

Integrated carbon-nitrogen-phosphorus cycling for sustainable agriculture – a knowledge gap and investigation of the role of phosphatase enzymes

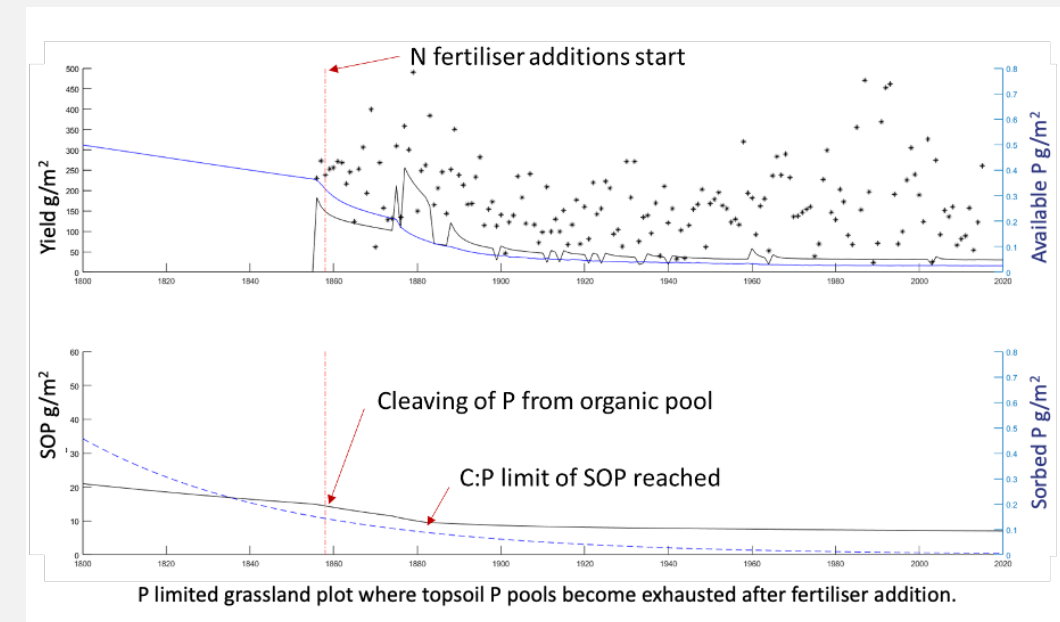
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Using a C-N-P model (N14CP) we found a gap in representation of P cycling processes.

- We applied the N14CP model to several temperate agricultural sites. Across control plots (no fertiliser), those with both N&P addition, and with P addition (n=52) simulated yields were under-estimated by 15%, whereas **at plots receiving only N fertiliser (n=10) yields were underestimated by 77%**.
- The model simulates Net Primary Productivity assuming Liebig's law of minimum; NPP is controlled by most limiting factor of temperature, precipitation, N or P availability. Prior to fertiliser addition all plots were limited by N availability. When N fertiliser is applied NPP and P demand increase, and available P declines. P is then cleaved from organic pools until a maximum C:P ratio is reached, at which point P severely limits simulated NPP and crop yields. However, observed yields do not show such a decline.
- Potential sources of missing the missing P explored but unable to explain the deficit, including atmospheric deposition, weathering and 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.

Could this be due to phosphatase enzymes?



More on the model and P process gap in Janes-Bassett et al, 2020

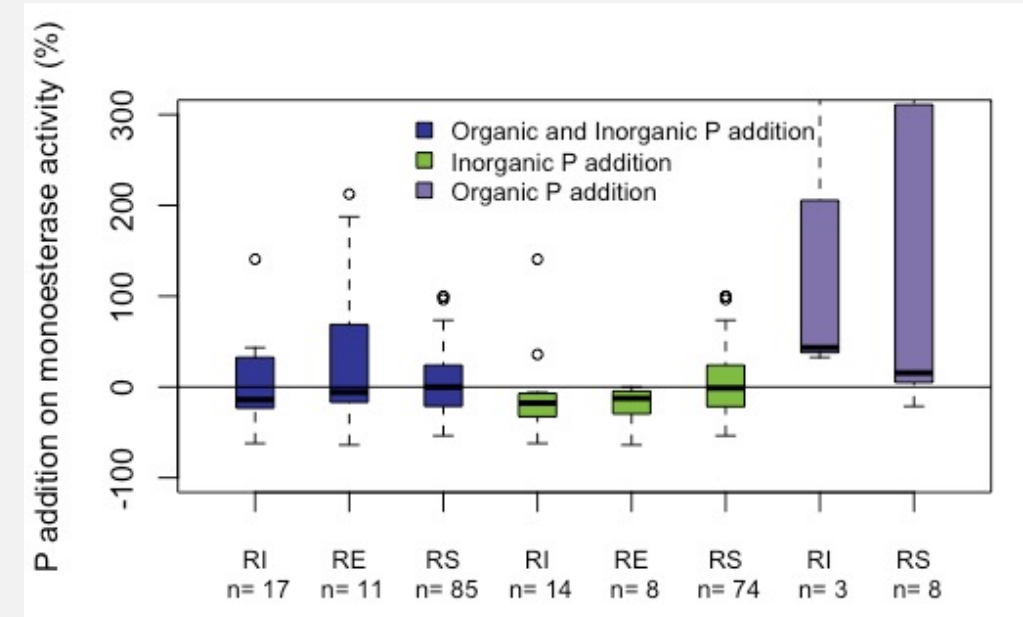
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- We conducted a meta-analysis on relevant literature comparing phosphatase (monoesterase) activity in P sufficient and deficient conditions.
 - 113 paired observations from 24 papers.
- Monoesterase activity in P addition and control experiments are not significantly different across root intact/extract/soil rhizosphere data BUT mixed effects models suggest organic/inorganic addition explains significant variance in the data (up to 46%).
 - Mixed-effects models indicate organic addition increases monoesterase activity by 118% for root intact data ($p < 0.01$) or 66% for soil rhizosphere data ($p < 0.01$).
 - Monoesterase activity decreases per unit increase in inorganic P addition up to -0.8% (soil rhizosphere data $p < 0.0001$).
- ***Is the availability of organic P more important determining monoesterase activity than P deficiency?***



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How much does this contribute to plant derived P – difficult to say...

- **We need more data:** Only 24 papers, partly as we only included studies reporting SE/SD.
- We looked at correlations between response and variables such as root to shoot ratio, biomass, P content of plant (in root and shoot) but this isn't always recorded, complicating analyses.
 - As mixed effects models require a complete case basis, any data not including these variables is excluded, further reducing sample size.
- **Phosphatase enzymes are just one mechanism of many that could explain the 'missing P' we observe.**
 - Role of organic acids – also often not reported with phosphatase enzyme activity and other variables mentioned above.

