IOWA STATE UNIVERSITY

New Practices for Nutrient Reduction: STRIPs and Saturated Buffers

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Situation

- Increasing concern for local and regional waters
- Substantial demand for agricultural products
- Hypoxia Action Plan in 2008 called for development and implementation of comprehensive N and P reduction strategies for states in the Mississippi/Atchafalaya River Basin
- Increasing concern about phosphorus loading to Lake Erie and the role of drainage in this loading

Nitrate-N Reduction Practices

	Practice	% Nitrate-N Reduction [Average (Std. Dev.)]	% Corn Yield Change
Nitrogen Management	Timing (Fall to spring)	6 (25)	4 (16)
	Nitrogen Application Rate (Reduce rate to MRTN)	10	-1
	Nitrification Inhibitor (nitrapyrin)	9 (19)	6 (22)
	Cover Crops (Rye)	31 (29)	-6 (7)
Land Use	Perennial – Pasture/Land retirement	85 (9)	
	Perennial – Energy Crops	72 (23)	
	Extended Rotations	42 (12)	7 (7)
Edge-of-Field	Controlled Drainage	33 (32)*	
	Shallow Drainage	32 (15)*	
	Wetlands	52	
	Bioreactors	43 (21)	
	Buffers	91 (20)**	

*Load reduction not concentration reduction

**Concentration reduction of that water interacts with active zone below the buffer

Phosphorus Reduction Practices

	Practice	% Phosphorus-P Reduction [Average (Std. Dev.)]	% Corn Yield Change
Phosphorus Management	Producer does not apply phosphorus until STP drops to optimal level	17 (40)	0
	No-till (70% residue) vs. conventional tillage (30% residue)	90 (17)	-6 (8)
	Cover Crops (Rye)	29 (37)	-6 (7)
Land Use	Perennial – Land retirement	75 (-)	
	Pasture	59 (42)	
Edge-of-Field	Buffers	58 (32)	
	Terraces	77 (19)	

Assessment did not include stream bed and bank contributions although recognized as significant

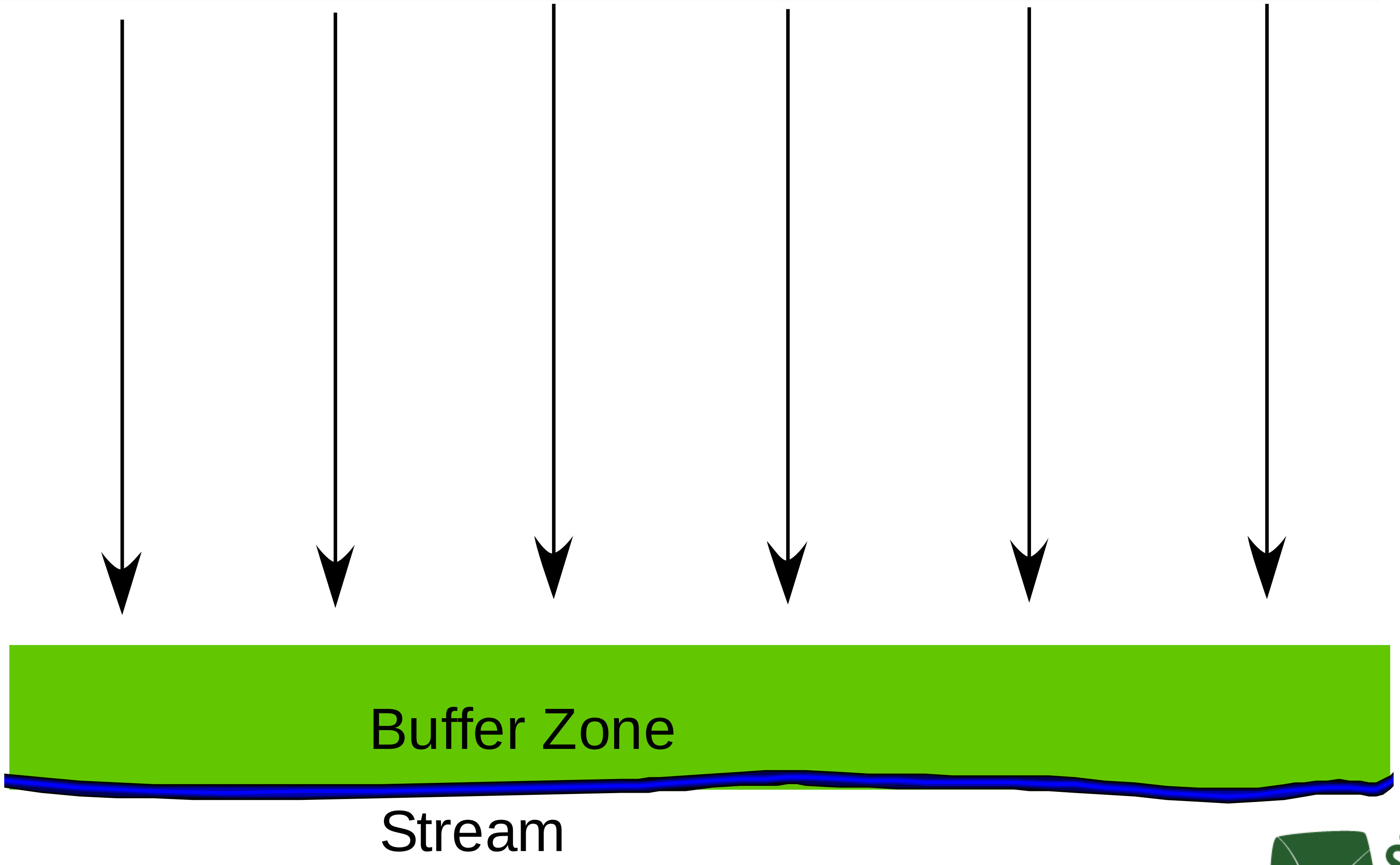
Prairie Strips within the Row Crop Landscape

- *Question:* Would strategic placement of small amounts of prairie cover within agriculturally-dominated landscapes have disproportionate benefits on water quality, biodiversity, and socioeconomic systems?

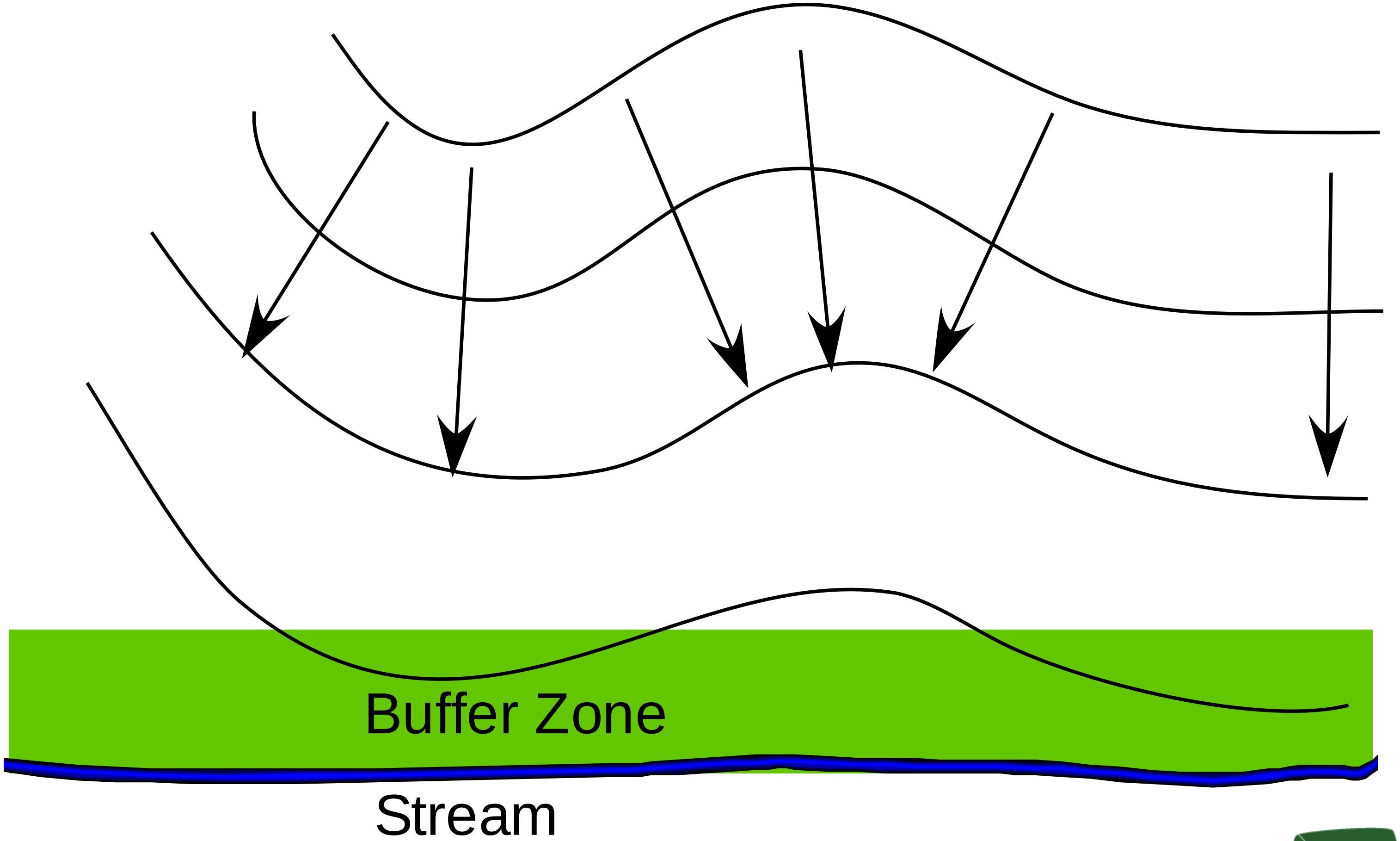
What is unique?

Natural Flow Conditions

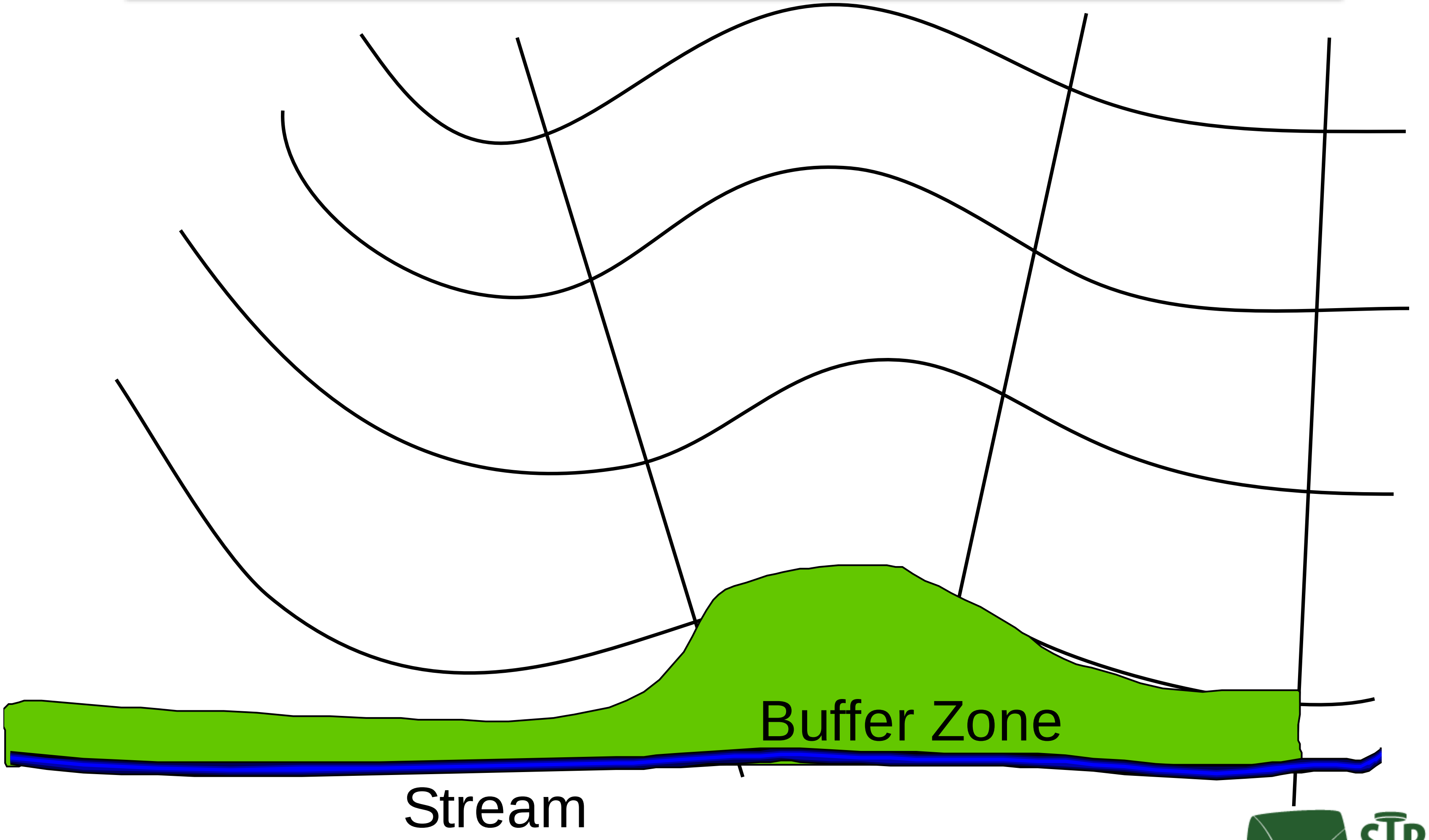
Assumed Flow to Buffer



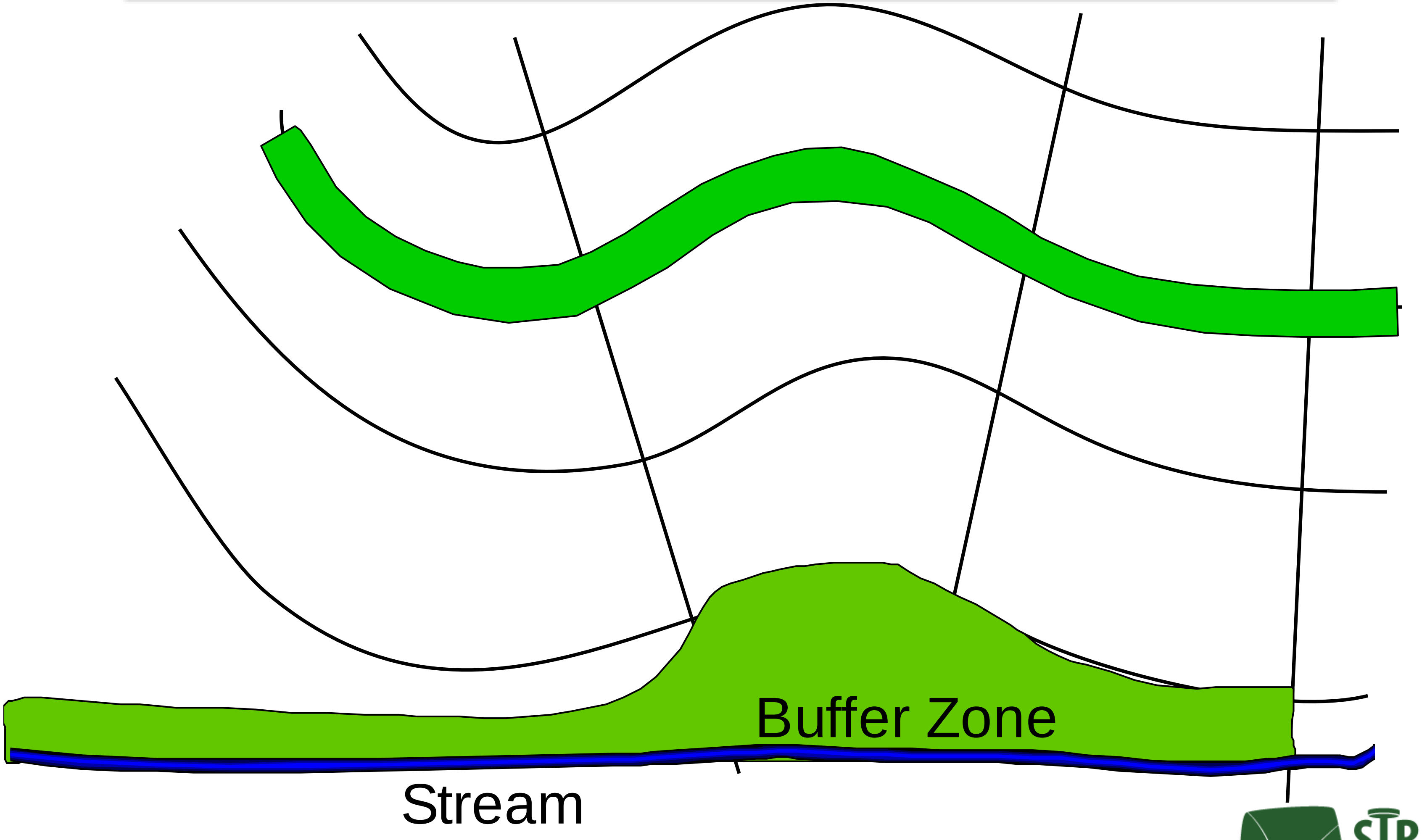
Actual Flow to Buffer



Potential Buffer Design



Potential Buffer Design



STRIPS: Science-based Trials of Row-crops Integrated with Prairies

Neal Smith National Wildlife Refuge, Prairie City, IA

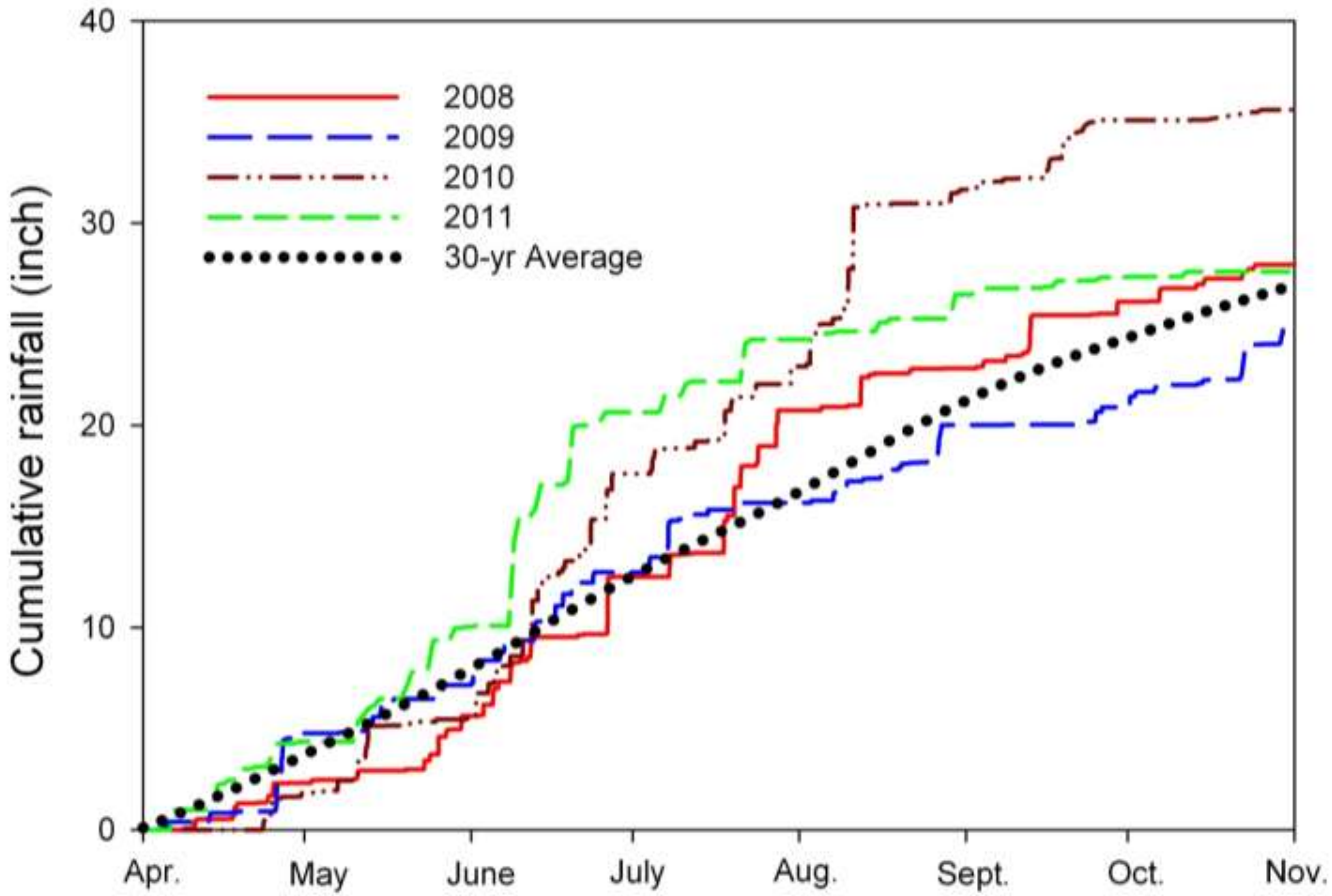
12 experimental watersheds, 0.5 to 3.2 ha each, 6 to 10% slope

Four treatments:
100% crop (no-till)
10% buffer, at toe slope
10% buffer, in contour strips
20% buffer, in contour strips

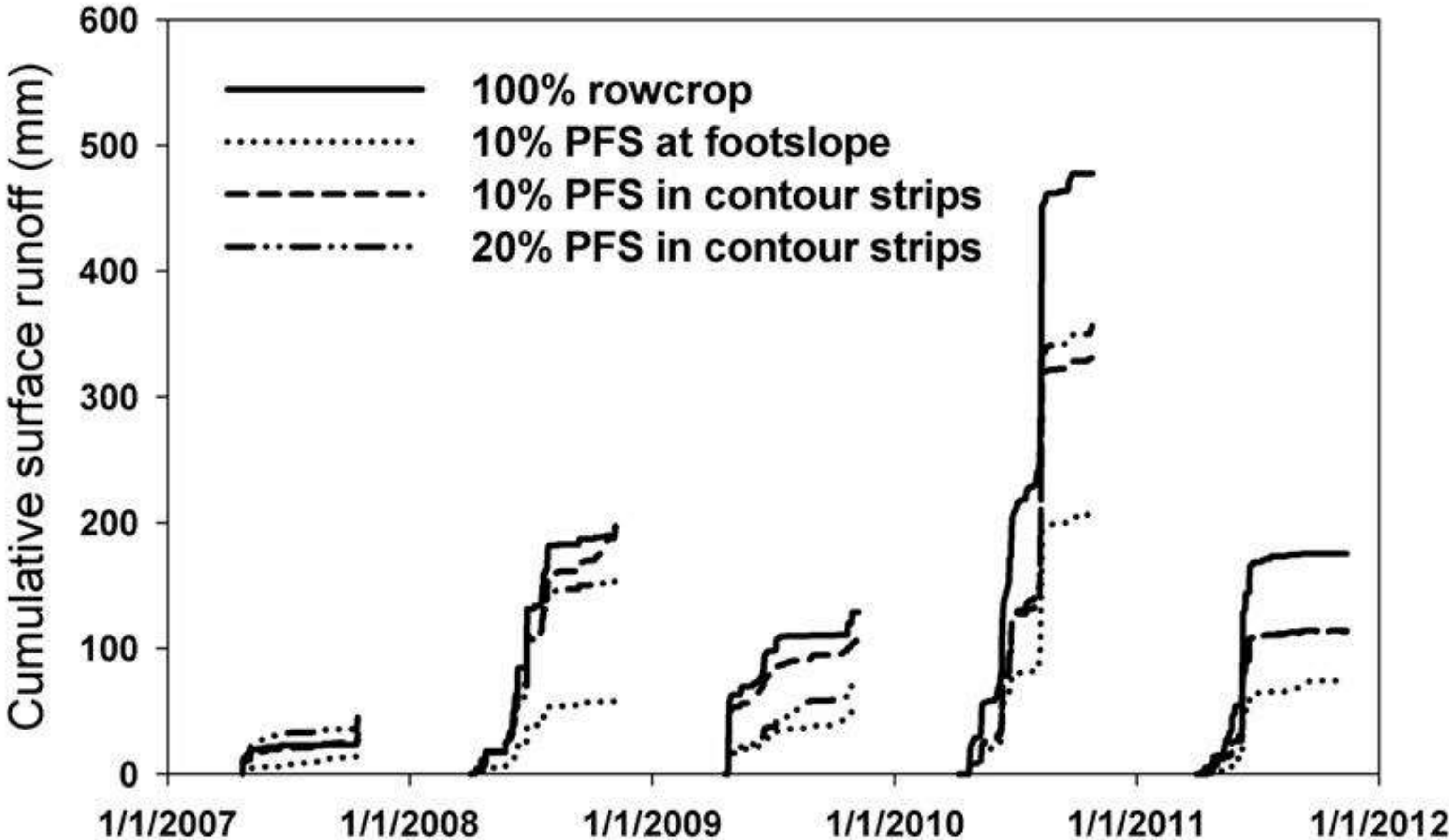
Surface Runoff Monitoring

H-flumes monitor movement of water, sediment, and nutrients

Precipitation

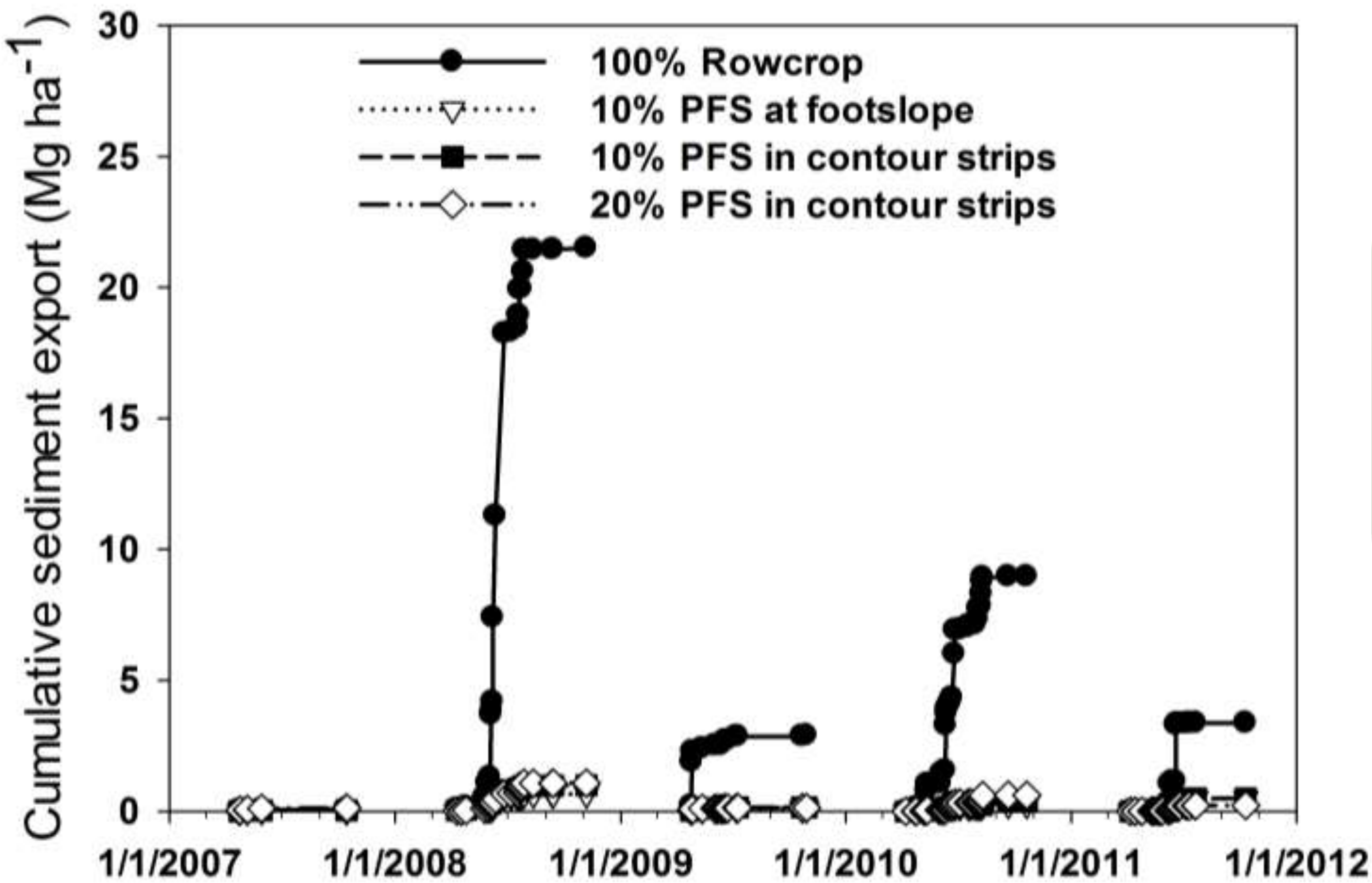


Surface Runoff



Helmers et al., 2012

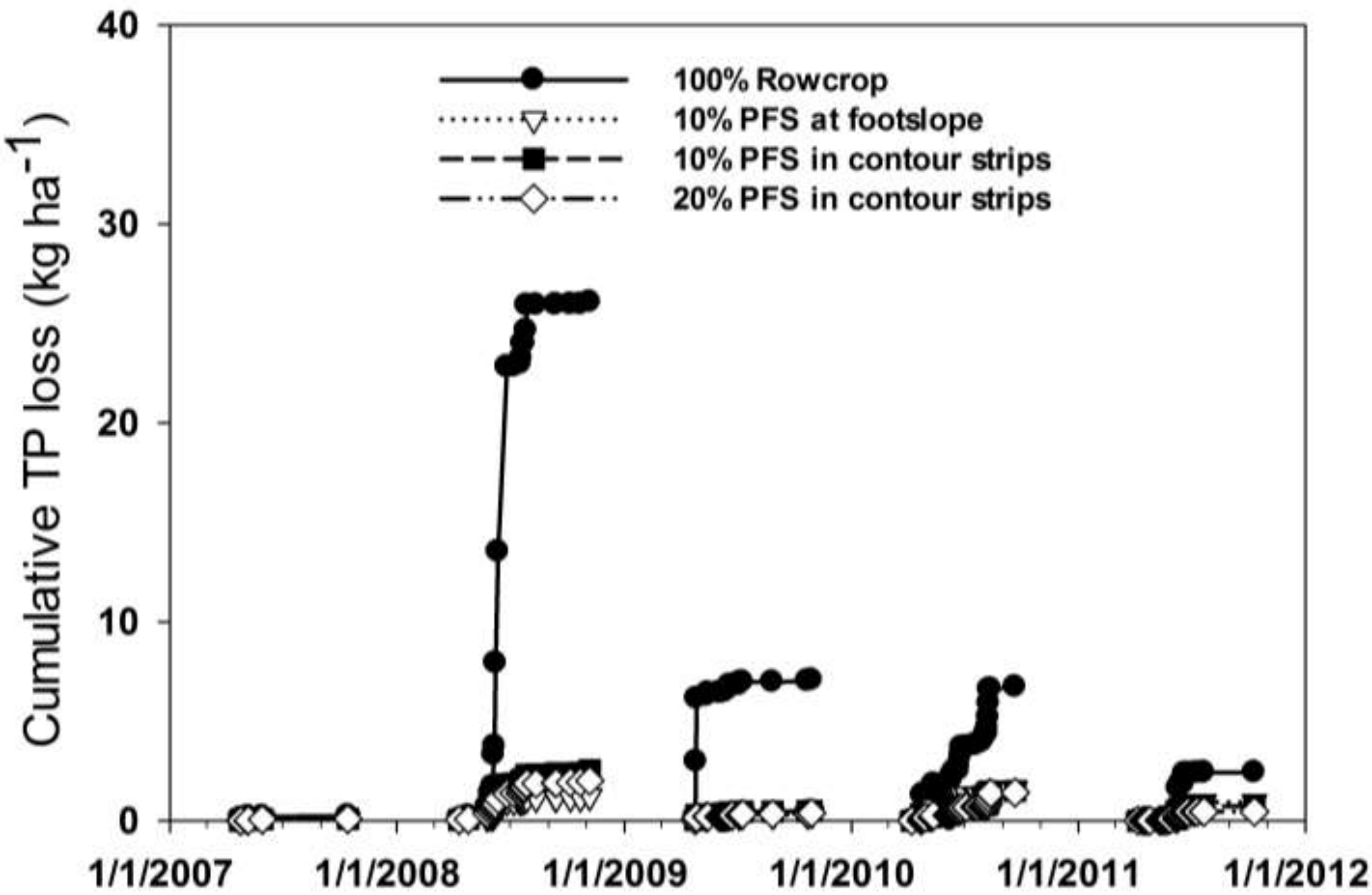
Sediment Loss in Runoff (2007-2011)



>95% Reduction in sediment export from watersheds with prairie filter strips

Helmers et al., 2012

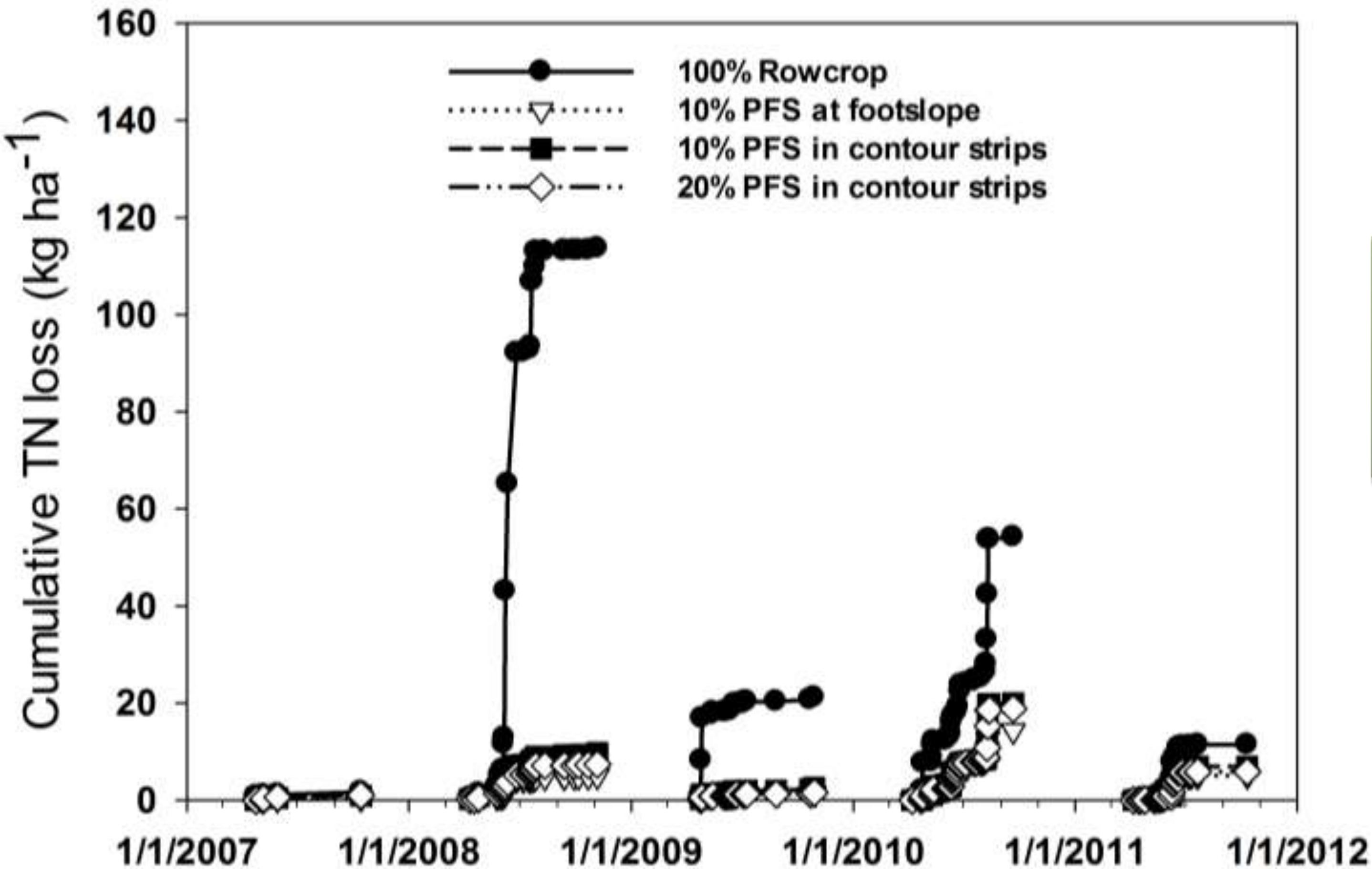
Phosphorus Loss in Runoff (2007-2011)



>90% Reduction in TP export from watersheds with prairie filter strips

Zhou et al., in press

Total Nitrogen Loss in Runoff (2007-2011)



>90% Reduction in TN export from watersheds with prairie filter strips

Zhou et al., 2014

Visual Examples (4 inch rain in June 2008)

100% Crop

10% Prairie
90% Crop

100% Prairie

Average Cost of Strips to Farmers

Cost calculation assumption:
One acre of prairie "treats" the run-off from about 9 acres of row crops

Annualized Total Costs [1]	Higher Quality Land (CSR 83)	Medium Quality Land (CSR 73)	Lower Quality Land (CSR 60)
Cost per treated acre [2]	~ $40	~ $30	~ $24
Cost per treated acre with CRP [3]	$5	$4	$3

1. 4% discount rate; 15-year management horizon; average Iowa land rent charge.
2. Assumes 1 ac of prairie treats about 9 ac of row crops
3. Represents treated acre costs to farmer after CRP

≤ 10% of total cost

+

~ 10% - 15% of total cost

+

Upwards of ~ 90% total cost

Keep in mind that cost scale with opportunity costs

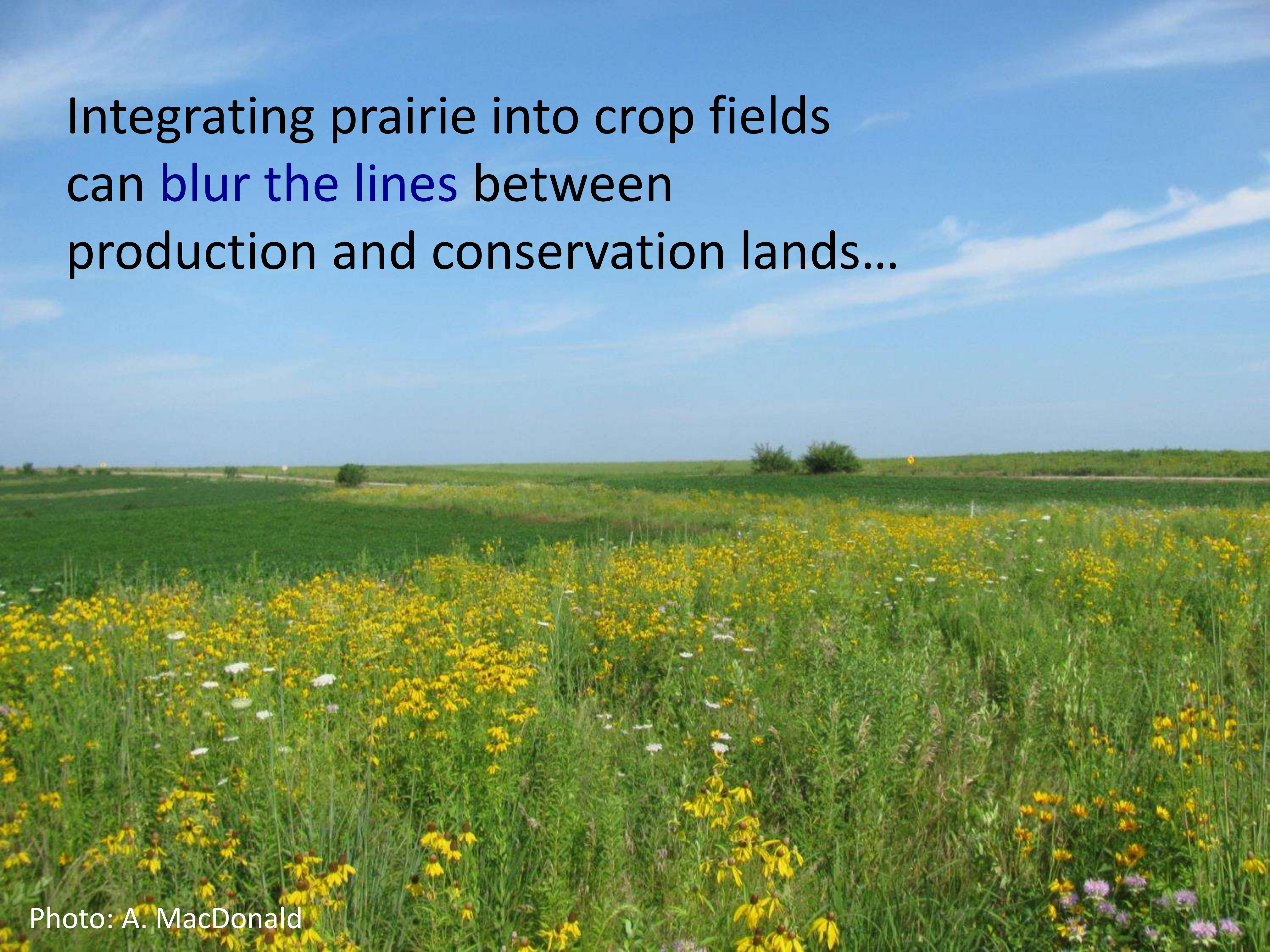
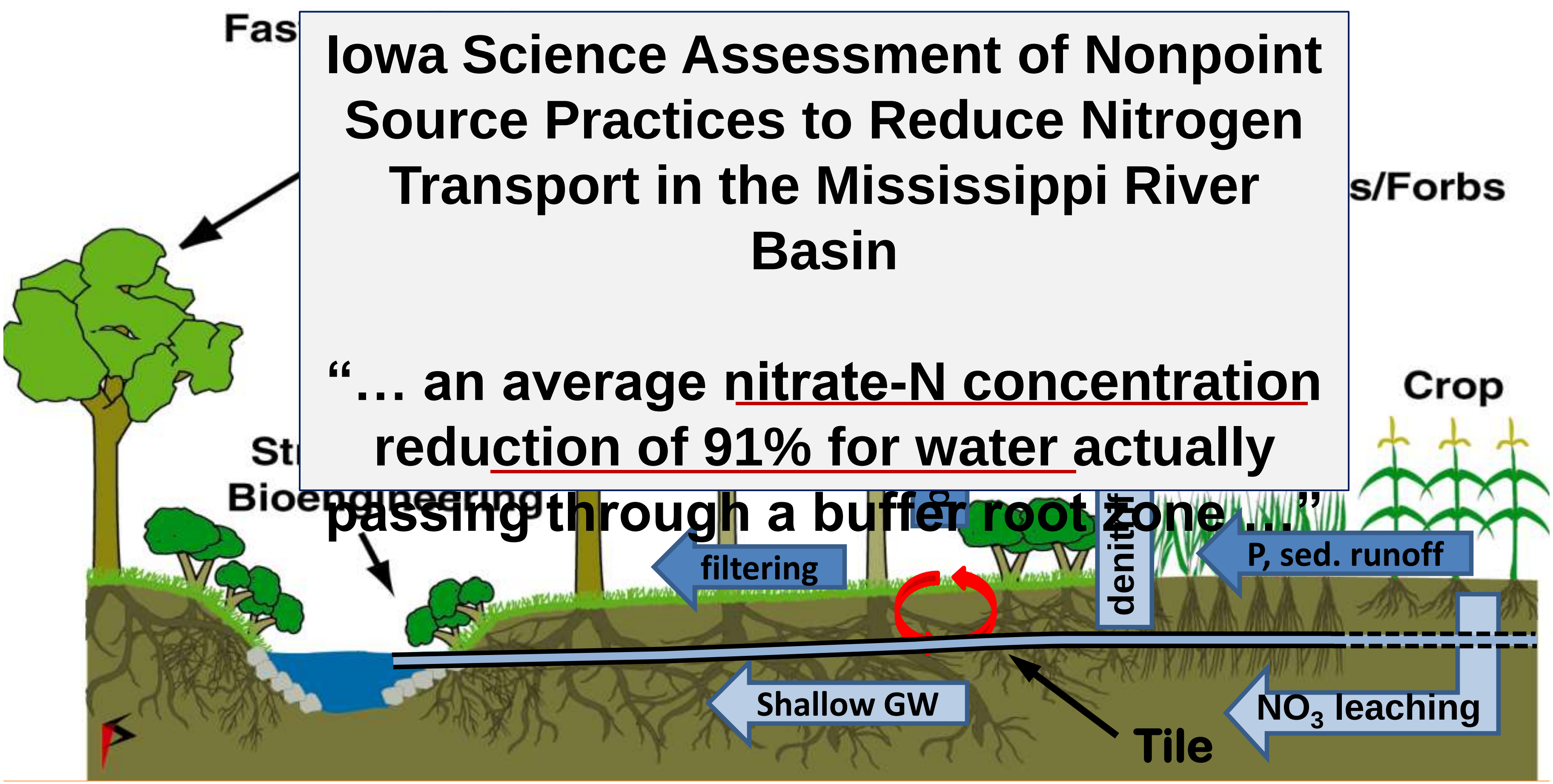


Photo: A. MacDonald

Schematic of nutrient retention in a riparian buffer



Iowa Science Assessment of Nonpoint Source Practices to Reduce Nitrogen Transport in the Mississippi River Basin

"… an average nitrate-N concentration reduction of 91% for water actually passing through a buffer root zone …"

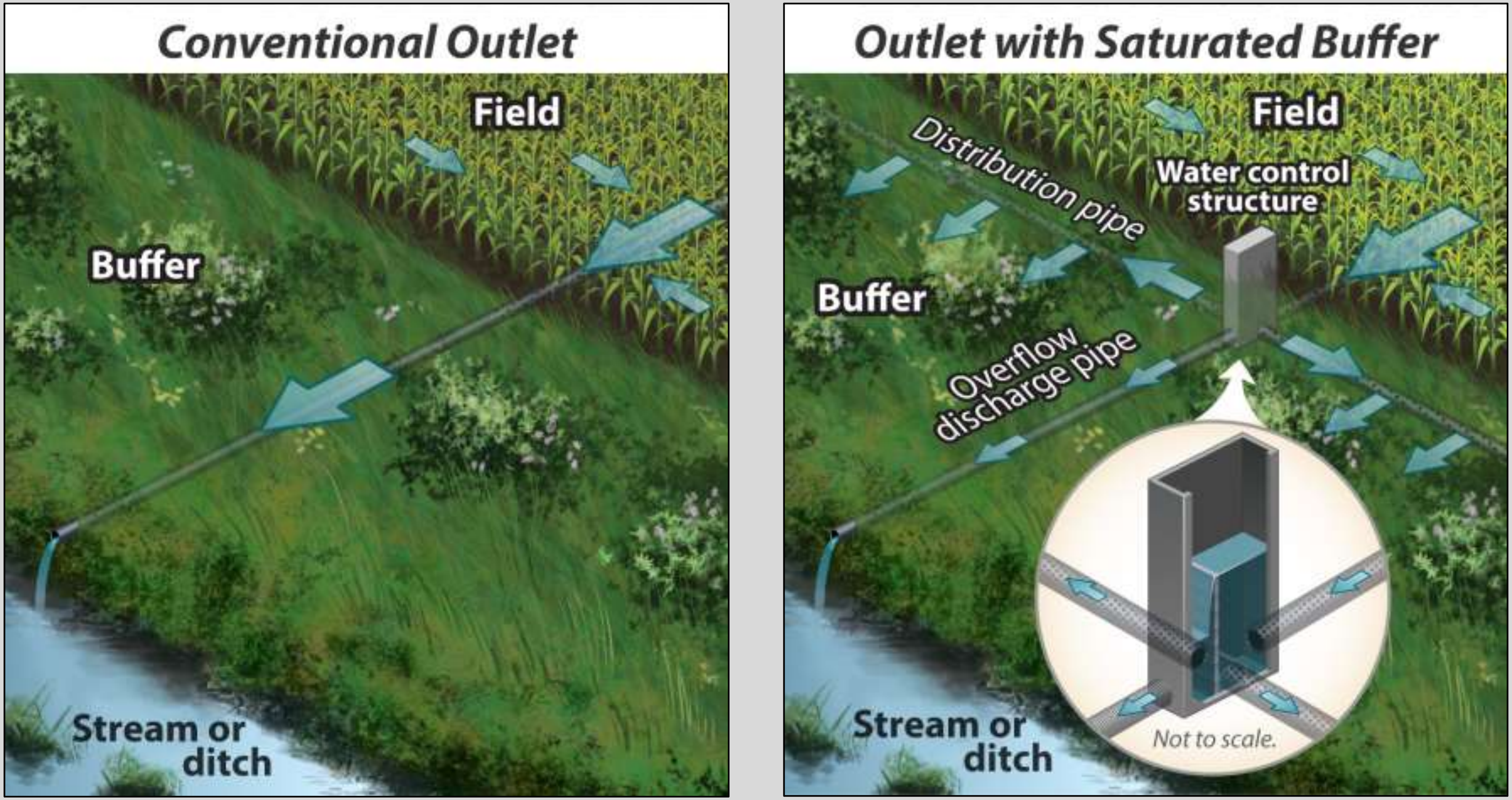
Alternatives for Tile-drained Landscapes?

Nutrient-Removal Wetland

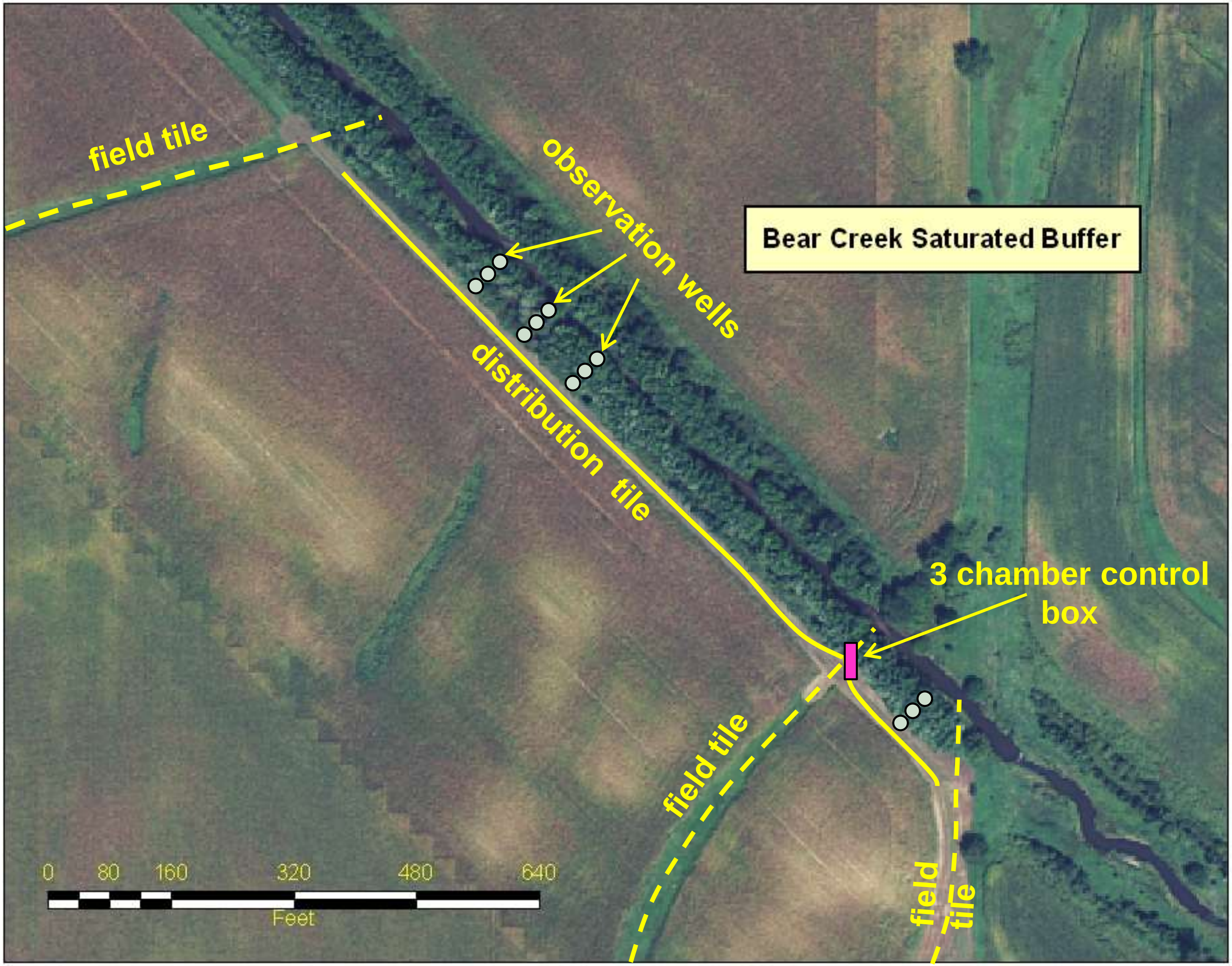
Bioreactor

Question

Could reconnecting tile flow to riparian buffers remove substantial amounts of nitrate before it reaches surface waters?

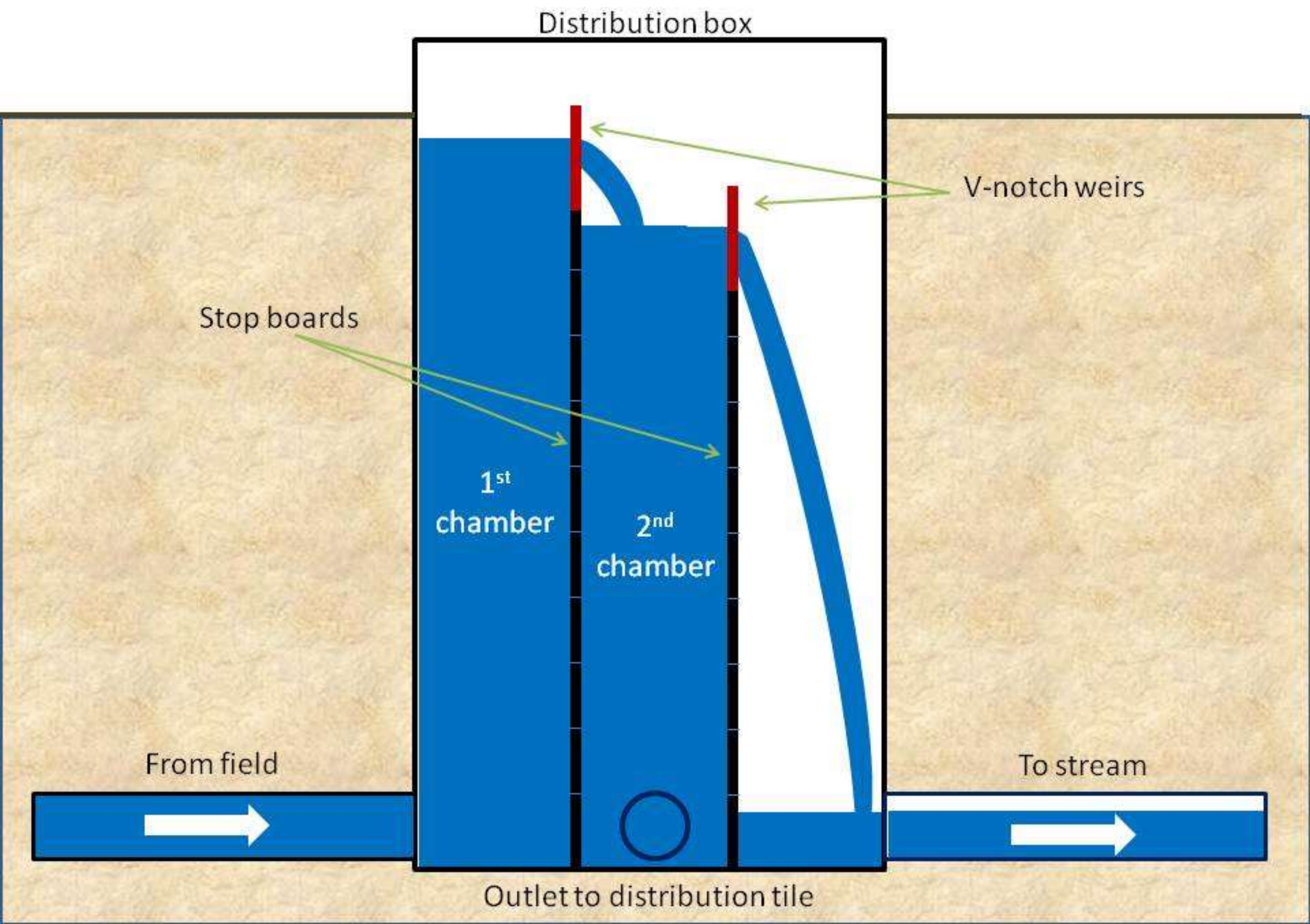


Conventional Outlet
Field
Buffer
Stream or ditch
Outlet with Saturated Buffer
Field
Distribution pipe
Water control structure
Buffer
Overflow discharge pipe
Stream or ditch
Not to scale.

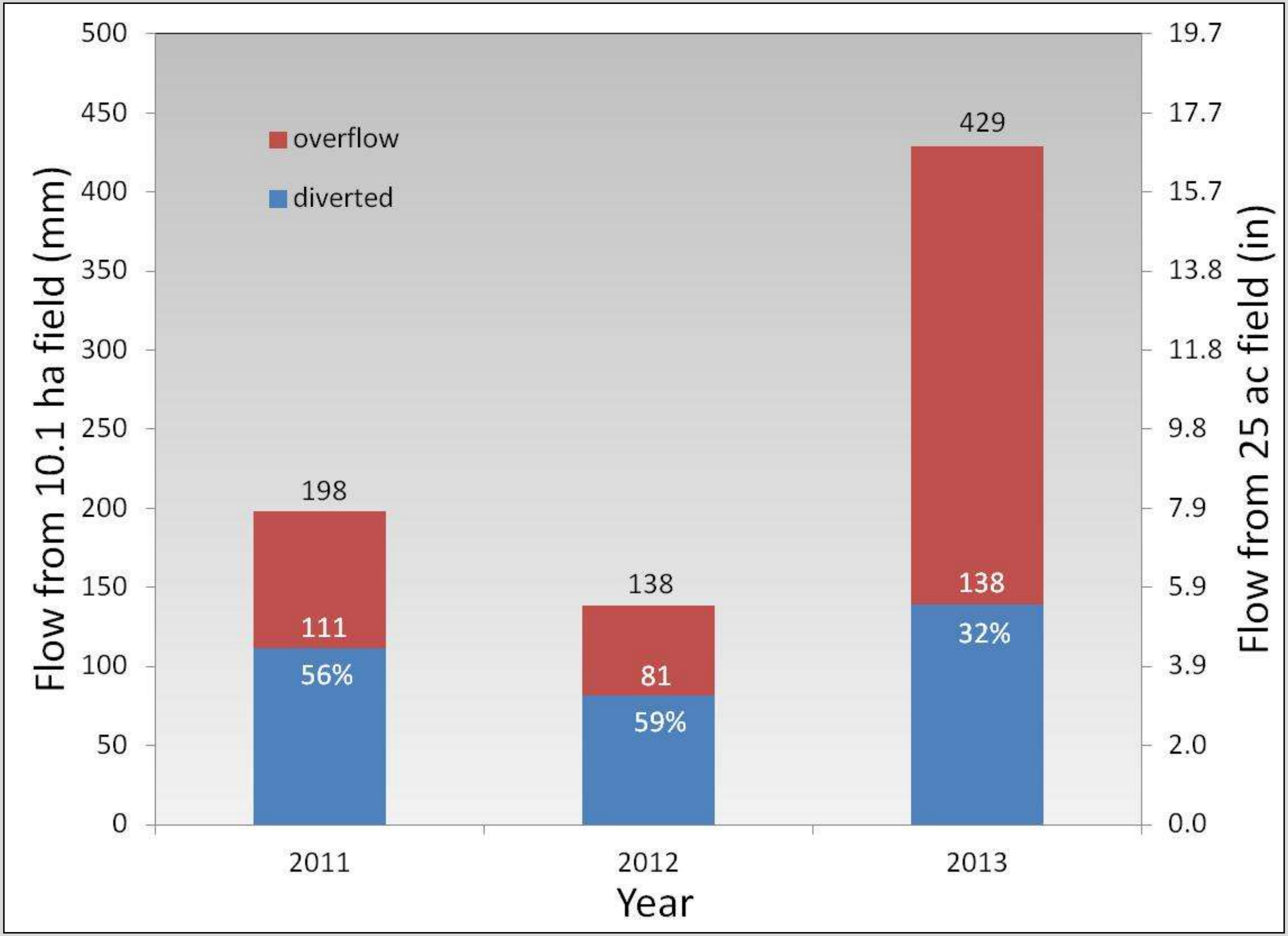


Bear Creek Saturated Buffer
field tile
observation wells
distribution tile
3 chamber control box
field tile
field tile
0 80 160 320 480 640
Feet

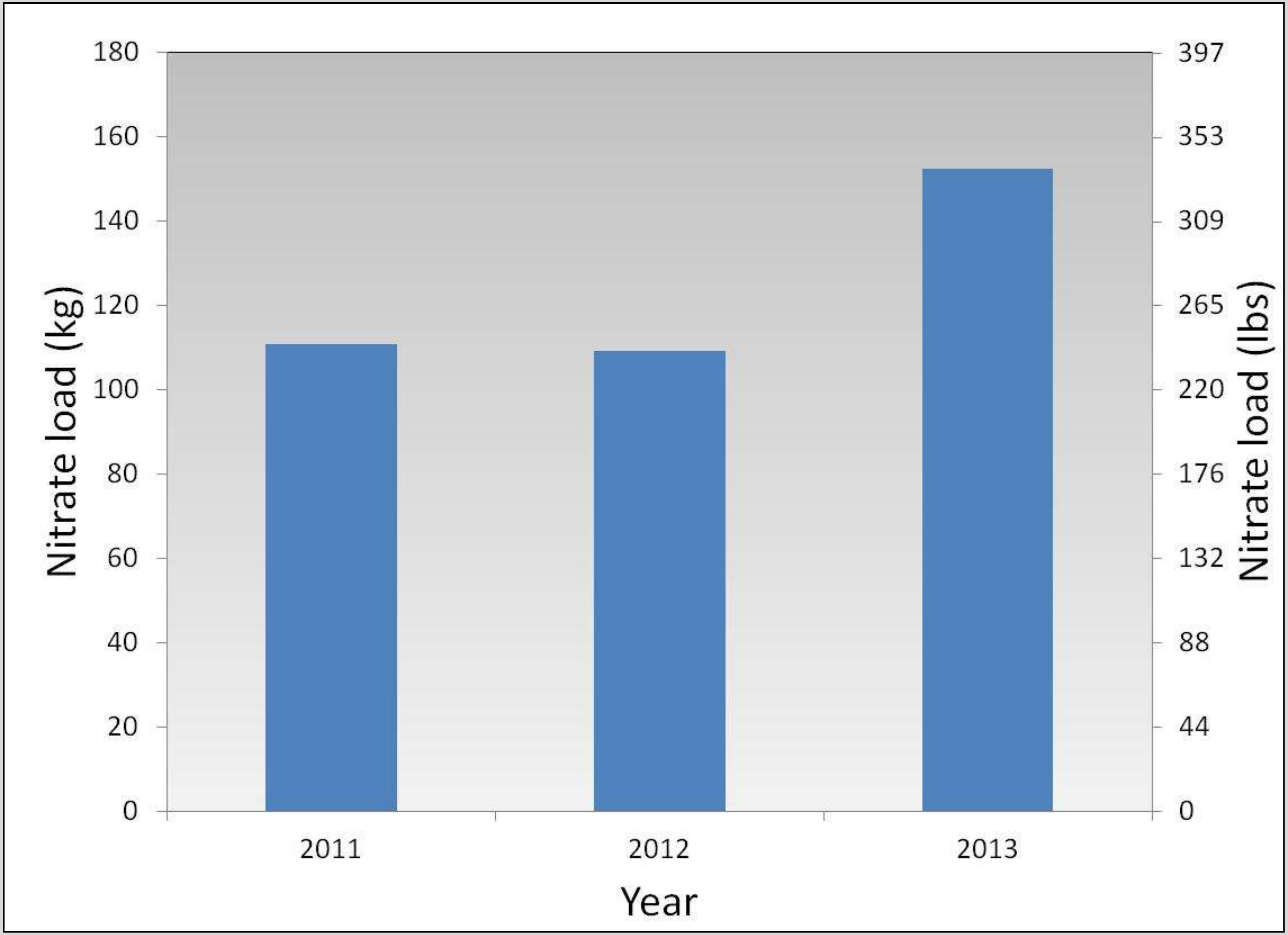
Top view


Distribution box
V-notch weirs
Stop boards
1st chamber
2nd chamber
From field
To stream
Outlet to distribution tile

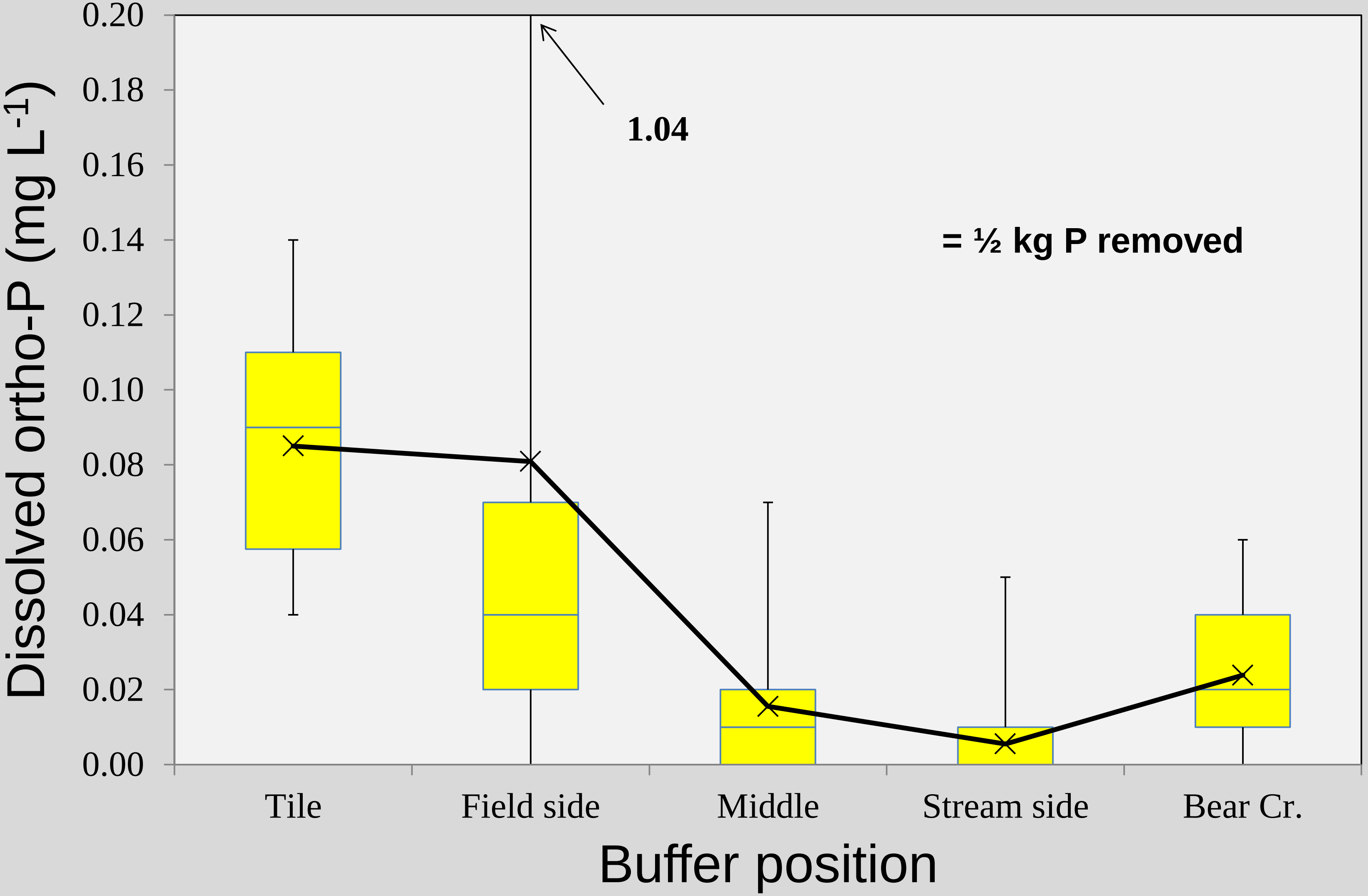
Tile Flow Diverted or Discharged to Stream



Nitrate Removed by Buffer



P Removal in 2012



Economics

- Assuming a 20 year life expectancy, the total cost of the installation at Bear Creek would be $5,188 over 20 year or $259 per year.
- Our first three years of monitoring at Bear Creek showed an annual removal rate of 168 kg (371 lbs) of nitrate-N.
- Thus, the cost per kg N removed for this prototype system was $1.54 per kg nitrate-N removed. These prices are very competitive with estimates for other nitrate removal practices such as constructed wetlands and fall planted cover crops.

Potential Impact

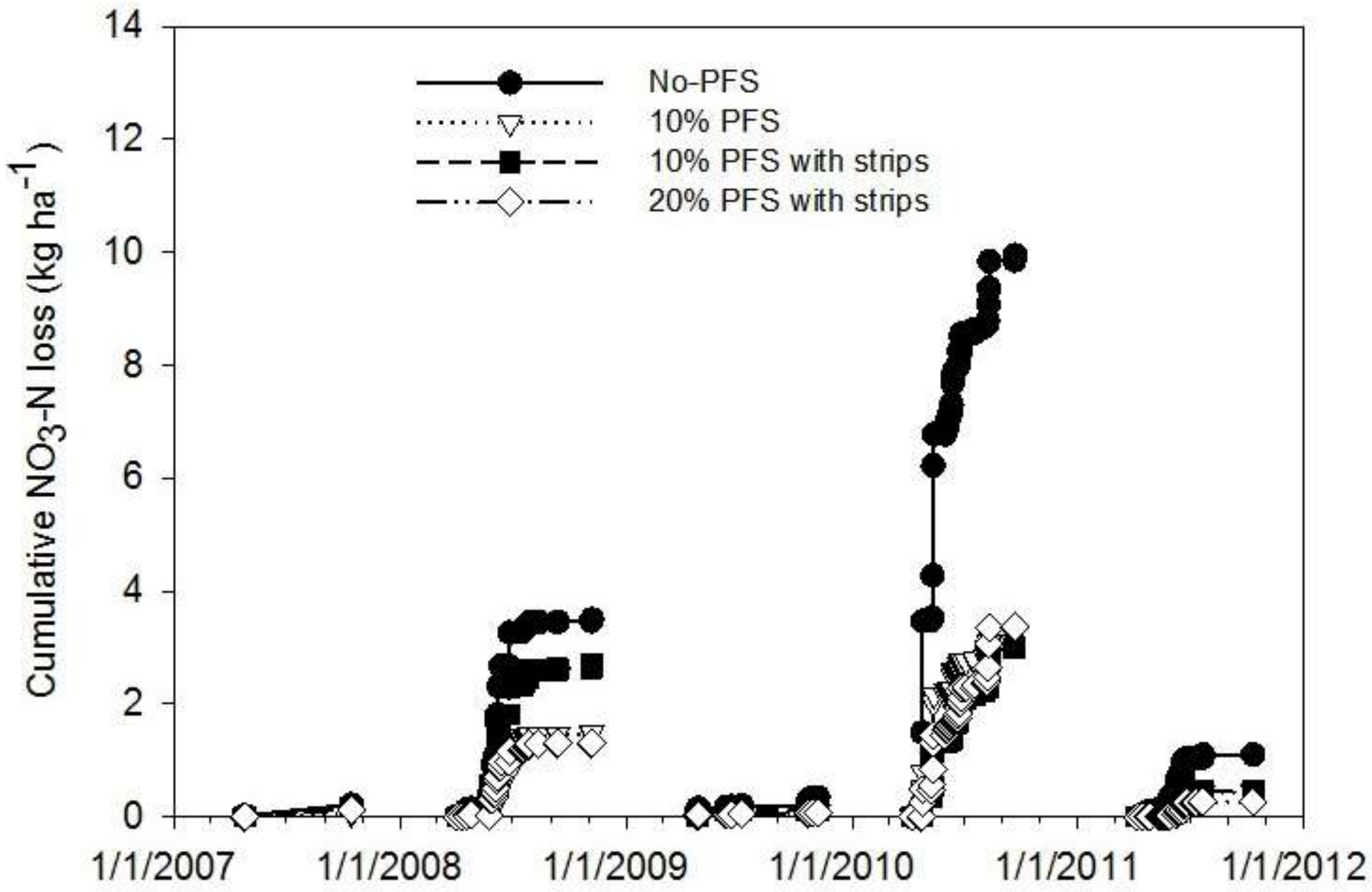
- We estimate that there currently are 380,000 acres of riparian buffers in Iowa
- If we assume that that only 20% of the buffers are suitable for this practice and use the nitrate removal rate found for the first three years at Bear Creek (1,164 lbs N mi^{-2} yr^{-1})
- We calculate that potentially 32 million lbs N yr^{-1} could be removed from Iowa streams using existing saturated buffers
- This is equivalent to about 5.3% of the current N load in Iowa streams
- In addition, these riparian buffers would continue to serve a significant role in phosphorus, sediment, and pesticide removal and would benefit wildlife

Sources: NASS, USEPA, ISU

Summary

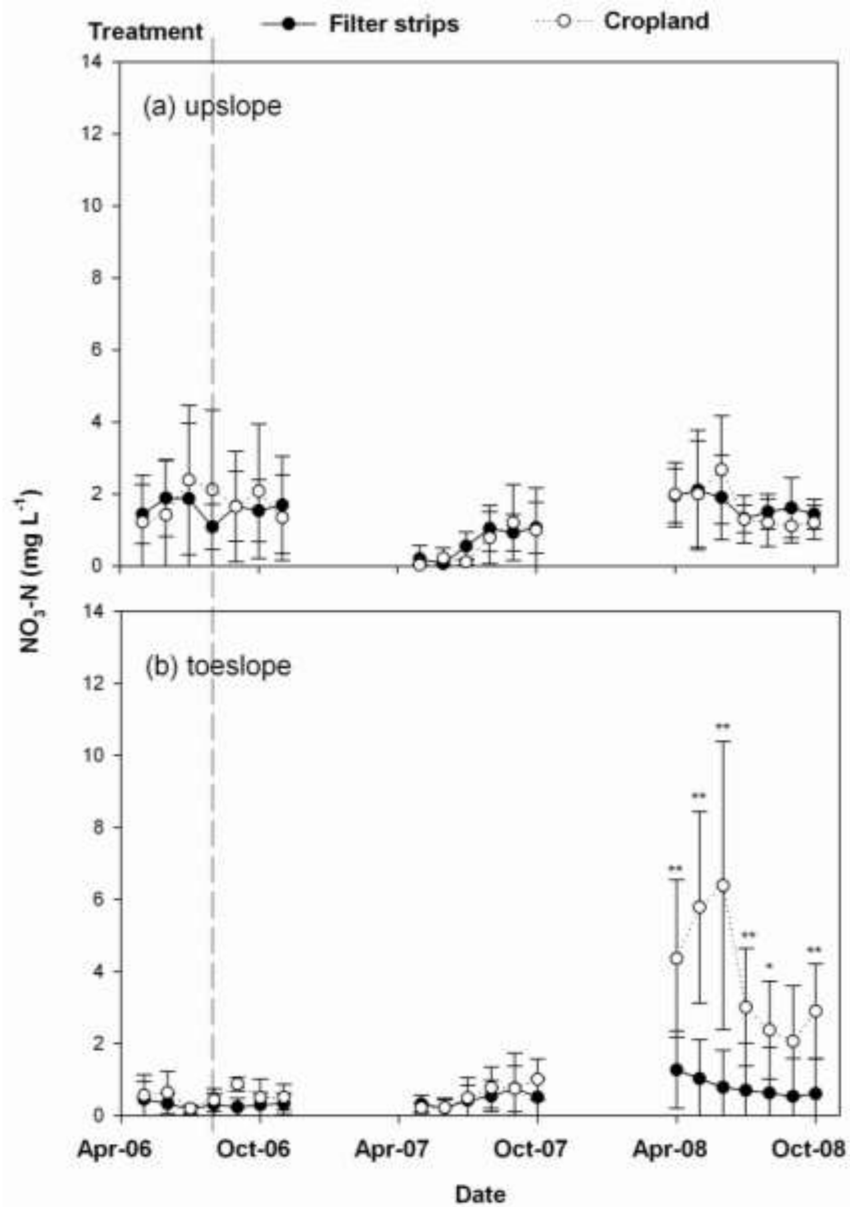
- **First three years shows re-saturating riparian buffers can remove all the nitrate diverted into them**
- **The cost of the practice is comparable to other N removal practices**
- **Additional studies to focus on hydrology, N fate, greenhouse gasses, vegetation impacts, and stream bank stability**
- **Interim Conservation Practice Standard 739 – Vegetated Subsurface Drain Outlet**

Nitrate-N Loss in Runoff (2007-2011)



Zhou et al., 2014

Nitrate-N Concentrations in Groundwater

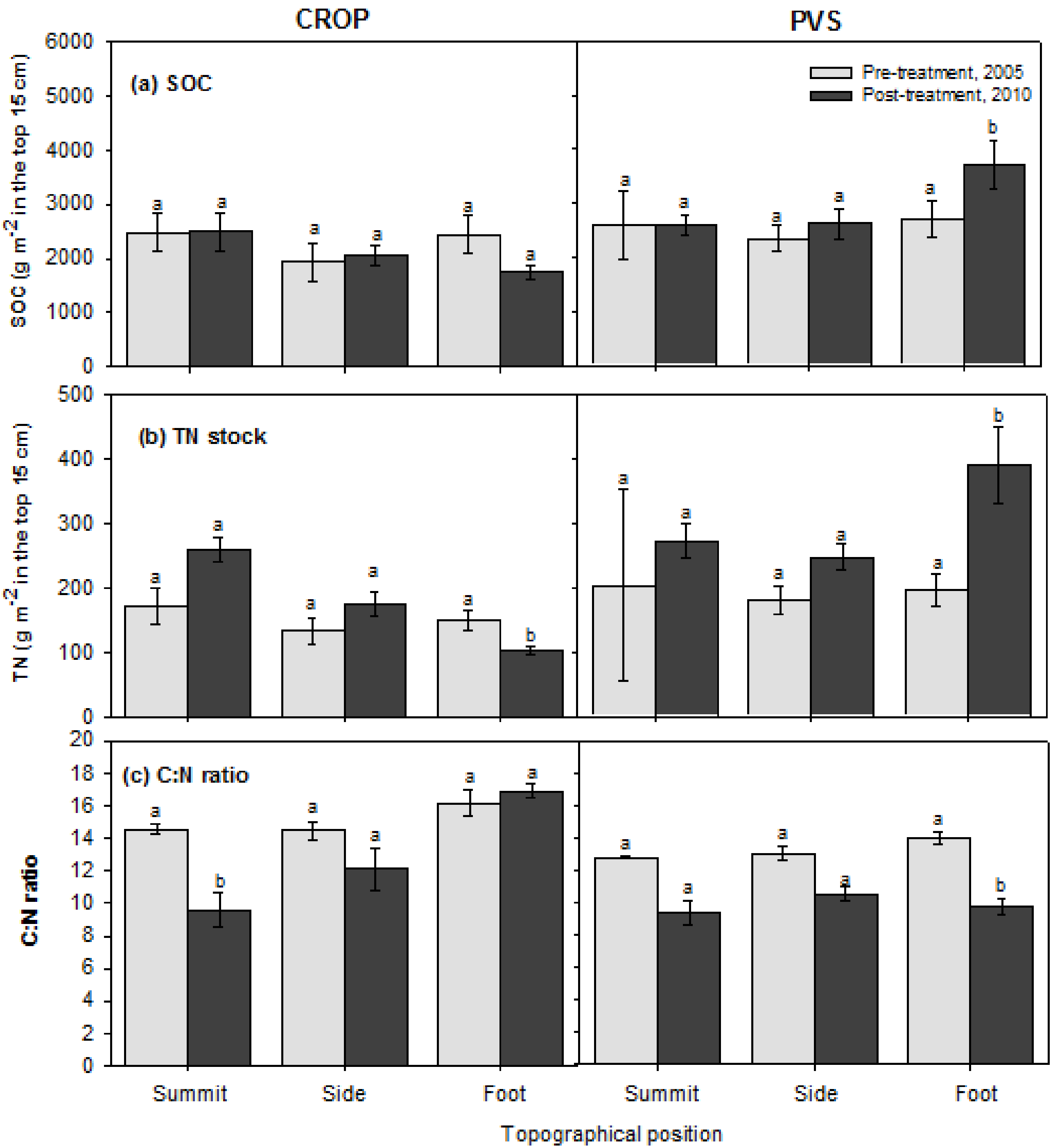


NO_3-N concentrations in shallow groundwater at (a) upslope and (b) toeslope positions. Error bars denote the standard deviation of the replicates. Statistical difference of mean nitrate concentration between treatments (grass filters vs. cropland) was indicated for each monitoring period using two significant levels (** $p < 0.05$, * $p < 0.1$).

Site History

- Watersheds under primarily bromegrass cover until fall 2006
- Watershed instrumentation: spring 2005
- Pre-treatment data collection: 2005 – 2006 field seasons
- Treatment establishment: fall 2006 & spring 2007
  - Soybean planted in 2007
  - Prairie strips sown in July 2007
- No-till corn-soybean rotation in cropped areas

Soil Carbon and Nitrogen



Experimental Watershed Treatments

12 watersheds: