Multiple Benefits

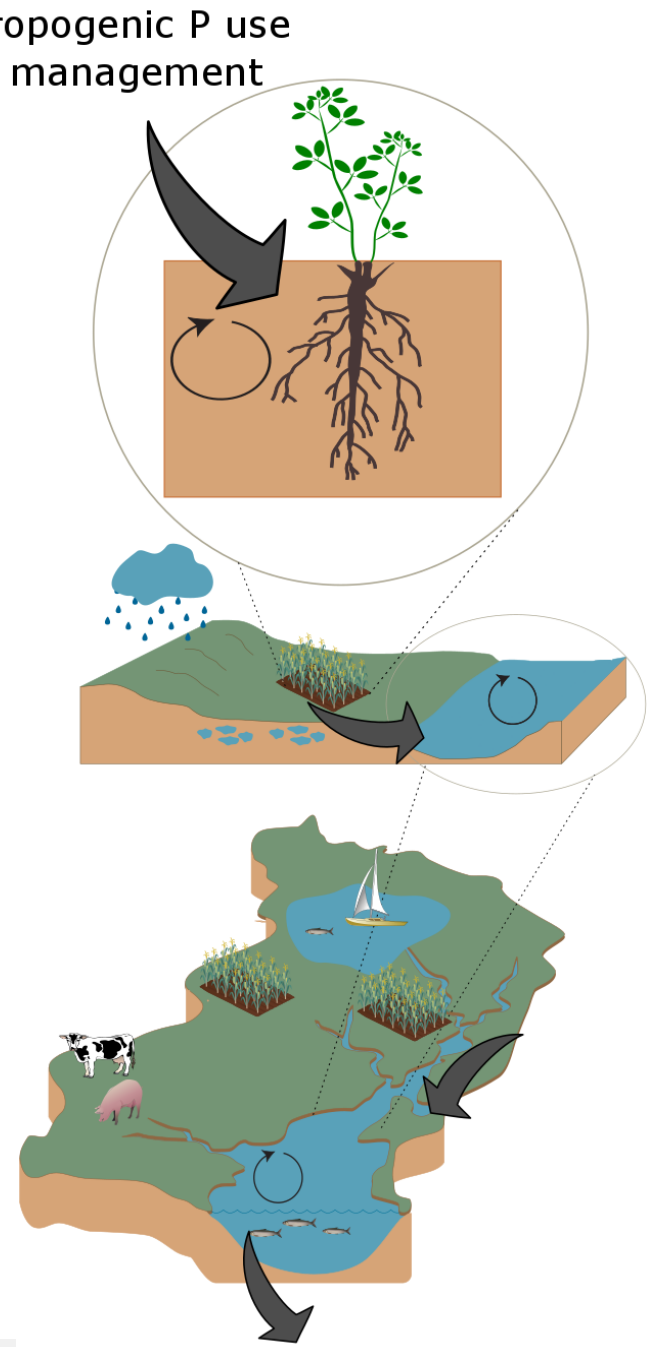
Sustainable Phosphorus Alliance

Michael Weintraub, Graham MacDonald, Laura Johnson, Phillip Haygarth, Tom Bruulsema, Tiequan Zhang, Jianbo Shen, Paul Withers, Douglas Smith, Andrew Sharpley, Katrina Macintosh, Donnacha Doody, Helen Jarvie, Lydie-Stella Koutika, Susanne Kraemer, Michael Miyittah, Richard McDowell, Stephen Powers

@sustainP

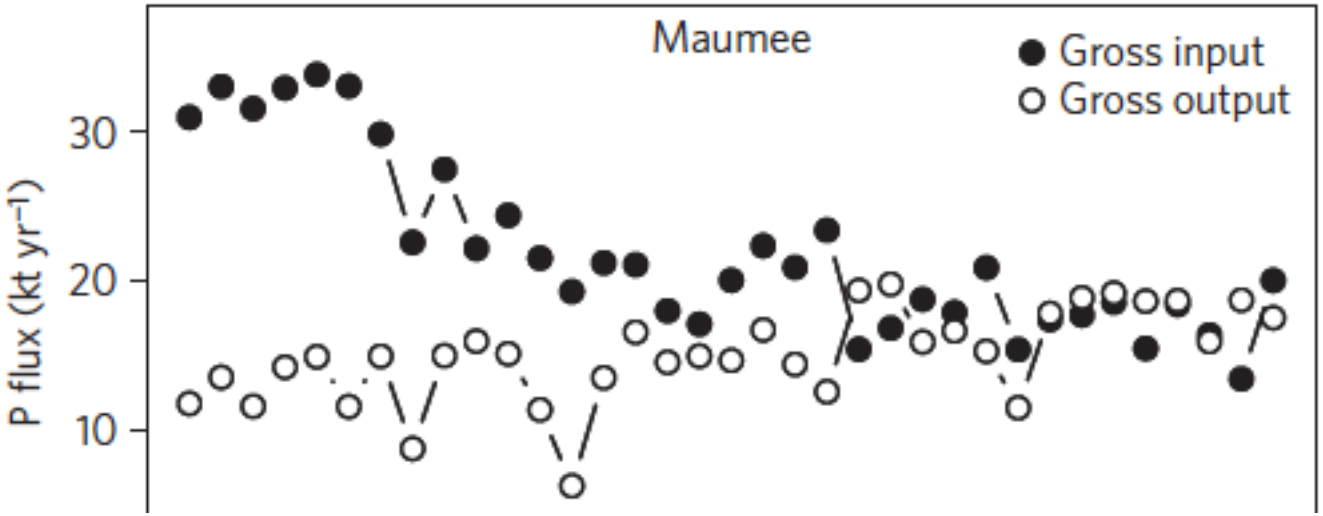
P can runoff in stormwater and cascade downstream

Once downstream, P can have unintended impacts on the “goods and services” we receive from the natural environment – Ecosystem Services



Adapted from MacDonald et al 2017

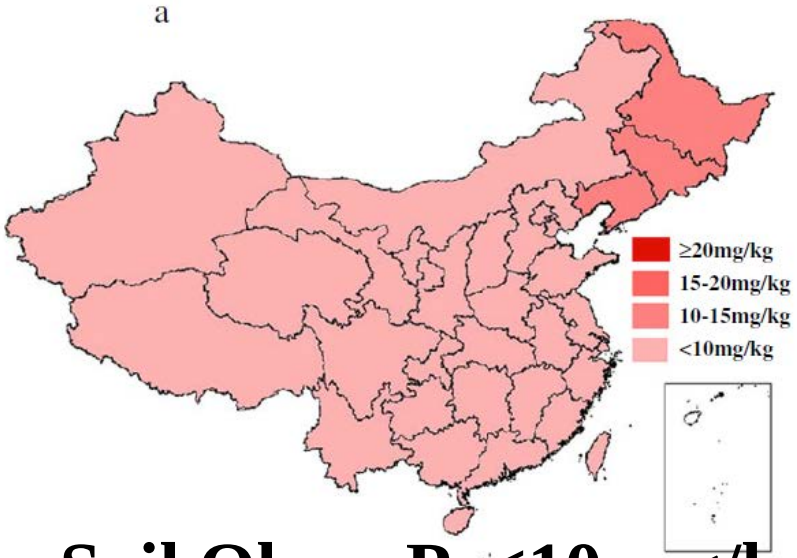
Inputs and Outputs of Excess P are often Disconnected



We do not see decreased outputs in response to decreased inputs yet

Powers, S. M. et al. (2016). Long-term accumulation and transport of anthropogenic phosphorus in three river basins. *Nature Geosciences* DOI: 10.1038/NGEO2693

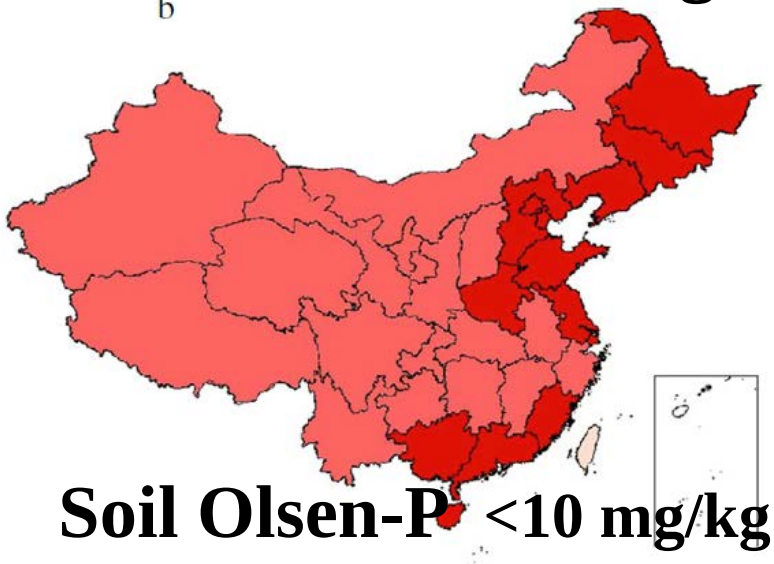
Increased soil available P in China



Average soil available Olsen-P, 1980

7.4mg/kg

Soil Olsen-P <10 mg/kg accounting for 79.4%



Average soil available Olsen-P, 2006

20.7mg/kg

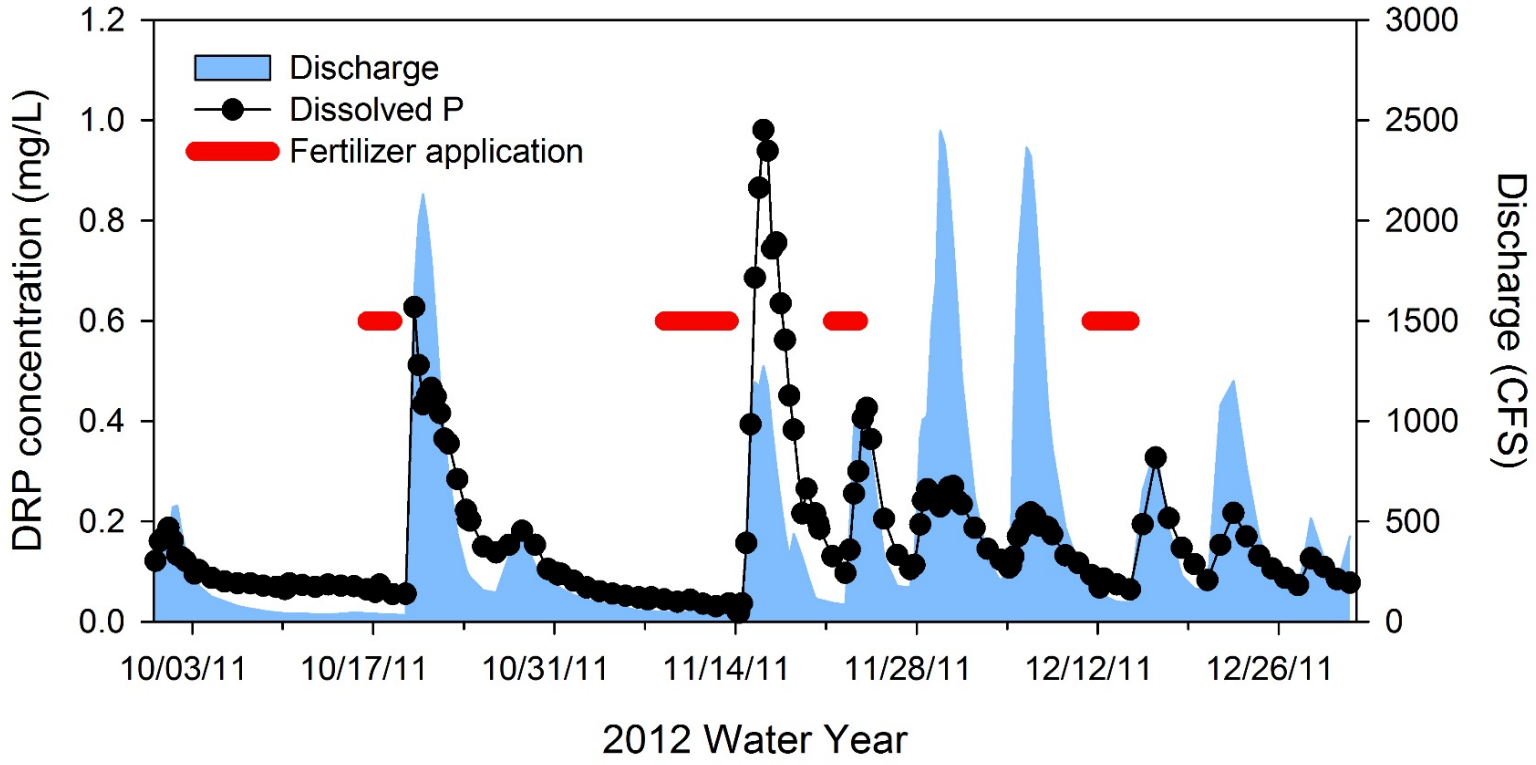
Soil Olsen-P <10 mg/kg accounts for 23.5%

(Li et al., 2011, Plant and Soil)

Not all P losses are from excess P applications (timing and placement)

Phosphorus loss associated with fertilizer application just prior to precipitation

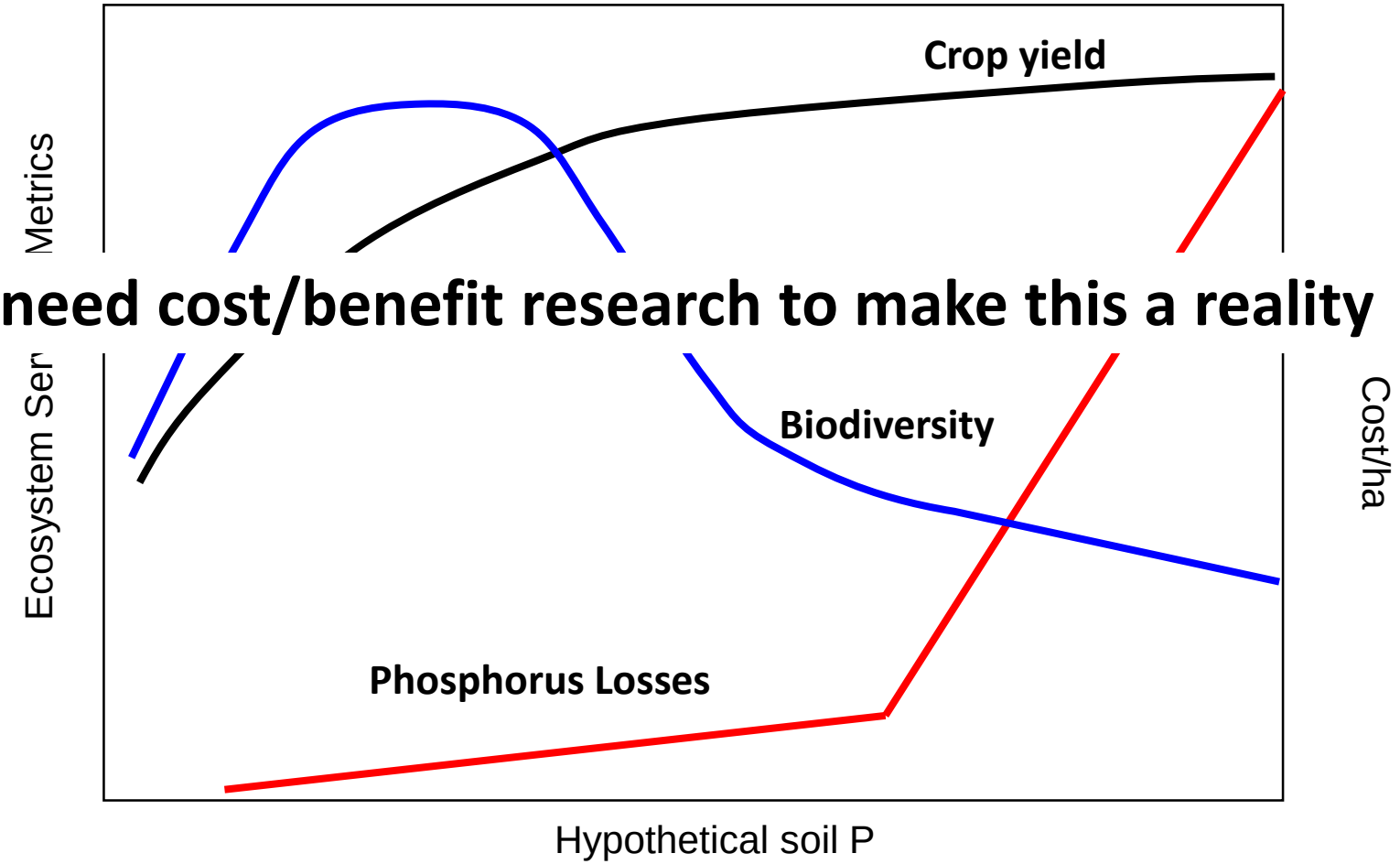
Honey Creek in Ohio



Managing for Crop Productivity is not Enough…

Sustainable Phosphorus Alliance

Can we manage agriculture to achieve benefits aside from just productivity?



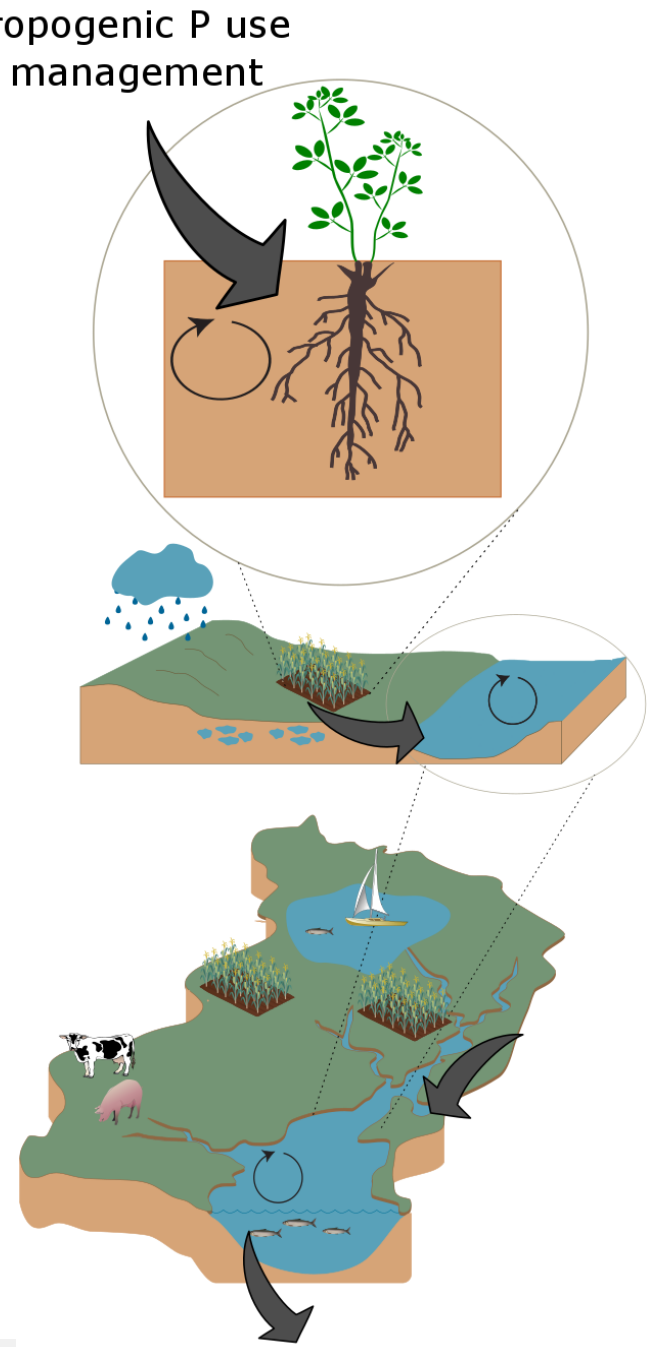
We need cost/benefit research to make this a reality

Ecosystem Services

Food-fiber-fuel
Nutrient cycling
C storage
Water retention
Landscape aesthetic

Impacts of P

Crop productivity
Biodiversity
Water quality
Fish
Recreation
Property value



Adapted from MacDonald et al 2017

Practices to Improve P Management

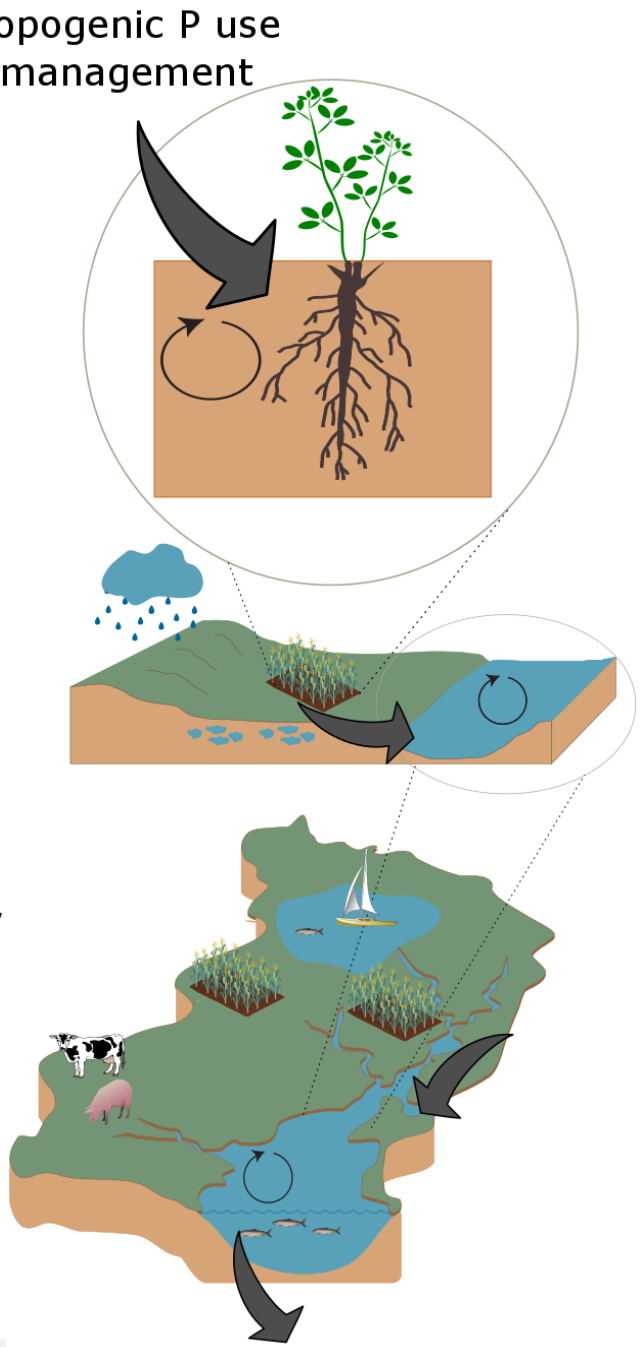
Reuse organic P waste

Draw down P in P saturated soils

Water management

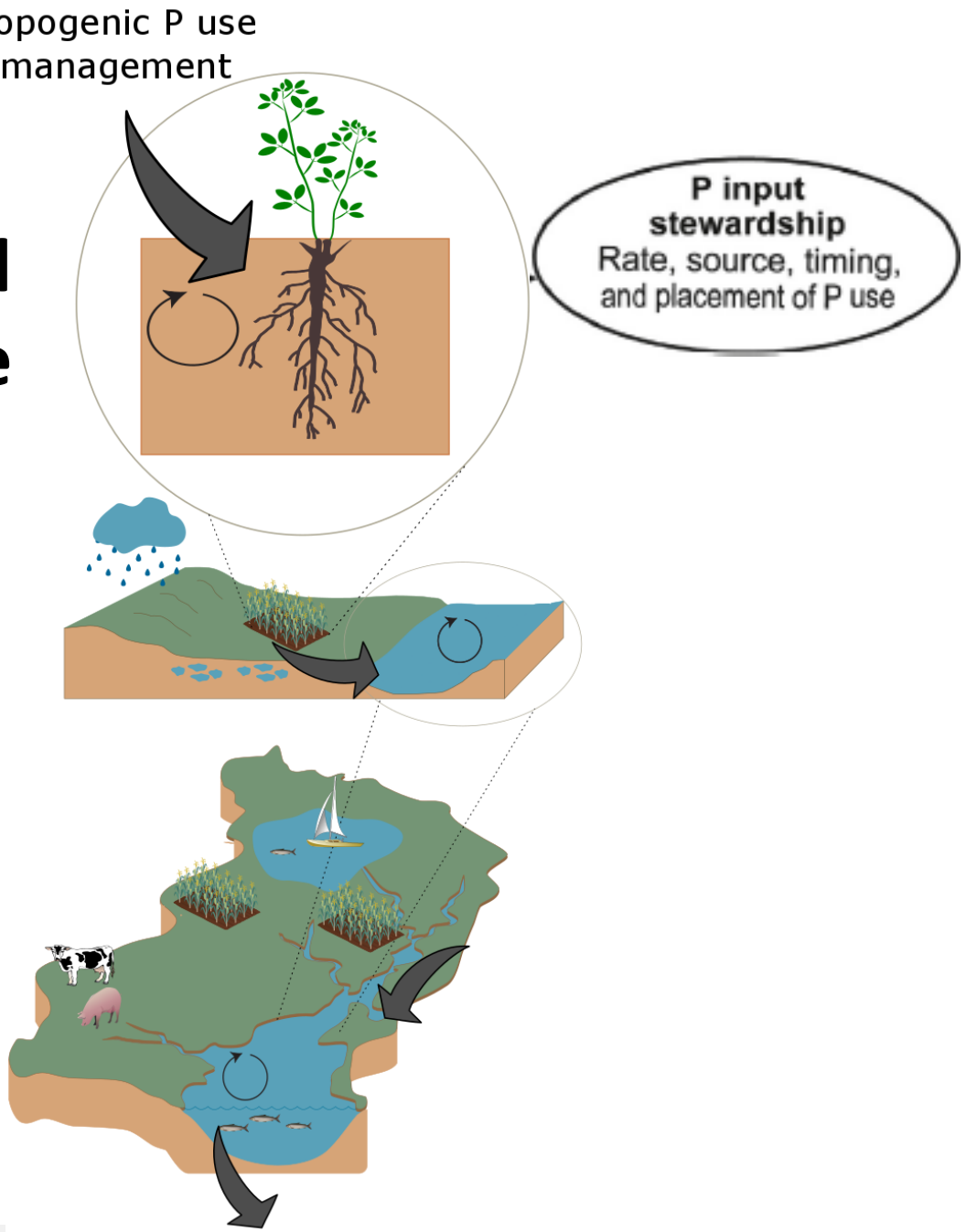
Soil erosion control

Improved fertilizer efficiency



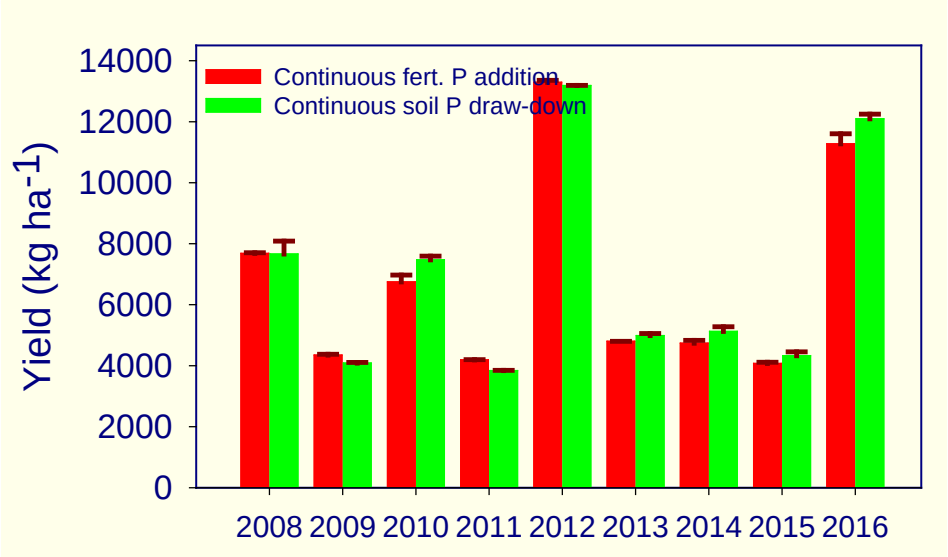
Adapted from MacDonald et al 2017

Changes at the Small Scale can Benefit the Entire System

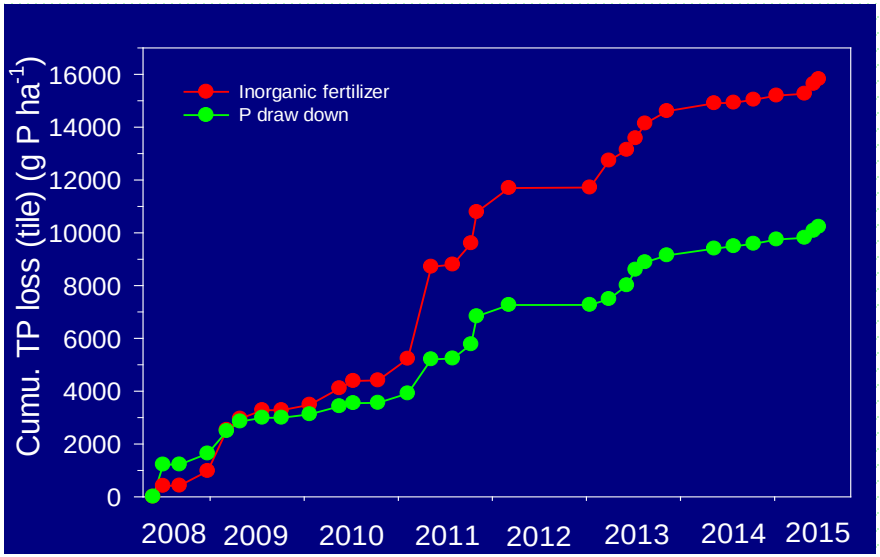


Adapted from MacDonald et al 2017

Example: Soil P Drawdown



- Soil P was sufficient to support crop P without added P for over 9 years



- Soil P loss (tile) with P draw-down decreased by 35%, relative to continuous P addition
- Tile drainage P loss accounts for ~85% of total soil P loss

But, There can be Tradeoffs…

What does a holistic approach to P management look like?

- We can implement all aspects of the 4R nutrient stewardship at the farm scale to maximize crop productivity and water quality
  - Right source: use recycled sources of P fertilizer such as struvite
  - Right rate: use soil tests that incorporate soil buffering capacity to ensure proper application of P
  - Right time: match applications to crop demand and low risk of runoff
  - Right place: apply fertilizer below the surface of the soil to prevent unintentional losses
- Each point of stewardship comes with a cost
- Major challenge→ what is the cost of maintaining water quality relative to benefit of high crop productivity?

Possible Changes to Manage for Multiple Benefits (US)

Component	Agronomic	Agronomic + water quality
Soil P test	Mehlich 3	Mehlich 3 + buffering capacity
Soil sampling	Single depth only	Stratified or gridded sampling
Interpretation	Agronomic optimum	Economic optimum
Fertilizer sources	Standard fertilizer	Use struvite
Fertilizer application	Single rate application	Variable rate application
Crop system	Current varieties/rotations	Designer varieties/rotations to improve soil P acquisition efficiency

Conclusions

- This is a complex issue
  - P sources and impacts are not connected in time and space
  - P loss occurs without excess P application
  - Managing P often gets more complicated and expensive the further you get from its source
  - But benefits of small scale solutions cascade to the large scale

- Agricultural management should involve more than one ecosystem service (productivity), but this is limited by a lack of knowledge about cost/benefits of specific ecosystem services

- A holistic approach to P management will provide multiple benefits on a wide scale throughout the economy

Questions?