Crop-soil organic phosphorus cycling
A key knowledge gap for sustainable food and water resources

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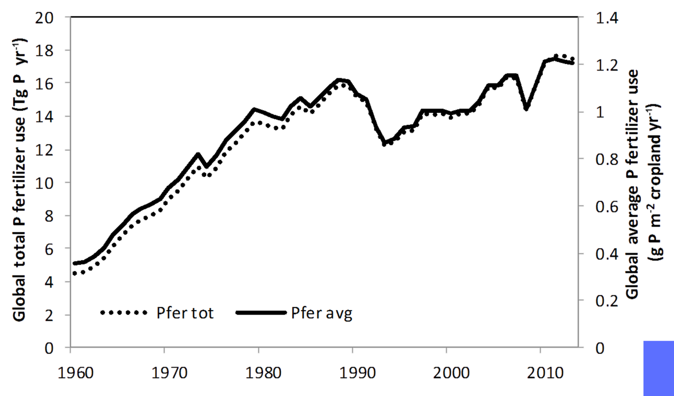
Phosphorus, soils and food production

Phosphorus is essential for agricultural production, global average P fertilizer use is around 1.2 g P m^{-2} yr^{-1}[1]. Yet the vast majority of this P is not taken up by plants, and excess application poses issues to water quality. Organic P represents a significant portion of global P stocks; 33% representing up to 117 years of P for agricultural production[2].

Here we present findings from a plant-soil model of integrated C-N-P cycling, applied across natural and agricultural systems. Our results indicate a gap in current understanding of P cycling in agriculture, and the potential role of organic P sources in these environments.

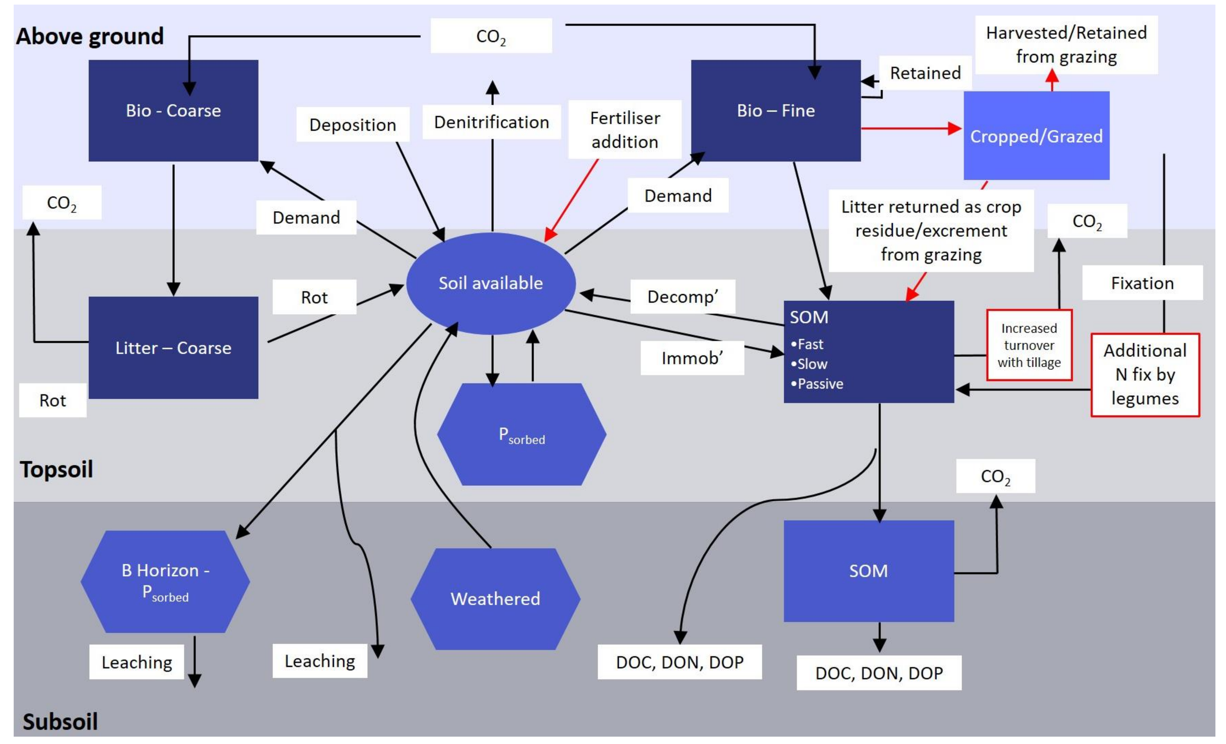


Modelling soil P

N14CP model

We used the N14CP-Agri model[3]. This model*:

- Requires no site-specific calibration
- Uses readily available input data
- Operates over long timescales
- Simulates land use change.



The model was applied across natural sites[4], and agricultural experimental sites. Using observational data (topsoil C, N, C:N) the results demonstrate the ability of the model to capture magnitudes and variation of key variables in both natural and agricultural land uses, and across a range of management practices.

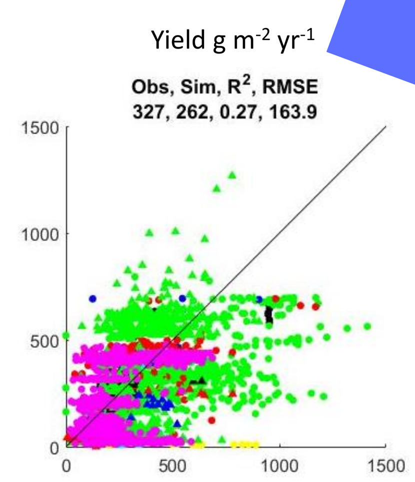
Applying the model: Issue with P limited plots

Missing phosphorus

The model works well when applied to natural (n=88) and the majority of agricultural land uses (n=52 includes control plots, N&P addition, and P only addition).

In agricultural settings with N fertilizer only (n=10) yields were underestimated by 77%.

Net Primary Productivity (NPP) is simulated assuming Liebig's law of minimum (controlled by the most limiting of temperature, precipitation, N or P availability). Prior to fertilizer addition all plots were N limited. N fertilizer increases NPP and P demand. Simulated available P declines and is then cleaved from organic pools until a maximum C:P ratio is reached, at which point P severely limits NPP and crop yields. However, observed yields do not show such a decline.

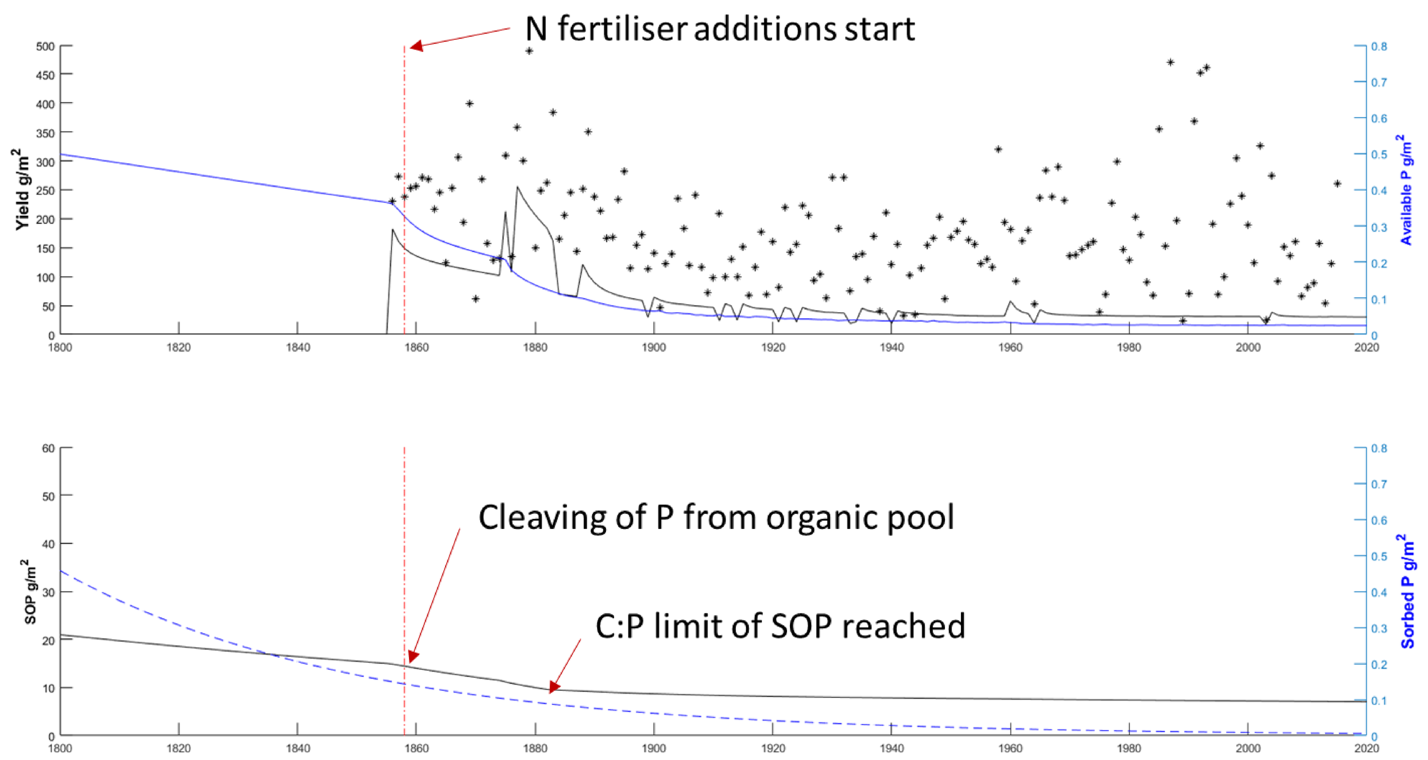


Observed vs. simulated yields across all 62 plots

Potential sources of the missing P explored but unable to explain this deficit:

- Atmospheric deposition – up to 0.027 g m^{-2} yr^{-1} [5 – Global ave' value]
- Weathering – up to 0.085 g m^{-2} yr^{-1} [6]
- Flexible plant stoichiometries.

Extra P required to simulate observed yields for these plots ranged from 0.15-2.5 g m^{-2} yr^{-1} which is a similar magnitude to fertilizer application rates.

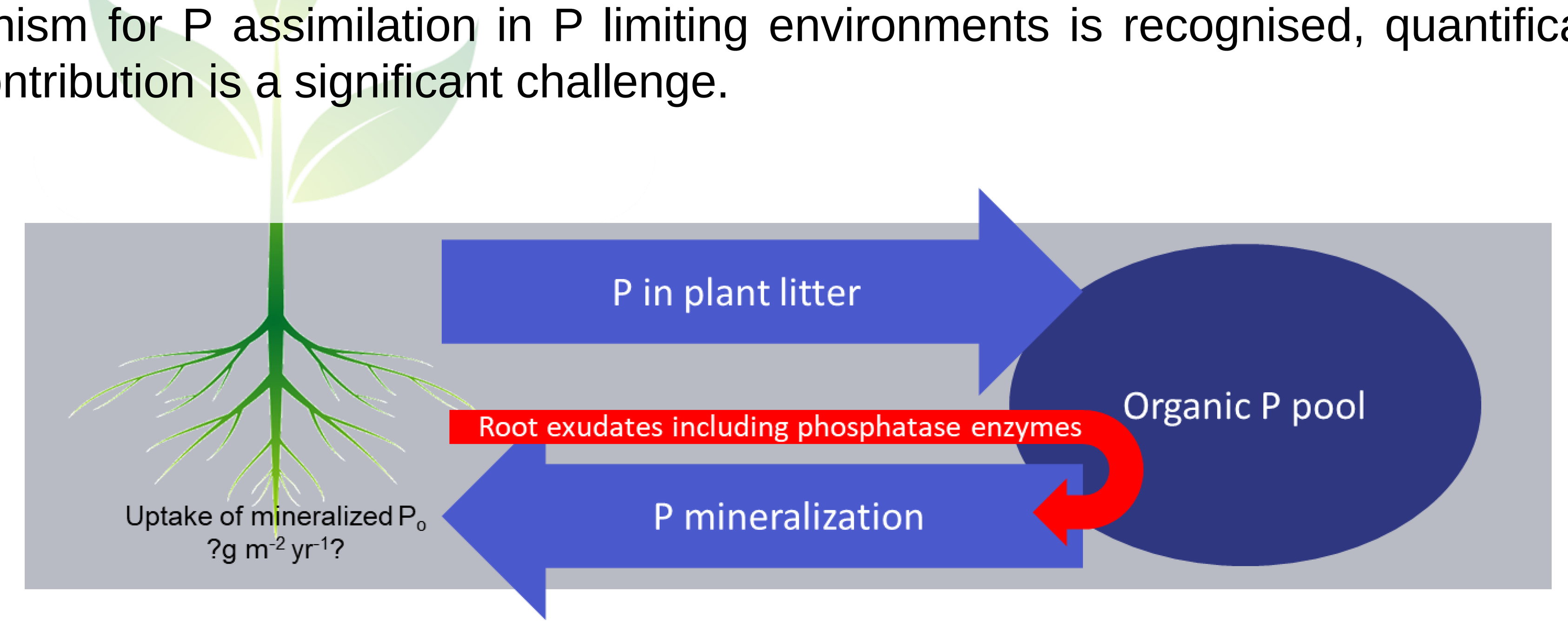


P limited grassland plot where topsoil P pools become exhausted after fertiliser addition.

Knowledge gap: Organic P

Organic Phosphorus – a resource?

It's clear the model, and our current understanding of P cycling in agricultural environments is omitting a significant process and/or source of P. Our representation of plant access to organic P is basic. Whilst the importance of phosphatase enzymes as a mechanism for P assimilation in P limiting environments is recognised, quantification of their contribution is a significant challenge.



Our research therefore highlights a key gap in our understanding of organic P cycling in soils, and the sustainability of agricultural systems given the finite nature of rock sources of P fertilizer.

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* For more info. come see our poster this afternoon B13E-2535

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References
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