How can long-term experimental plots can help us to understand the sustainability of different phosphorus inputs ?

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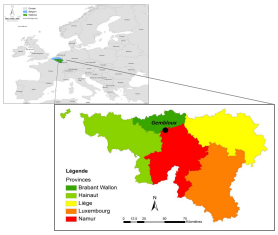
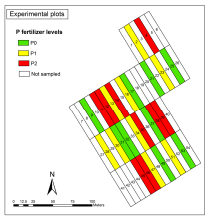
Introduction

Being an essential element for plant growth, phosphorus (P) generates eutrophication issue in surface waters and groundwater. In recent years, farmers have seen fertilizer prices increasing sharply and this was followed by a decrease in consumption of fertilizers. More and more farmers choose to overlook P fertilization. Is this sustainable for the soils and for the farmer in the long-term ? Do organic fertilizers have a similar effect than mineral fertilizers?
To answer to all these questions, different studies are made but often at short-term and long-term data are rarely available. However, these data are essential to have a long-term vision.



Experimental plots

Two experimental plots of the Walloon Agricultural Research Center were sampled. Established since, respectively, 1967 and 1959 in a loamy soil representing 30% of the Walloon surface area of Belgium, these experimental plots evaluate the effect of 3 P and K input levels and different organic inputs on the production.
Soils samples were taken in plots and analyzed in laboratory. So, different P indicators (degree of P saturation, total P, inorganic P, available P and water-soluble P) and edaphic parameters (TOC, pH, …) were determined.



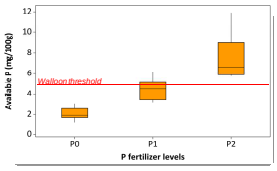
P0, P1 and P2 are: no P fertilizer, P inputs corresponding to P export by crop and to the double of P export, respectively.

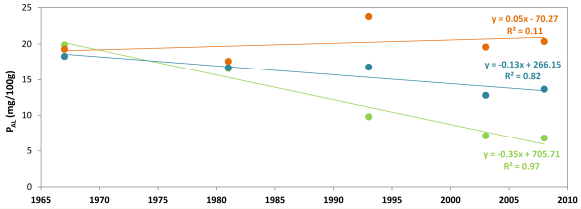
Aims and results

Below, you can find some example of questions that were studied with long-term experimentation.

Consequences of zero P-input on soil P content ?

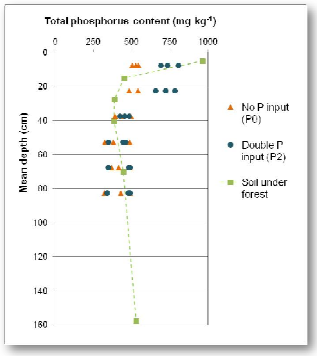
The study of evolution of P content is possible with long-term experimental plots. The acetate-lactate P (P_{AL}) content of the soil, high at the beginning of the experiment, decreased even when the inputs correspond to compensation of P removed by the previous crop. No sharp decline of P content has been observed. Moreover, this long-term experiment showed that no difference of yield was observed during about 20 years.
So, overlooking P fertilizer is possible in the short-term but P content has to be followed at long-term (current situation on the graph to the right).





Is there leaching in loamy soils ?

In loamy soils, leaching can be expected when P inputs are important. So, P movement and distribution though the soil profile were studied.

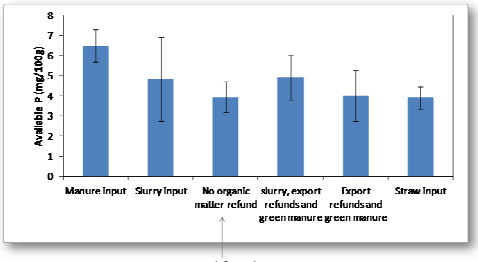


However, even in case of double P input, no evidence of accumulation of P could be observed beyond the plough layer. Moreover, a comparison with a similar soil under forest showed that the levels of total P in depth were similar.

⇒The risks of leaching appear negligible in these soils.

Differences between mineral and organic fertilizers ?

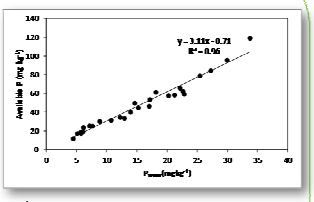
Similar P content were brought into the soil under different organic forms since 1959. Difference of available P content can only be observed for manure.



Mineral fertilizers

Which indicator is pertinent ?

Many analytical methods exist and were studied in this experiment.
All indicators permitted to differentiate clearly P fertilizer levels and are correlated with yields. Moreover, all indicators are also well correlated to each other and it is difficult to chose a better indicator. Other criteria should be taken into account.



Relationships with yields

P indicators	*R^2 (linear regression)*	*R^2 (logarithmic or second degree regression)*
Total P	0.48	0.53
Mineral P	0.43	0.50
Organic P	0.02	0.06
Available P	0.44	0.54
P extracted by water (P_{water})	0.48	0.57
P extracted by oxalate (P_{ox})	0.52	0.56
Degree of P saturation (DPS)	0.51	0.53

Financial interest of fertilization ?

Meanly, zero P-input engenders a decrease of yield of 7%, while a double input increases yield of 2% in comparison to plots with an input corresponding to crop export. Financially (taking into account the profit explained by yield differences but also price of fertilizers), the zero P input option does not seem profitable in the long-term, except for years with both low prices for crops and low difference between yields.
Similarly, double input of P removed by the previous crop is never financially sustainable.

	P0	P1	P2
Mean relative yields	93%	100%	102%

To conclude, long-term experimental plots permit to answer to different agronomical but also environmental questions. Moreover, these plots help to study the sustainability of cropping systems in real situations and to determine appropriate management of P.

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