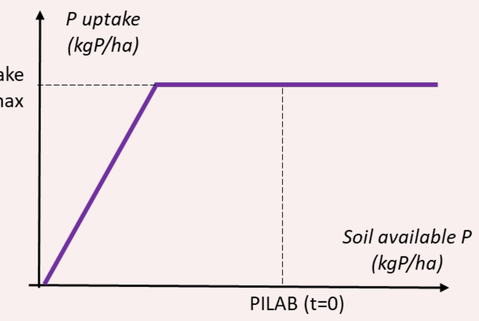

Figure 5- Crop P uptake response to soil available P

Livestock

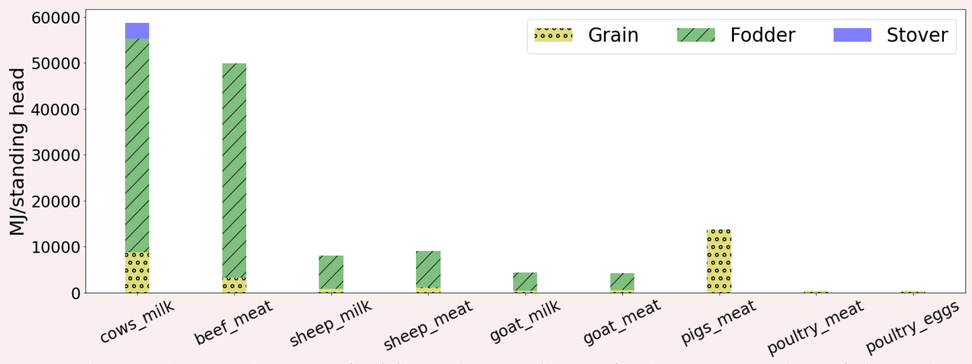

Figure 6- Demand in energy (MJ) for each type of intake (grain, stover and forage), for each livestock specie. This input is specific to the gridcell considered

◈ Demand in protein as well as N excretion rate for each specie are also inputs to the model

Output variables

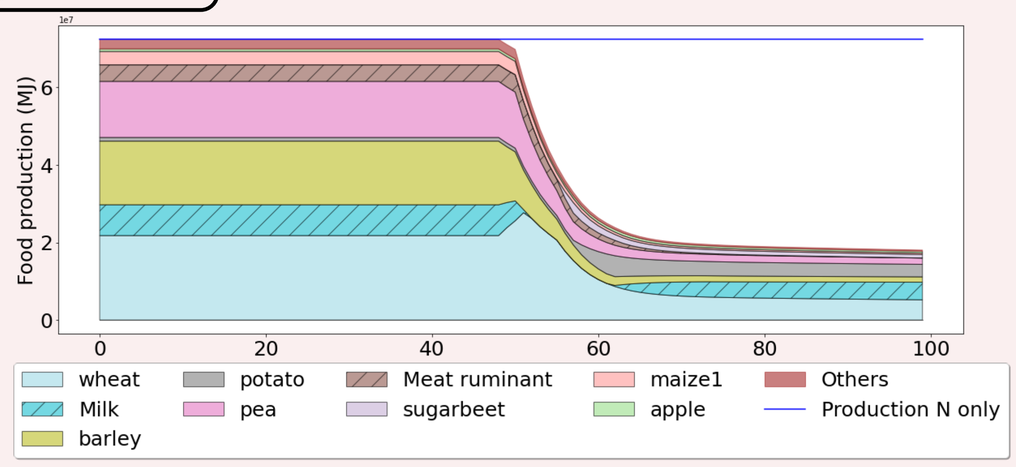

Figure 7- Temporal evolution of food production per crop and livestock products in the gridcell considered. Data are expressed in MJ and plotted over 100 years.

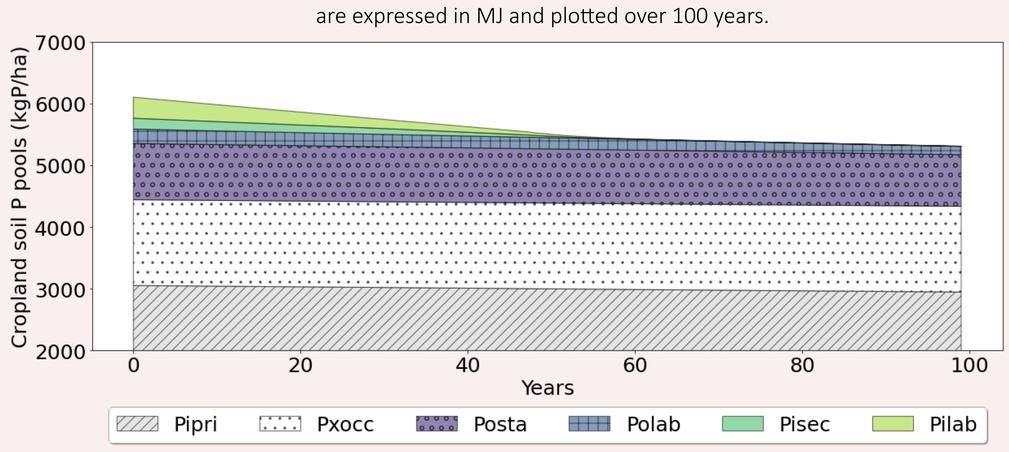

Figure 8- Temporal evolution of cropland soil P pools on the gridcell considered, over a 100-year time period. "i", "o", "lab" and "sta" refer to inorganic, organic, labile and stable, respectively. Pipri and Pxocc refer to an apatite and an occluded P pool, respectively.

Perspective: Global analyses in progress...

NB: Figures 7-8 show preliminary results related to one specific gridcell and should thus not be used to draw general conclusions

References: (1) Nowak et al. (2013); (2) Barbieri et al. (2021); (3) Muller et al. (2017); (4) Ringeval et al., GPASOIL-v1.1, a global dataset on phosphorus in agricultural soils, under review for Scientific Data