Phosphorus balances after 145 years of contrasting crop rotation and fertility management practices: insights from the Morrow Plots

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Introduction

- The widespread use of phosphorus (P) fertilizers has driven a global reallocation of geologic P reserves, a significant portion of which now resides in agricultural soils as legacy P
- Large legacy P stores create agronomic inefficiencies in fertilizer use and pose a threat to the health of waterways when excess P is lost through runoff and erosion
- Quantifying historical P flows at the field scale can shed light on the impact that historically popular management styles have had on soil P stocks, while informing the way that nutrient accounting systems are applied

Objectives

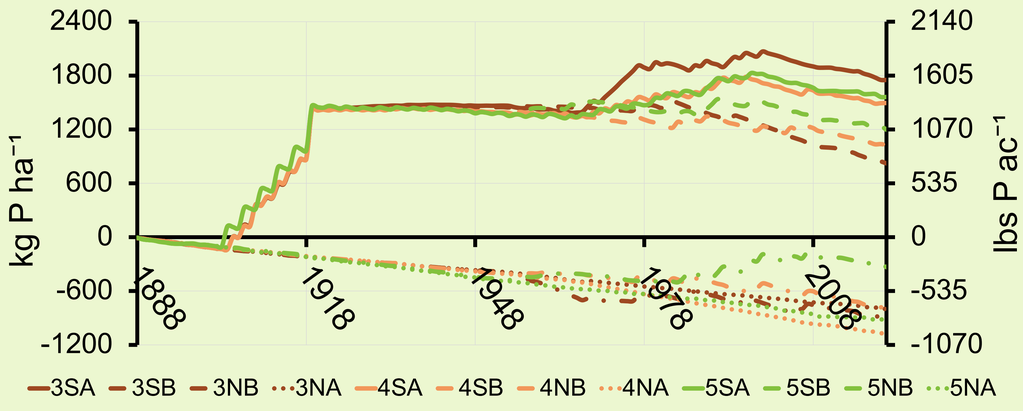
- Assess the degree to which a mass balance approach reflects soil P stocks over 145 years
- Determine the reliability of Mehlich 3 (M3) P and M3-based saturation ratio to estimate the magnitude of legacy P accrual

Methodology

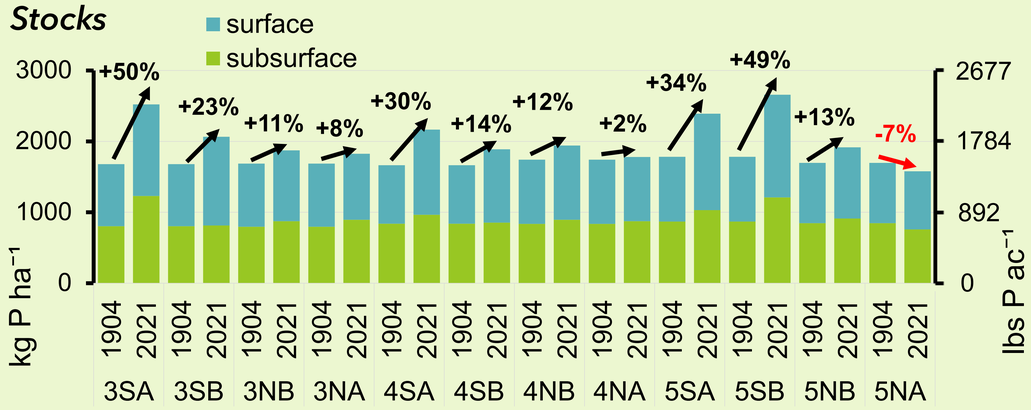
- 145-year agronomic balances (1888-2021) were calculated for a subset of 12 plots, representing a range of fertilization intensities and three crop rotations
- Soil P stocks were empirically quantified by testing archived soils for total P content (1904-2021)

Results

Agronomic Balances

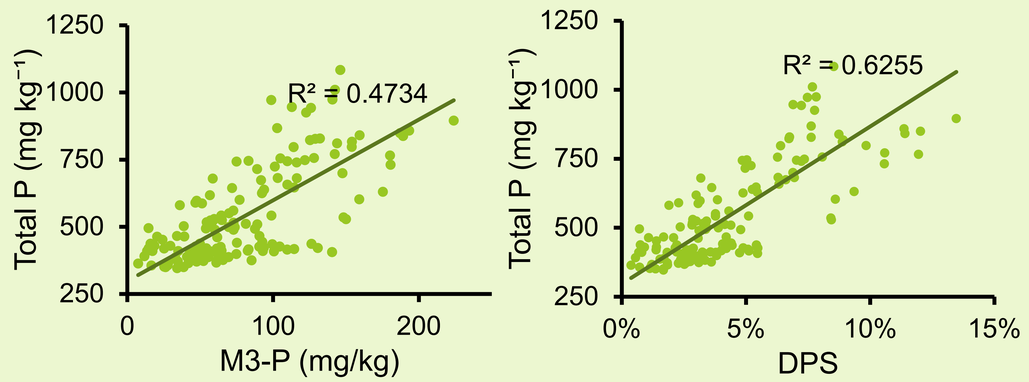


Stocks



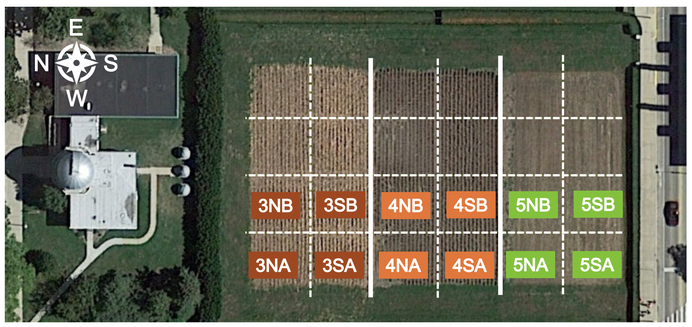
Soil test P and DPS

Degree of P saturation (DPS)=P_{M3}/Al_{M3}



Results

- Balances were overwhelmingly positive for high and medium input plots, and negative for low input and control plots
- Positive balances largely driven by rock phosphate application (1904-1919), which accounted for 42.3-54.0% of P inputs
- P stocks increased for all plots except for the unfertilized plot under diverse crop rotation
- STP was moderately correlated with total P (R^2 = 0.473), while M3-based saturation index showed a stronger relationship with P stocks (R^2 = 0.626)



Conclusions

- Agronomic balances are most accurate in predicting stock changes when the magnitude of inputs/removals is small; discrepancies grow as flows increase
  - Magnitude of change was consistently overestimated by balances
- M3-based saturation index (DPS=P_{M3}/Al_{M3}) may offer more accurate estimation of P stocks than M3-P alone