Manure Injection versus Broadcasting: Effects on Phosphorus and Soil Loss

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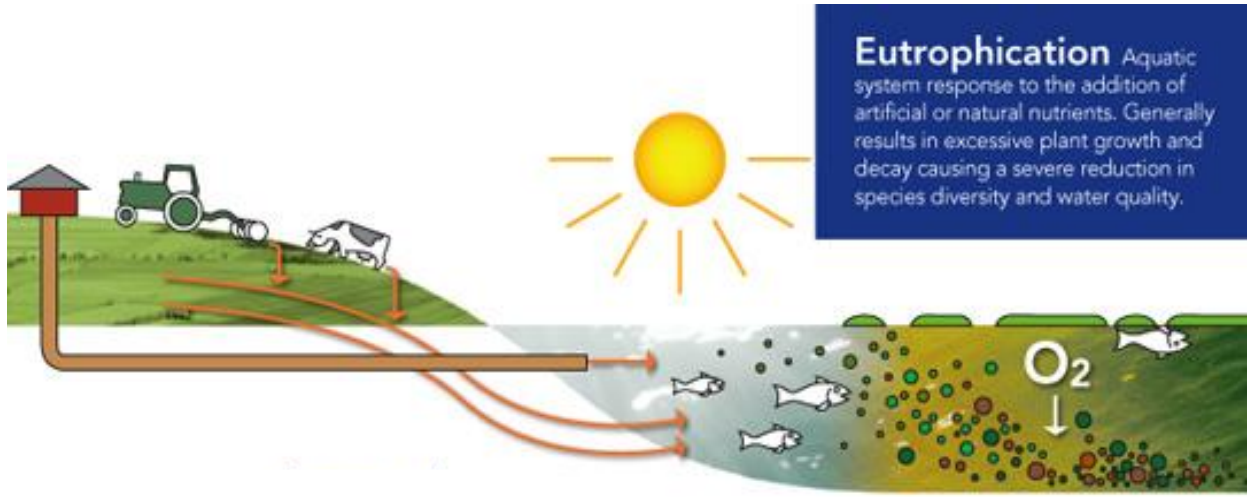
Eutrophication and sedimentation are pervasive issues in the Chesapeake Bay Watershed

https://sites.psu.edu/baxterpassion/2015/09/22/tiny-technology/



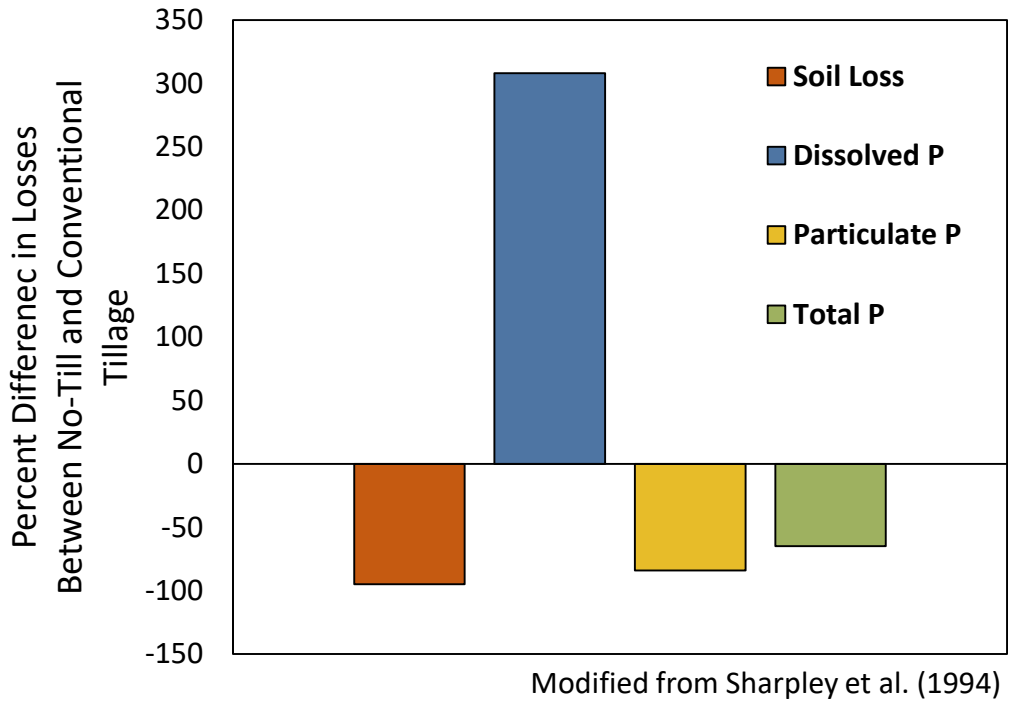
Modified from Ocion

To meet the TMDL goals set by EPA in 2010, Pennsylvania alone must reduce phosphorus and sediment losses by 0.7 and 531 million pounds per year, respectively.

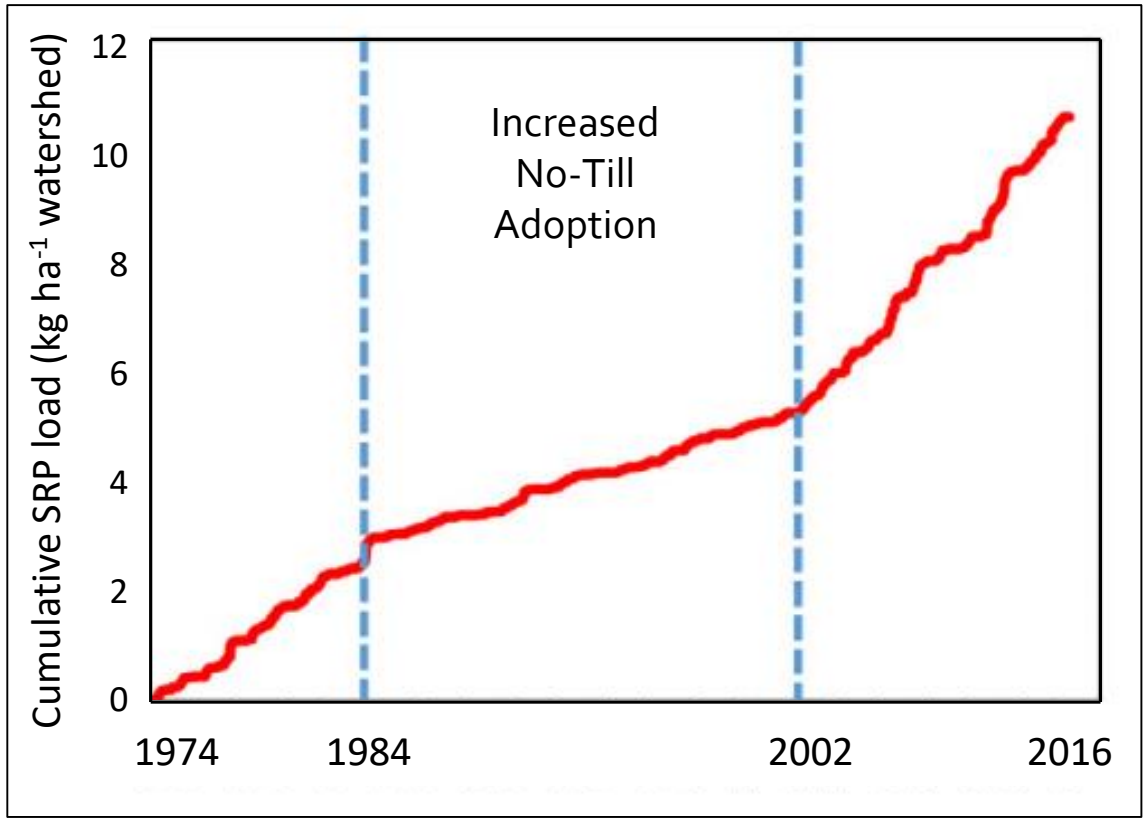
Clean water:
Great for PA
Good for the Bay

PA DEP, US EPA

Best management practices (BMPs), like no-till, that address one part of the problem can create new, long-term problems



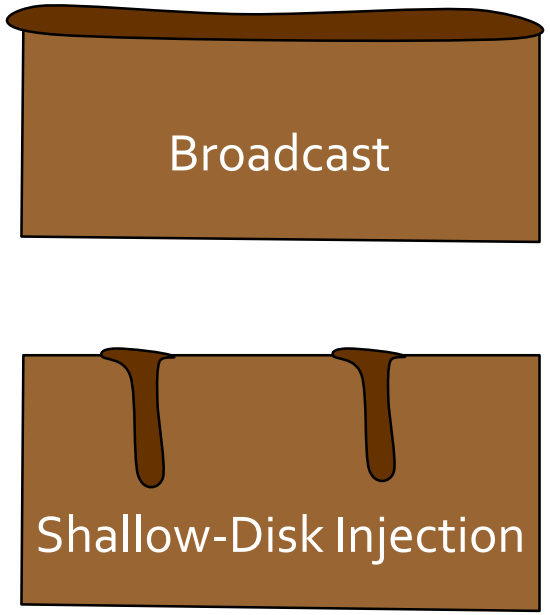
Modified from Sharpley et al. (1994)



Modified from Jarvie et al. (2017)

We need a solution that maintains the erosion-reducing benefits of no-till but reduces dissolved phosphorus losses

Dell et al. (2012)



Shallow-disk injection is a promising solution to reduce dissolved phosphorus losses without negating the benefits of no-till, but its effectiveness is still uncertain

Constituent	% Improvement: Injection versus Broadcast	References
Sediment/Erosion (TS)	0-14% (39% predicted)	Rotz et al. (2007); Maguire et al. (2011); Rotz et al. (2011)
Particulate Phosphorus (PP)	-1%	Rotz et al. (2007)
Dissolved Phosphorus (DP)	55 to 94%	Rotz et al. (2011); Maguire et al. (2011); Uusi-Kamppa and Heinonen-Tanski (2008)
Total Phosphorus (TP)	0 to 91%	Rotz et al. (2011); Uusi-Kamppa and Heinonen-Tanski (2008)

Objectives

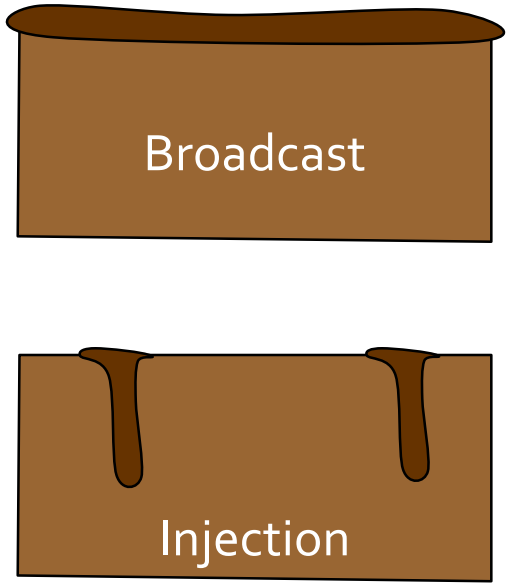
1. Describe the transport behavior of phosphorus (P) and total solids (TS) from plots receiving manure via surface broadcasting versus shallow-disk injection.

2. Determine the relative effectiveness of shallow-disk injection in reducing P losses in overland and subsurface flow, compared to broadcasting manure.

3. Determine how manure application practices, soil properties, landscape characteristics, and hydrologic characteristics interact to predict P losses.

Research was conducted on twelve experimental plots in central PA from January 2013 through May 2017

Aerial image source: Google Maps 2018



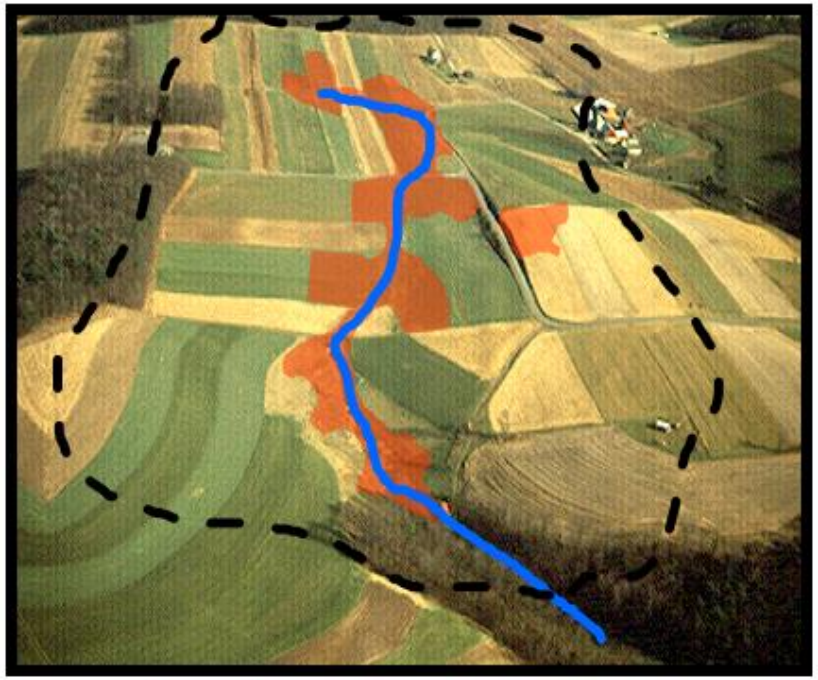
Overland and subsurface flow following natural rain events were measured and subsequently subsampled for total solids (TS) and phosphorus (P) concentrations

Objective 1:

Use L-Q relationships to describe the transport behavior of phosphorus (P) and total solids (TS) losses from plots receiving manure via surface broadcasting versus shallow-disk injection

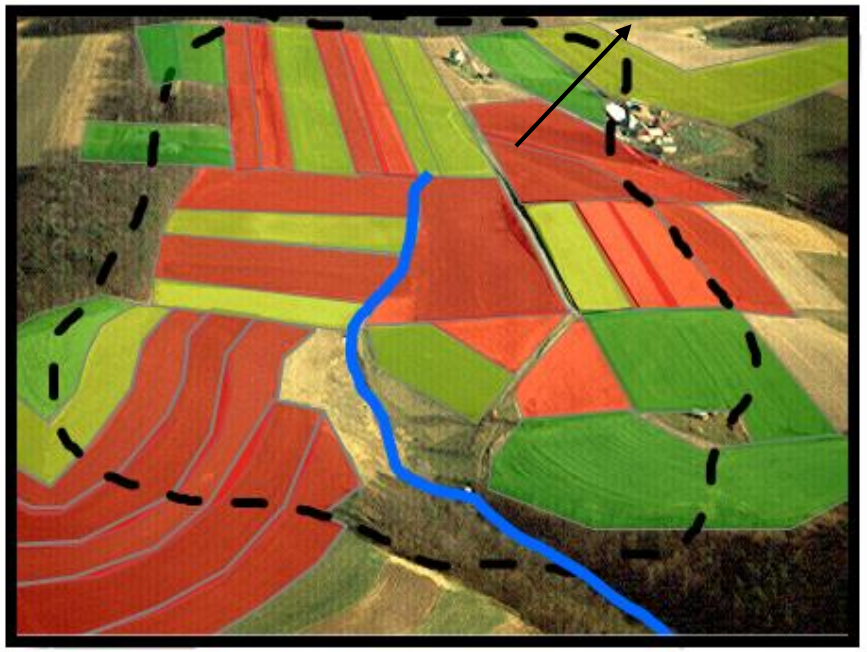
The Critical Source Area Concept, the basis for the PA P Index, describes where P exports are expected to be greatest in agricultural landscapes

P Loss

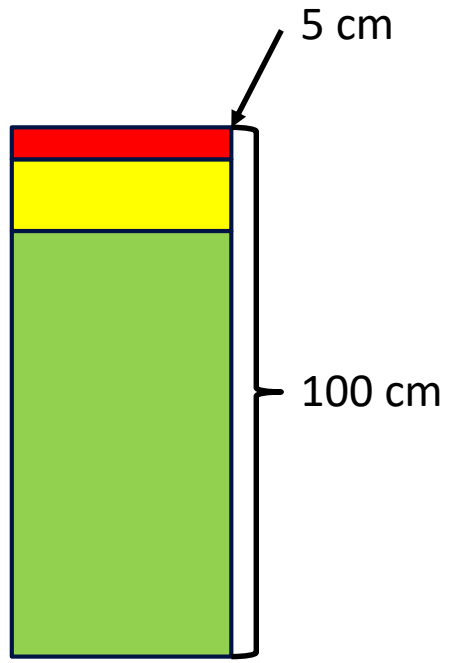


High P loss

P Soil Test

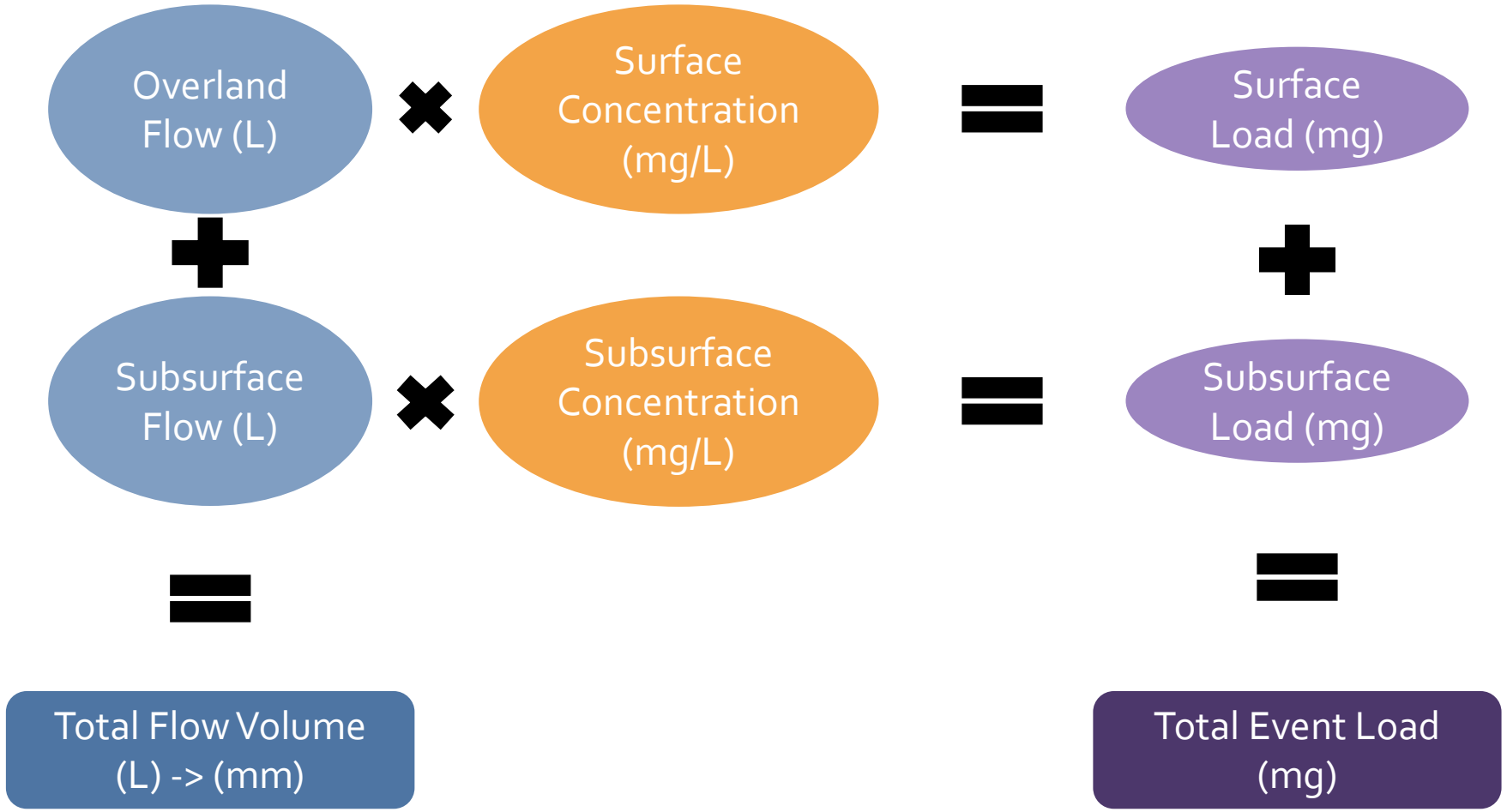


Low Med High

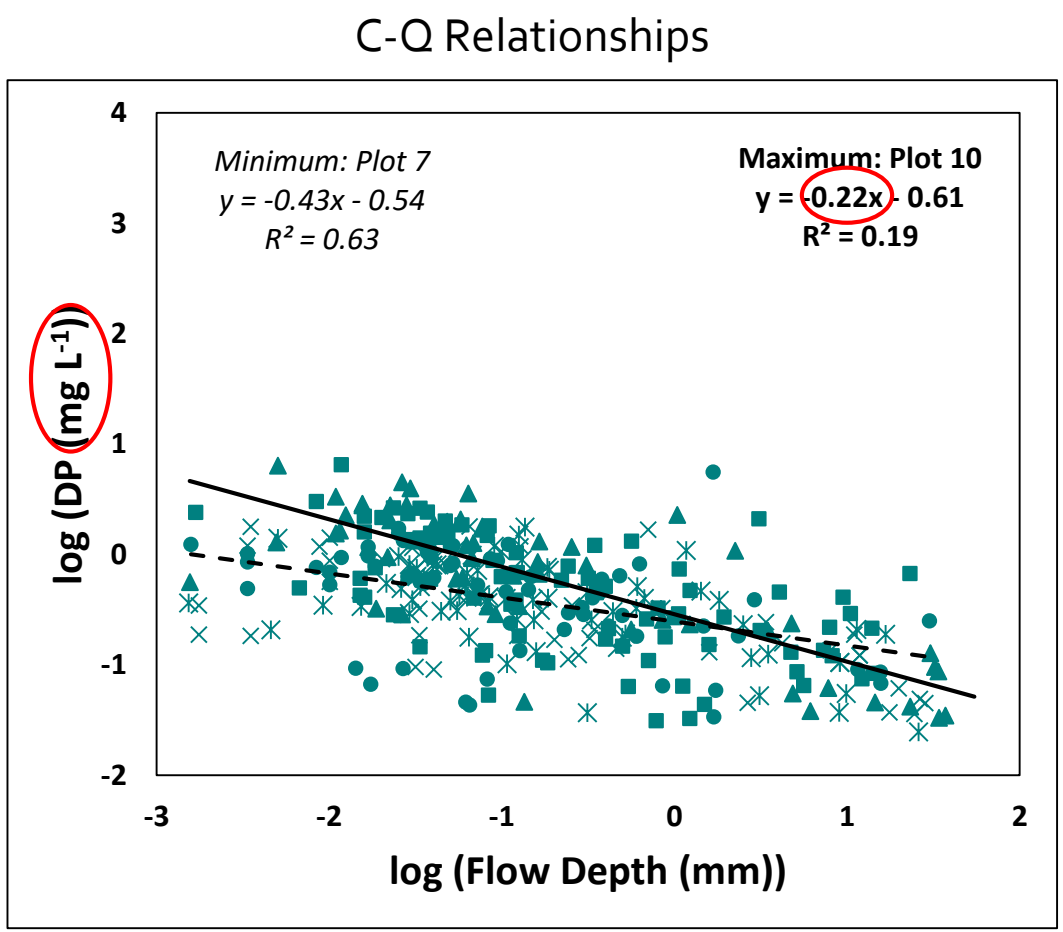


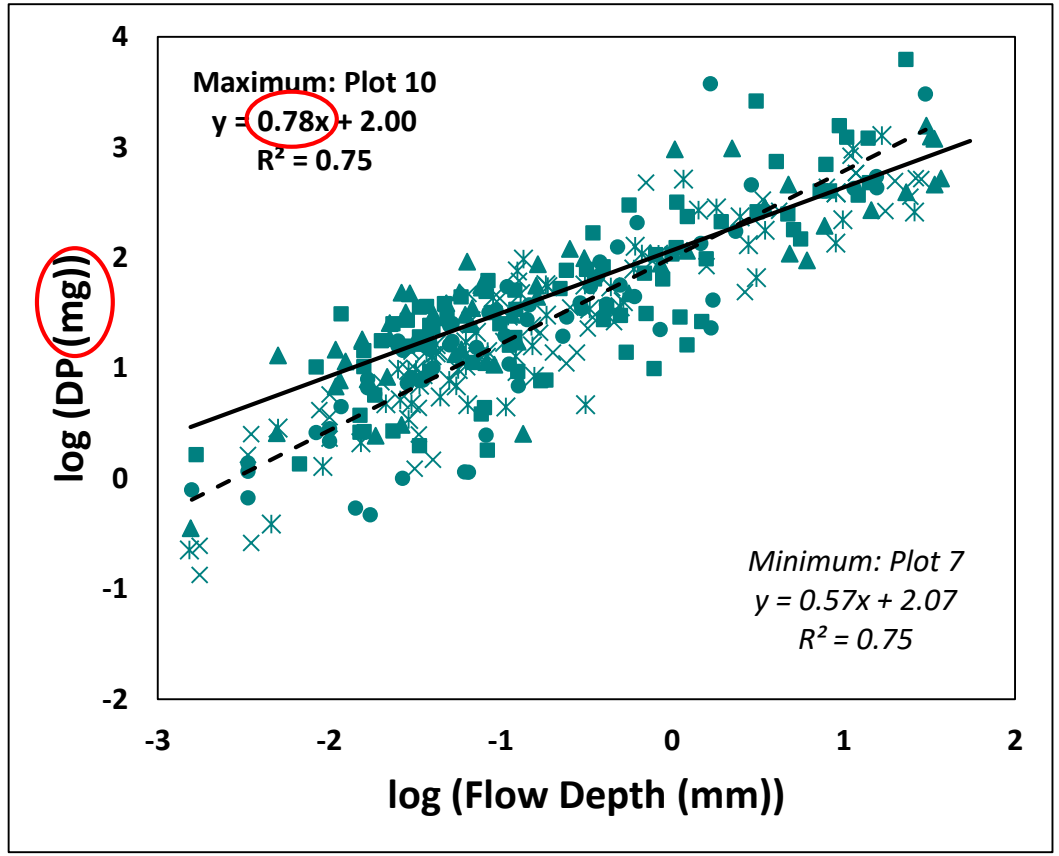
Beegle, modified from Sharpley, USDA-ARS

Loads for each constituent were calculated on an event-by-event basis as the product of concentration and flow volume for surface and subsurface flow



L-Q slopes >1 represent accretion, while slopes <1 represent dilution patterns



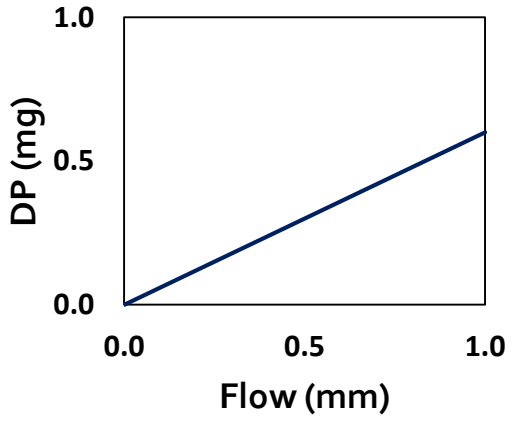


L-Q slopes are dependent on both source availability and transport potential

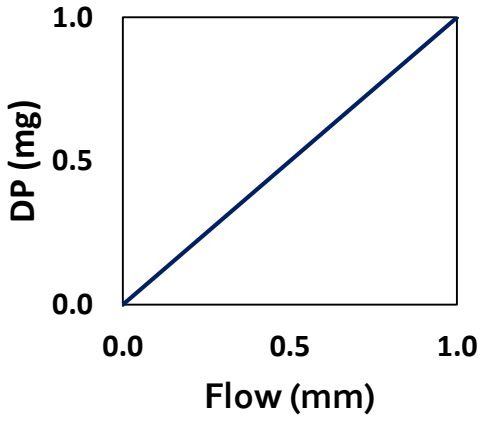
Slopes << 1: Dilution

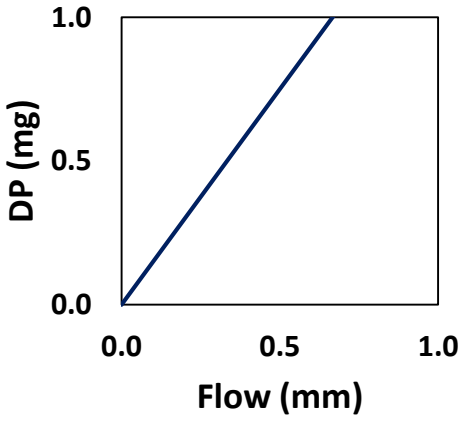
Slopes ~ 1: Chemostatic

Source-limited

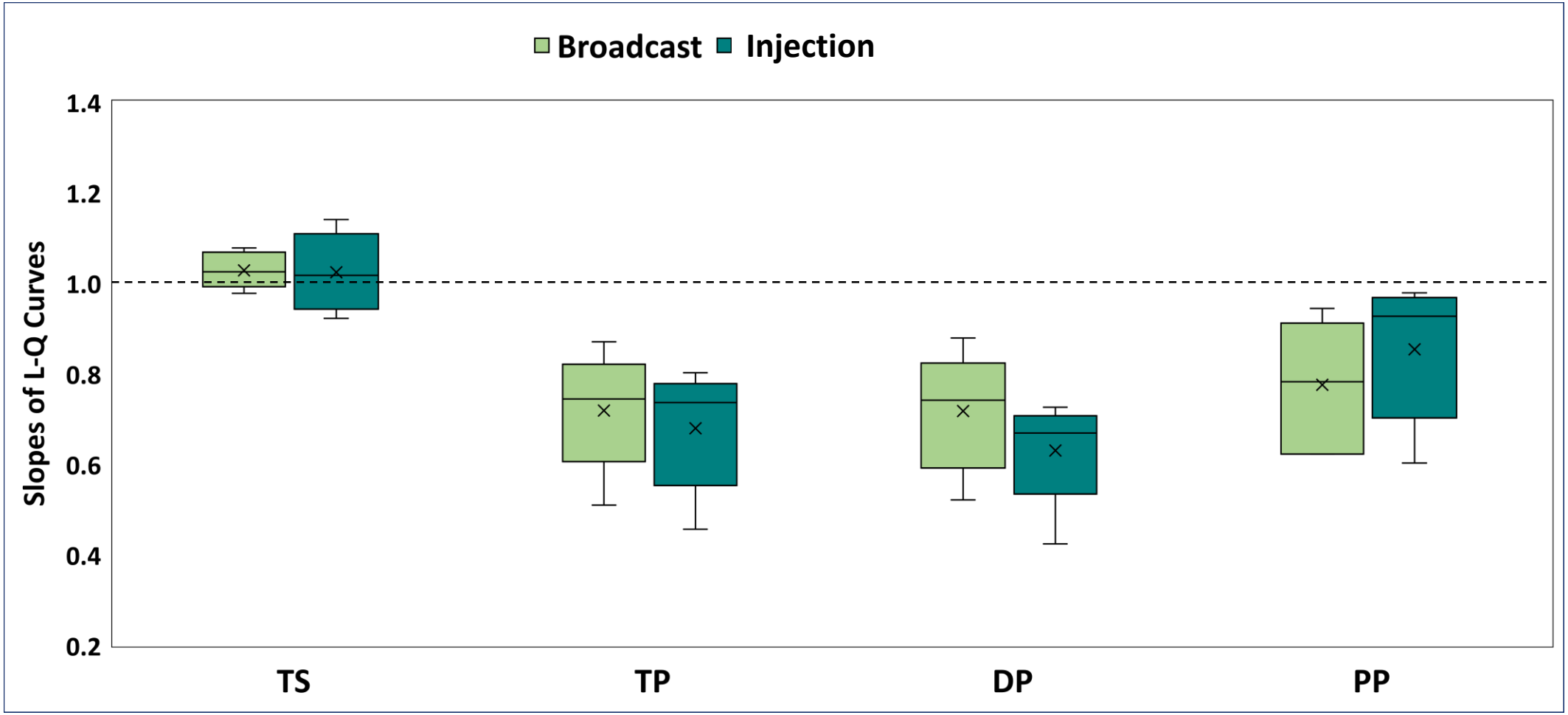


Transport-limited





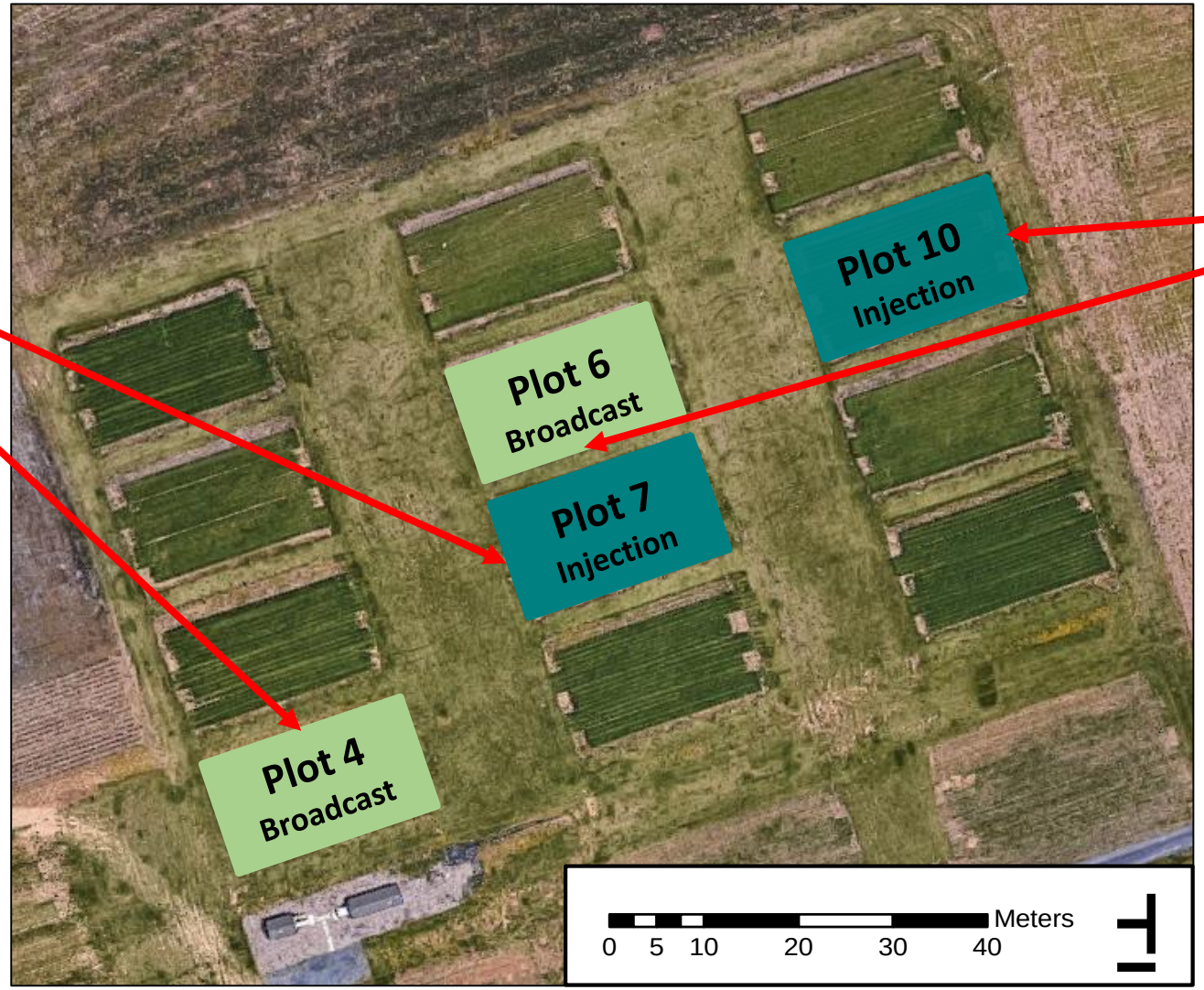
Injection resulted in lower L-Q slopes for DP but resulted in increased L-Q slopes for PP and little to no effect on TS or TP when compared to broadcasting



Plots with the lowest L-Q slopes tend to have a greater proportion of flow as subsurface flow than plots with greater L-Q slopes

Lowest L-Q slopes

Highest L-Q slopes



Plot 4: 6% overland flow
Moderate Mehlich-3 P

Plot 7: 4% overland flow
High Mehlich-3 P

Plot 6: 81% overland flow
Low Mehlich-3 P

Plot 10: 17% overland flow
Moderate Mehlich-3 P

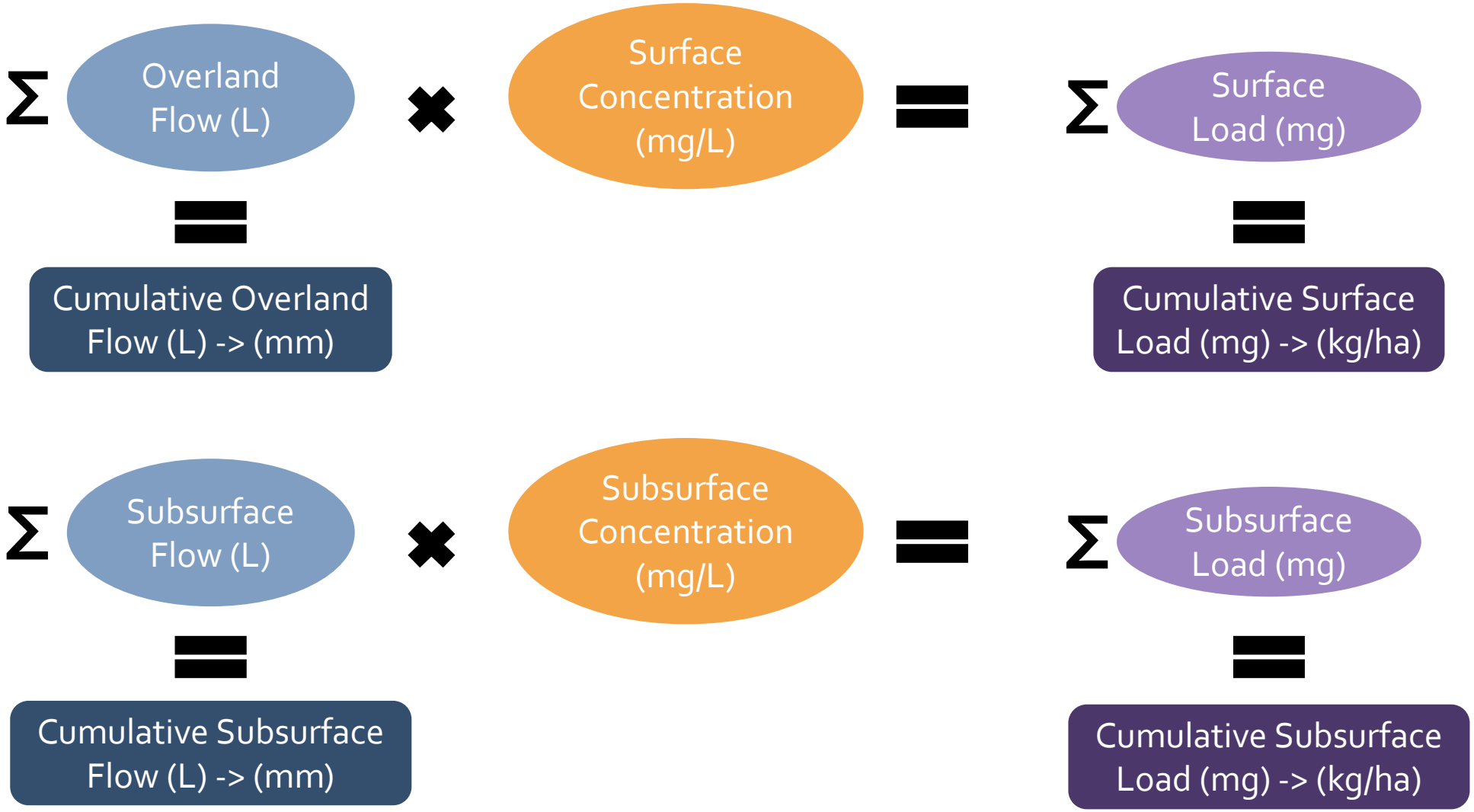
Injection versus broadcasting: Source-controlled or transport-controlled

- Manure injection showed more source-limited behavior than broadcasting for total phosphorus and dissolved phosphorus
- Manure injection did not differ from broadcasting in total solids losses
- Manure injection showed less source-limited behavior than broadcasting for particulate phosphorus losses
- However, none of these difference were statistically significant.

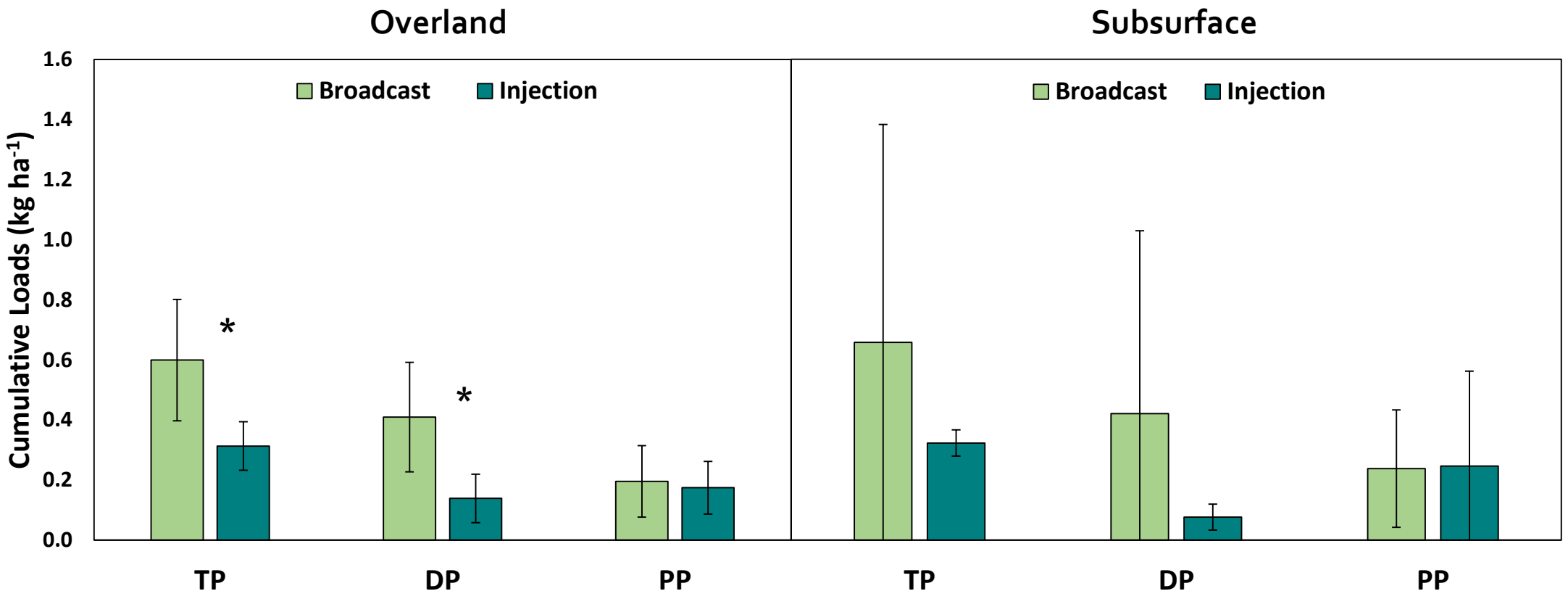
Objective 2:

Determine the relative effectiveness of shallow-disk injection in reducing P losses in overland and subsurface flow, compared to broadcasting

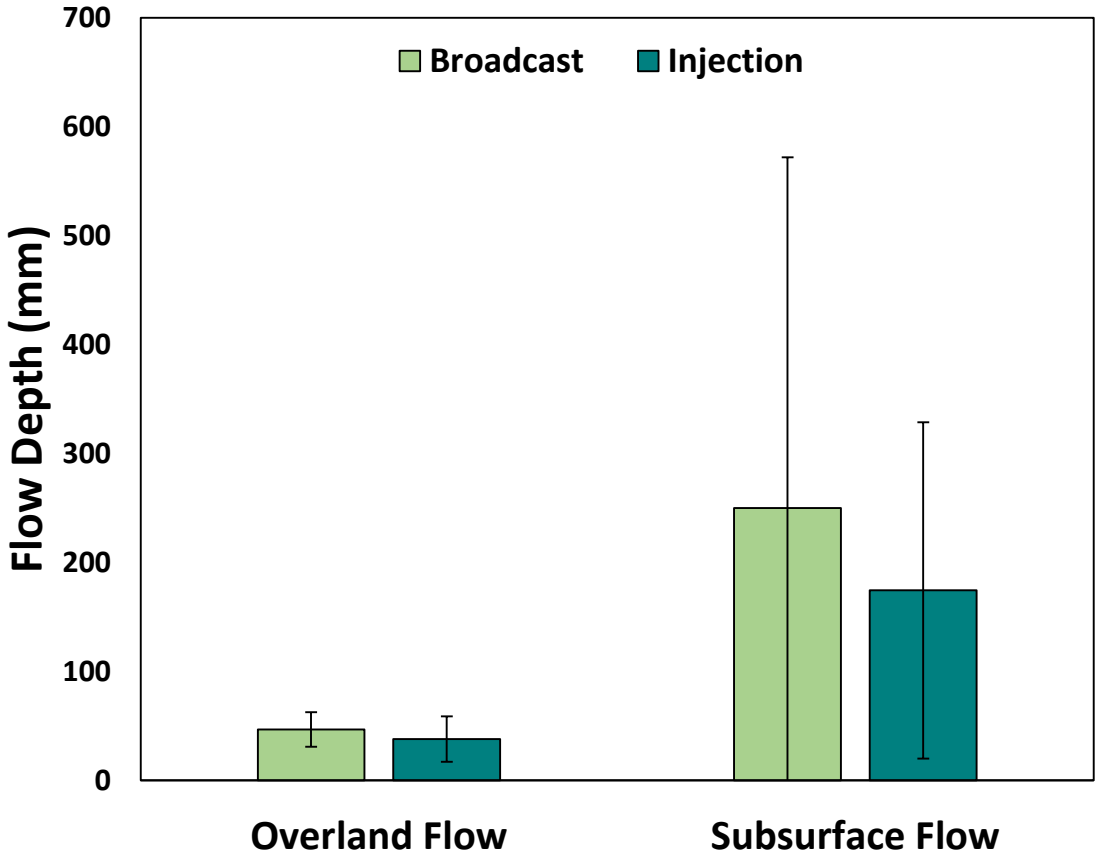
Cumulative P losses were calculated for 2014 and 2015 as the sum of all event loads



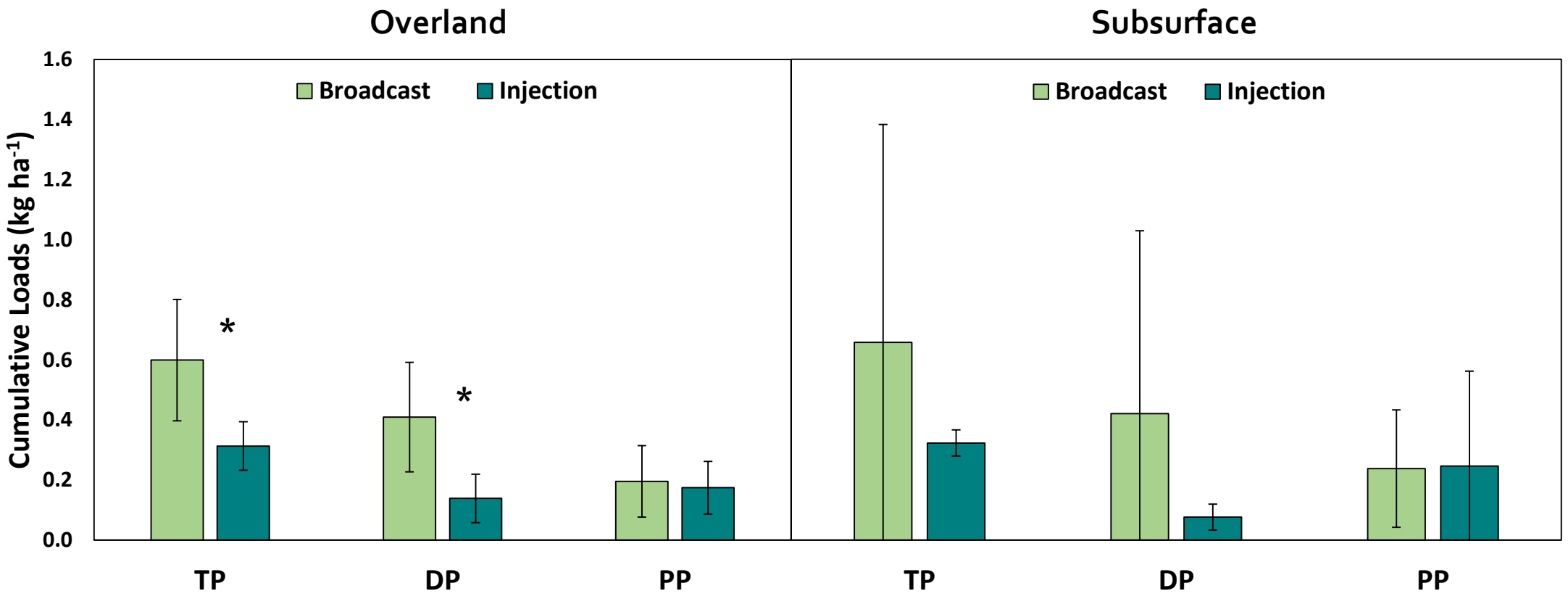
Injection plots exported significantly less DP and TP via overland flow than broadcast plots



Variability in cumulative losses depends on flow depths, which explains some, but not all, of the variability in P exports

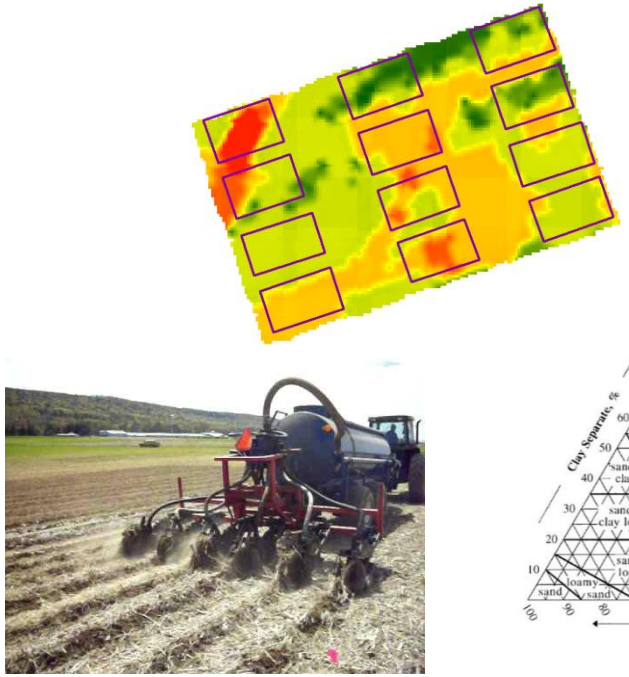


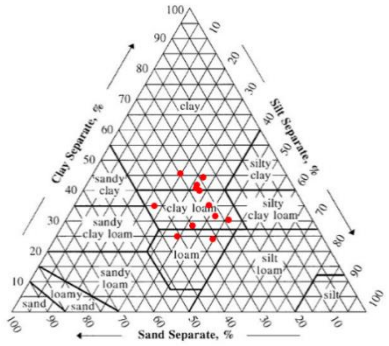
Injection, when compared to broadcasting, significantly reduced overland TP and DP losses without exacerbating PP losses.

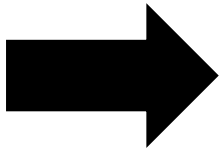


Objective 3:

Determine how manure application practices, soil properties, landscape characteristics, and hydrologic characteristics interact to predict TP, DP, and PP losses



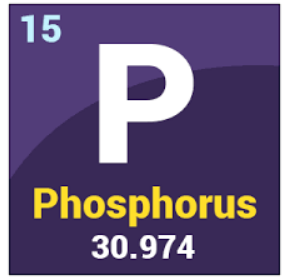




Potential characteristics influencing phosphorus losses:

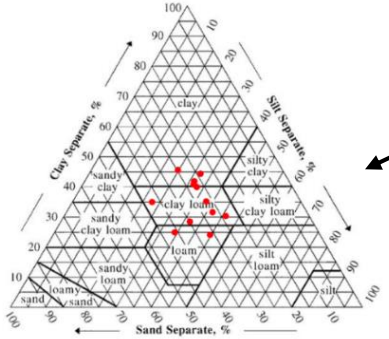
Hydrologic Characteristics

Chemical Soil Properties

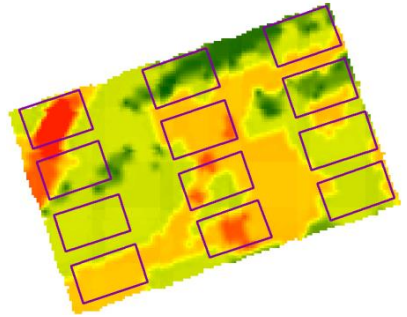


Manure Application Method

Physical Soil Properties



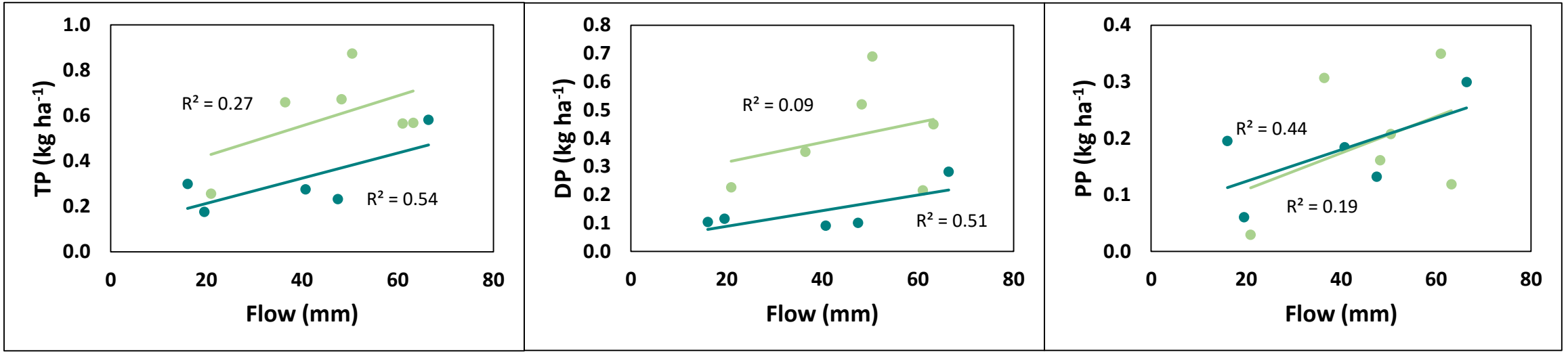
Landscape Characteristics

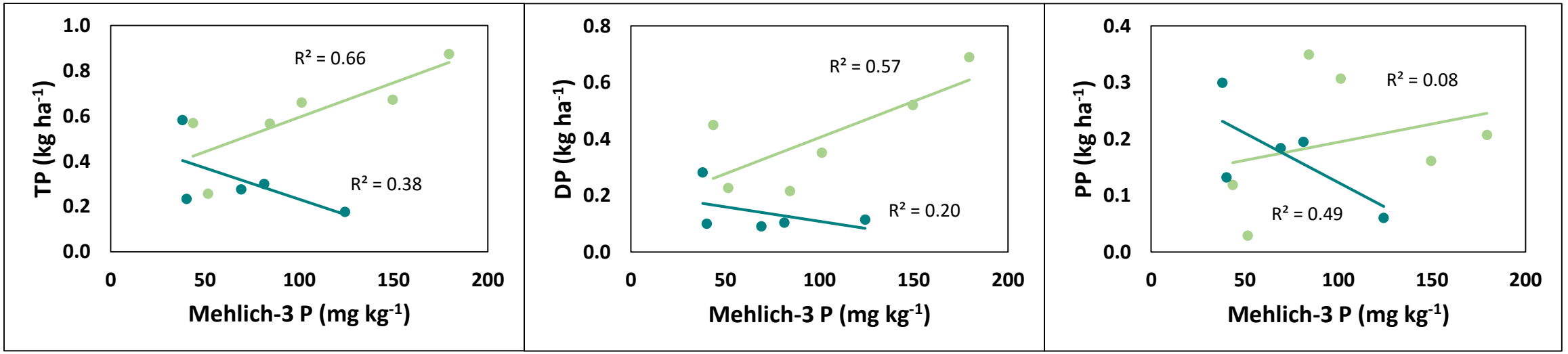


Overland Flow

Broadcast

Shallow-disk Injection

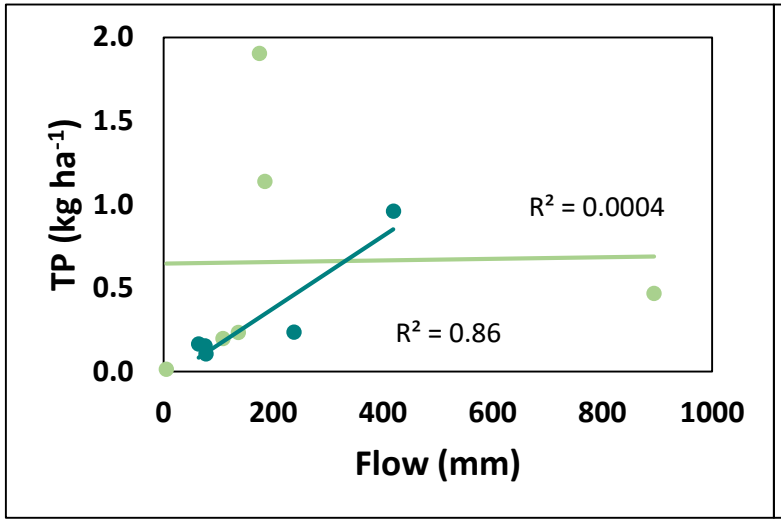


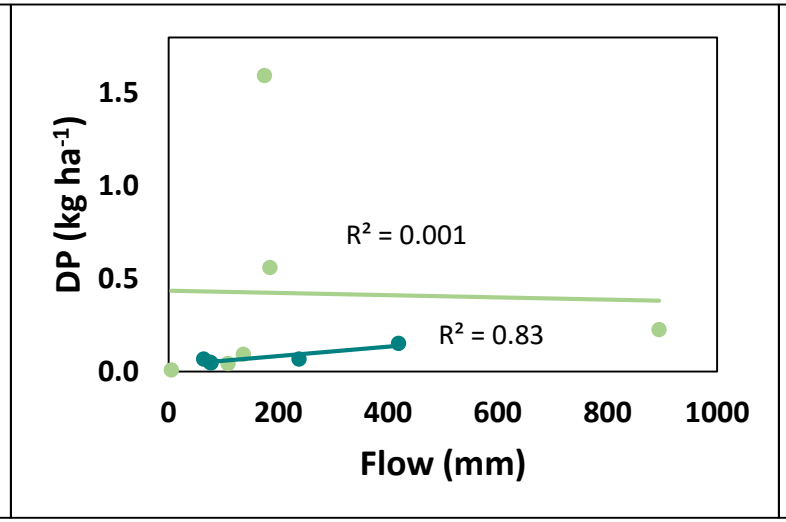


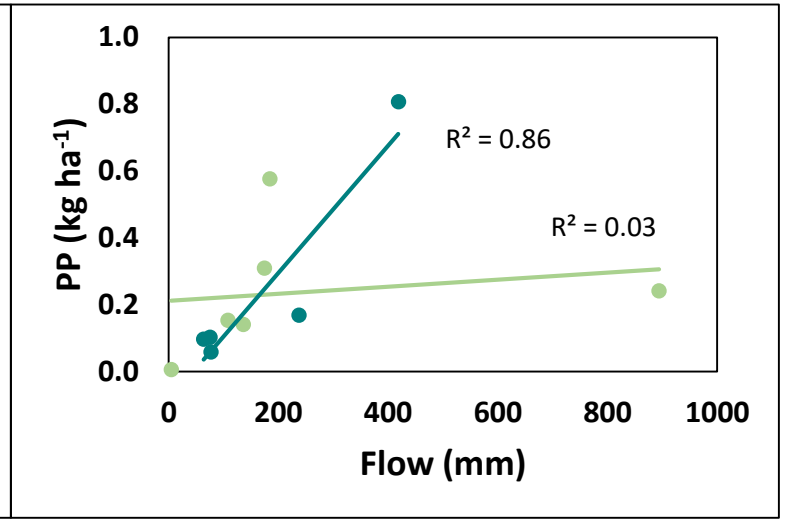
Subsurface Flow

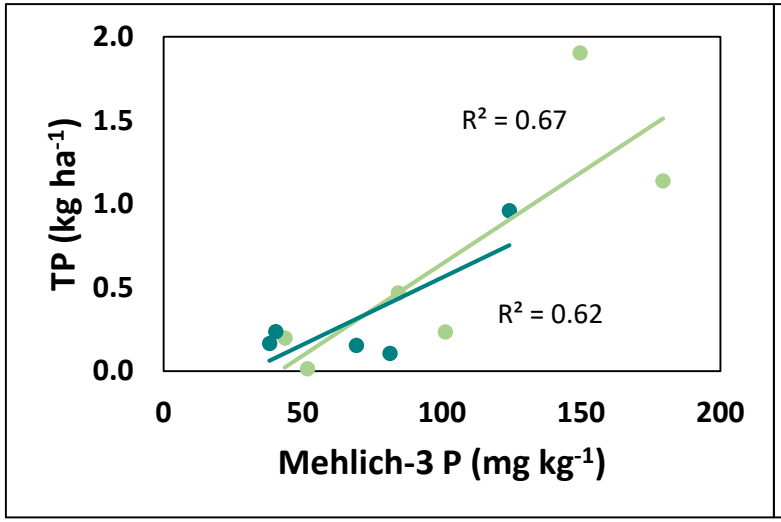
Broadcast

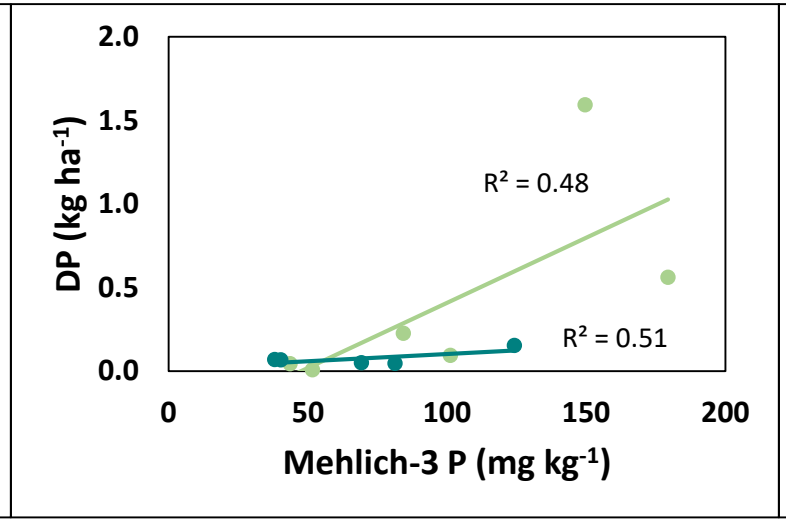
Shallow-disk Injection

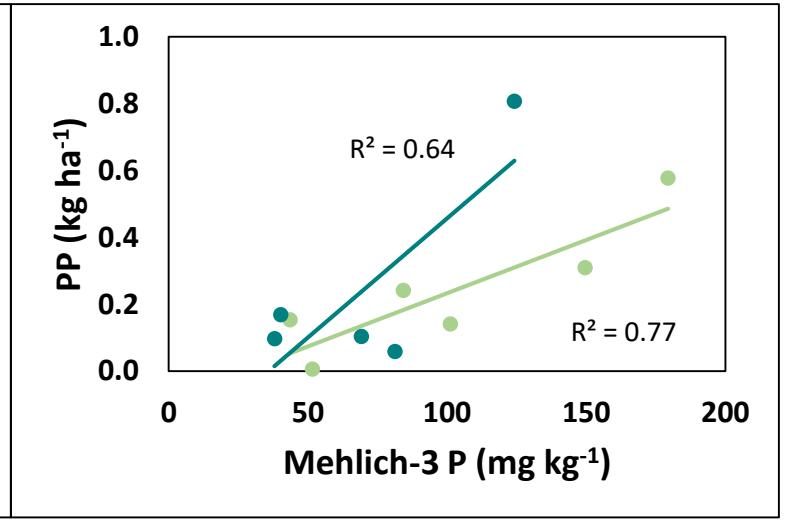




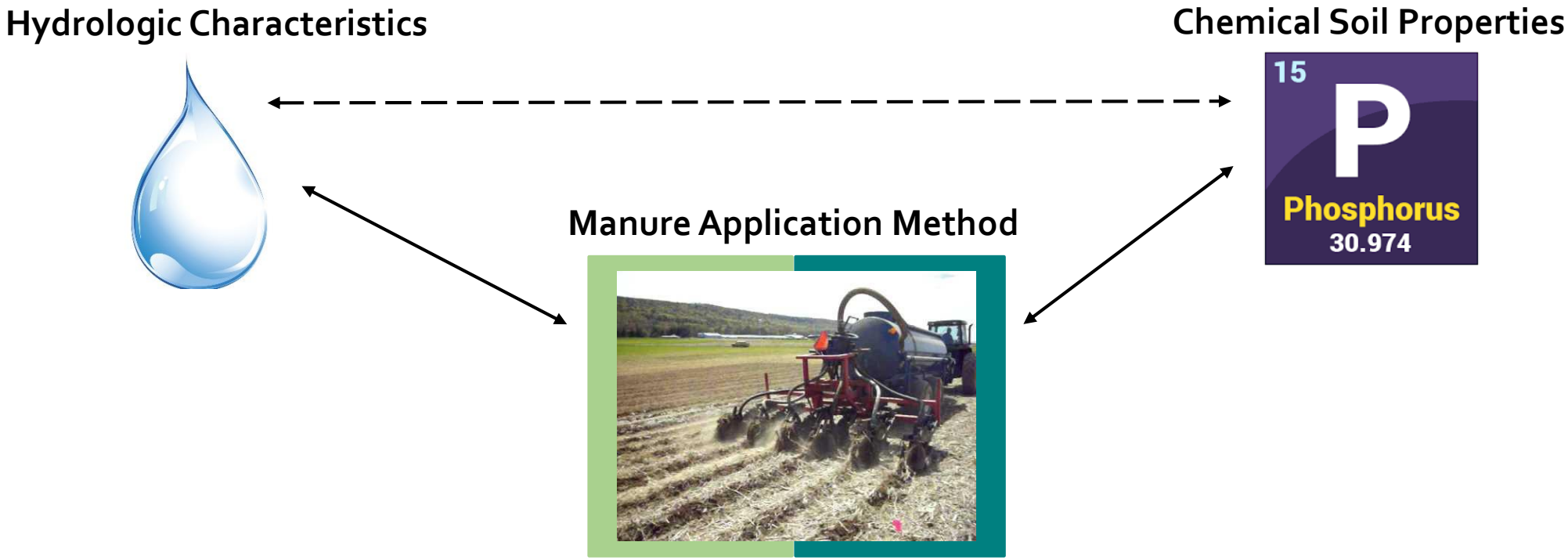






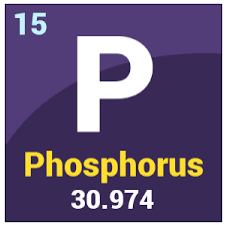


The combined effects of Mehlich-3 P and flow depth were the best predictors of all P losses, for both overland and subsurface flow



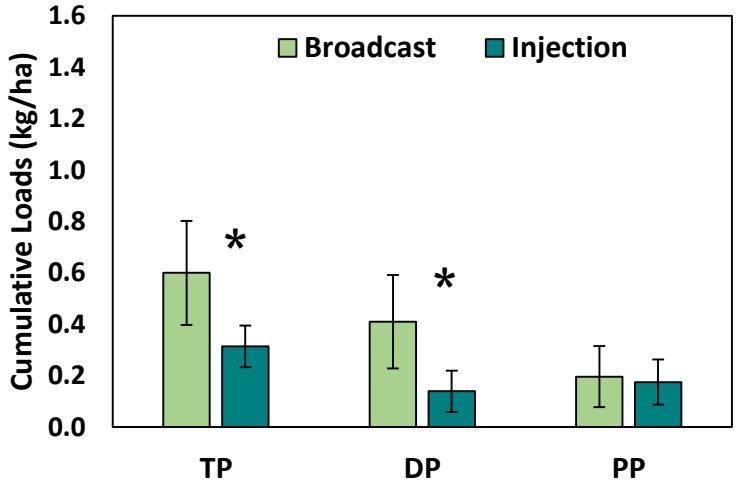
Conclusions and Implications

- Soil test P (source availability) and flow (transport potential) are the two biggest drivers of P losses, but soil and landscape characteristics can improve predictions



- The Critical Source Area concept is also applicable on the sub-field scale, based on the strong combined effect of flow and Soil Test P

- Shallow-disk injection is effective in reducing DP losses, particularly in overland flow, without exacerbating PP losses
  - It may also be useful in mitigating the development of legacy P issues in the future



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Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

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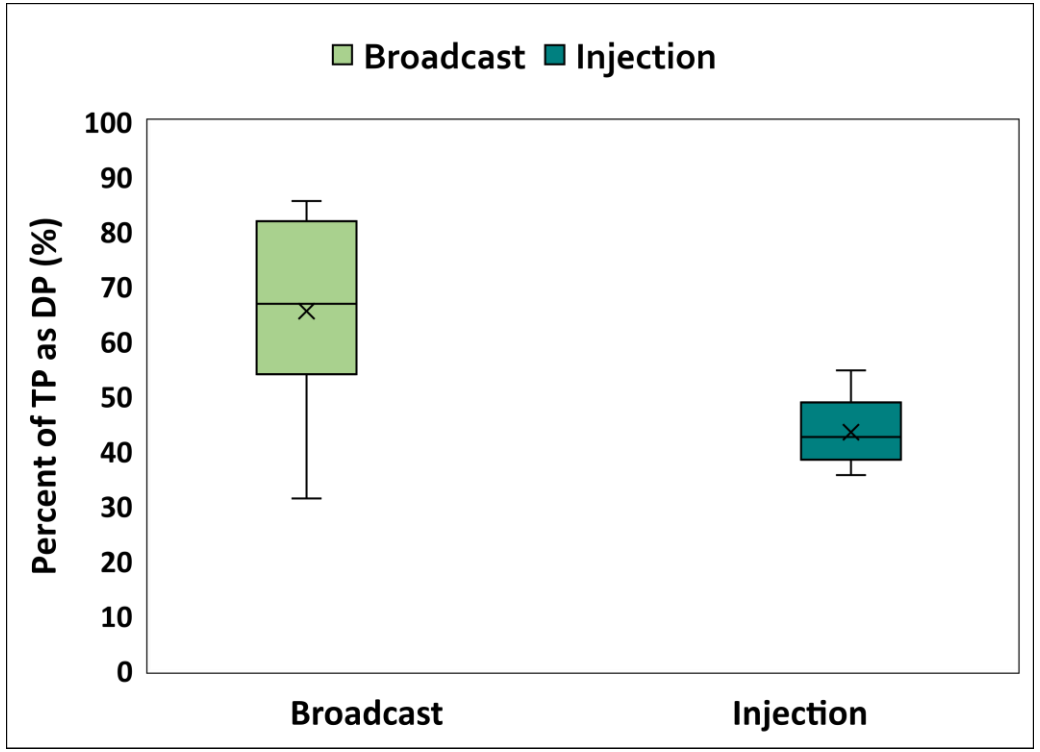
Thank you!

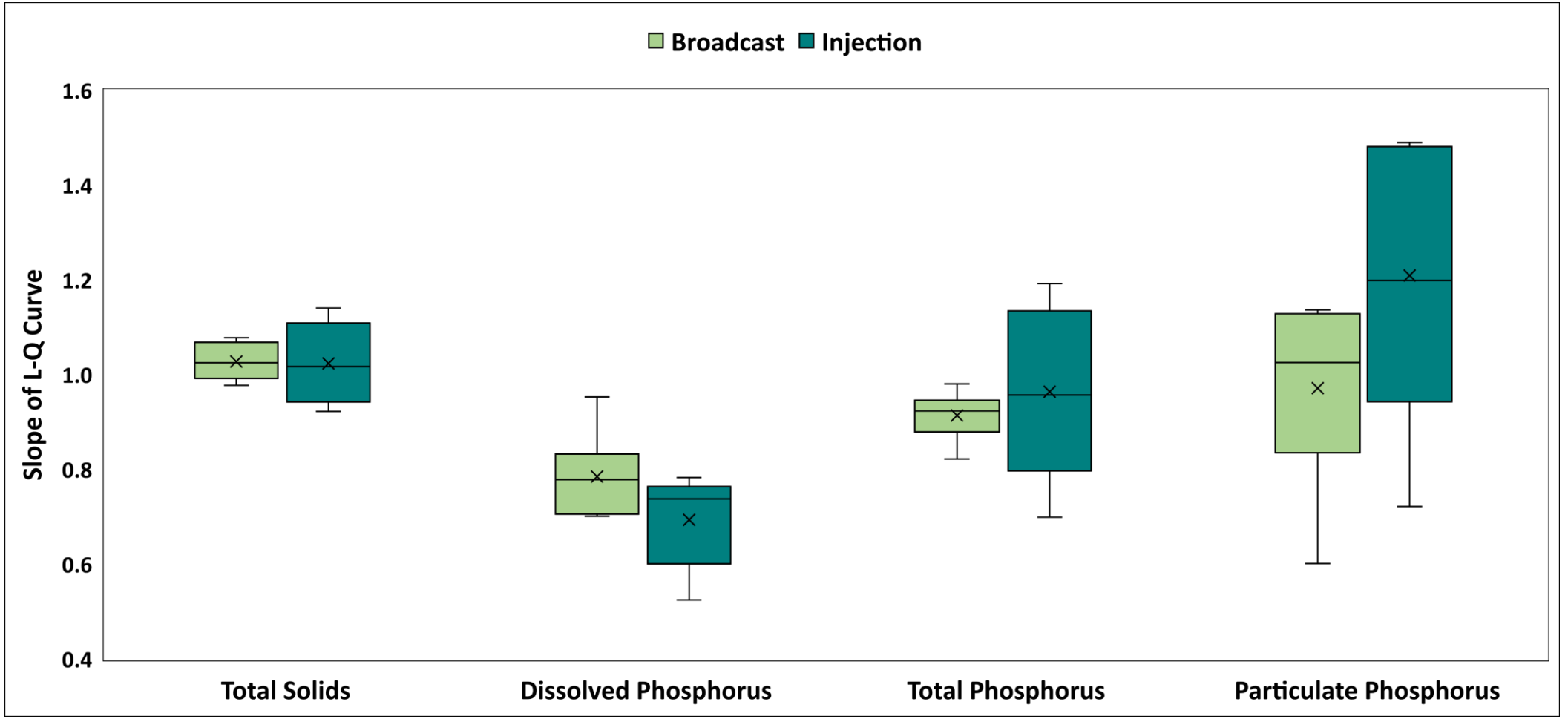
Questions?

T. Veith


Broadcast
Injection
Percent of TP as DP (%)
100
90
80
70
60
50
40
30
20
10
0
Broadcast
Injection

Concentrations below the LOD and LOQ were estimated using an upper and lower value to assess the sensitivity of the L-Q slopes to these values

Concentration	Lower Estimate	Upper Estimate
LOD < Concentration < LOQ	$\frac{(LOD + LOQ)}{2}$	$\frac{(LOD + LOQ)}{2}$
Concentration <LOD	O mg/L	LOD


Broadcast
Injection
Slope of L-Q Curve
1.6
1.4
1.2
1.0
0.8
0.6
0.4
Total Solids
Dissolved Phosphorus
Total Phosphorus
Particulate Phosphorus

Even with more extreme estimates of concentrations below the LOD, L-Q slopes remain relatively similar to those based on conservative estimates