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

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

*Load reduction not concentration reduction

**Concentration reduction of that water interacts with active zone below the buffer
<table>
<thead>
<tr>
<th><strong>Phosphorus Reduction Practices</strong></th>
<th>Practice</th>
<th>% Phosphorus-P Reduction [Average (Std. Dev.)]</th>
<th>% Corn Yield Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phosphorus Management</strong></td>
<td>Producer does not apply phosphorus until STP drops to optimal level</td>
<td>17 (40)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No-till (70% residue) vs. conventional tillage (30% residue)</td>
<td>90 (17)</td>
<td>-6 (8)</td>
</tr>
<tr>
<td></td>
<td>Cover Crops (Rye)</td>
<td>29 (37)</td>
<td>-6 (7)</td>
</tr>
<tr>
<td><strong>Land Use</strong></td>
<td>Perennial – Land retirement</td>
<td>75 (-)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pasture</td>
<td>59 (42)</td>
<td></td>
</tr>
<tr>
<td><strong>Edge-of-Field</strong></td>
<td>Buffers</td>
<td>58 (32)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Terraces</td>
<td>77 (19)</td>
<td></td>
</tr>
</tbody>
</table>

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

Buffer Zone

Stream
Actual Flow to Buffer

Buffer Zone

Stream
Potential Buffer Design

Stream

Buffer Zone
Potential Buffer Design

Stream

Buffer Zone
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

![Cumulative rainfall graph showing annual rainfall for years 2008, 2009, 2010, and 2011 compared to a 30-year average. The graph plots cumulative rainfall in inches against months from April to November.]
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)

Zhou et al., in press

>90% Reduction in TP export from watersheds with prairie filter strips
Total Nitrogen Loss in Runoff (2007-2011)

Zhou et al., 2014

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

<table>
<thead>
<tr>
<th>Annualized Total Costs 1</th>
<th>Higher Quality Land (CSR 83)</th>
<th>Medium Quality Land (CSR 73)</th>
<th>Lower Quality Land (CSR 60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per treated acre 2</td>
<td>~ $40</td>
<td>~ $30</td>
<td>~ $24</td>
</tr>
<tr>
<td>Cost per treated acre with CRP 3</td>
<td>$5</td>
<td>$4</td>
<td>$3</td>
</tr>
</tbody>
</table>

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

Keep in mind that cost scale with opportunity costs

Site prep & planting costs...

≤ 10% of total cost

Opportunity Cost of land = foregone rent or revenue

Management costs...

~ 10% - 15% of total cost

Upwards of ~ 90% total cost
Integrating prairie into crop fields can blur the lines between production and conservation lands...
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?
Tile Flow Diverted or Discharged to Stream

Flow from 10.1 ha field (mm)

Year

2011
198
111
56%

2012
138
81
59%

2013
429
138
32%

Flow from 25 ac field (in)
Nitrate Removed by Buffer


Nitrate load (kg)

- 2011: ~110 kg
- 2012: ~110 kg
- 2013: ~176 kg
P Removal in 2012

Dissolved ortho-P (mg L⁻¹)

Buffer position

Tile  Field side  Middle  Stream side  Bear Cr.

1.04 = ½ kg P removed
Economics

- Assuming a 20 year life expectancy, the total cost of the installation at Bear Creek would be $5,188 over 20 years 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 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
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:

0%  10%  10%  20%

corn - soybean row crops, ZERO TILLAGE
reconstructed prairie