Nitrate-nitrogen export in Lyons Creek and the Boone River

Iowa Water Conference
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Charles Ikenberry
Keith Schilling
Outline

- Background
- Data analysis (2009-2013)
  - Water yields, concentrations, loads
  - Trends/patterns
- Context
- Paired watersheds - How paired is paired?
- Minimum detectable change
Nitrate-nitrogen export in Lyons Creek and the Boone River
Data collection

- Three tile drain outlets in Lyons Creek
- Each tile outlet discharges to small tributary headwater
- Lyons Creek is a 11,200 acre HUC-12
Data collection

- Boone River downstream of Webster City
- Drainage area = 900 sq miles (580,000 acres)
## Watershed characteristics

<table>
<thead>
<tr>
<th></th>
<th>LCR3T</th>
<th>LCR4T</th>
<th>LCR5T</th>
</tr>
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<tbody>
<tr>
<td><strong>Area (acres)</strong></td>
<td>1,847</td>
<td>642</td>
<td>2,696</td>
</tr>
<tr>
<td><strong>Row crops (% of subbasin)</strong></td>
<td>93.1</td>
<td>92.1</td>
<td>90.4</td>
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<td><strong>Average soil texture (% of subbasin)</strong></td>
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<td>Sand</td>
<td>21.9</td>
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<td>Silt</td>
<td>40.9</td>
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<td>Clay</td>
<td>37.2</td>
<td>35.5</td>
<td>36.0</td>
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<td>***Organic matter</td>
<td>5.62</td>
<td>5.89</td>
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<tr>
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<td>&lt;1%</td>
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<td><strong>Slope classification (% of subbasin)</strong></td>
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<tr>
<td>0-2%</td>
<td>45.8</td>
<td>44.1</td>
<td>41.7</td>
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<tr>
<td>2-5%</td>
<td>51.3</td>
<td>49.4</td>
<td>52.7</td>
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RESULTS

Nitrate-nitrogen export in Lyons Creek and the Boone River
Flow patterns (water yield) in tiles and Boone are nearly identical.

Water yields highest April-July

Water yields do not always track rainfall
- Nitrate concentrations in tiles higher than in Boone (in-stream removal/dilution)
- Abnormally large spike in 2013

Extreme low flow in Q4 2013
Flow (mm day⁻¹)

Flow Exceedance (%)

High Flows

Moist Conditions

Mid-range Flows

Dry Conditions

Low Flows

59% of NO₃-N export

LCR3T

LCR4T

LCR5T

Boone
85% of NO₃-N export
98% of NO$_3$-N export
• 4T had highest water yield and NO$_3$ losses
• 3T had lowest
• 2011 → 2012 → 2013
• Compare 2009 & 2013
• Why?
Implications of patterns

• $\text{NO}_3^{-}-\text{N}$ transport is primarily hydrology-driven
  - Strategies must work during “wetter than average” conditions. Low flows insignificant
  - Hydrology doesn’t ALWAYS explain variation

• Patterns downstream mimic patterns in tile outlets
  - Efforts for nitrate reduction are most efficient at small watershed scale (500 to 3,000 acres)
Context of nitrate concentrations

Lyons Creek vs. Statewide Tile Nitrate as N 2014

Statewide Tile Nitrate Results
Lyons Creek Tiles

Courtesy of Iowa Soybean Association
Context of nitrate concentrations

Lyons Creek vs. Statewide Tile Nitrate as N 2014

Statewide Tile Nitrate Results

Lyons Creek Tiles

Courtesy of Iowa Soybean Association
## Losses/Exports

<table>
<thead>
<tr>
<th>Year</th>
<th>3T (in)</th>
<th>4T (in)</th>
<th>5T (in)</th>
<th>3T (lb/ac/yr)</th>
<th>4T (lb/ac/yr)</th>
<th>5T (lb/ac/yr)</th>
<th>3T (mg/L)</th>
<th>4T (mg/L)</th>
<th>5T (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>7.7</td>
<td>13.2</td>
<td>10.5</td>
<td>23.7</td>
<td>36.8</td>
<td>31.0</td>
<td>13.6</td>
<td>12.3</td>
<td>13.1</td>
</tr>
<tr>
<td>2010</td>
<td>16.1</td>
<td>27.3</td>
<td>19.4</td>
<td>35.6</td>
<td>66.2</td>
<td>49.1</td>
<td>9.8</td>
<td>10.7</td>
<td>11.1</td>
</tr>
<tr>
<td>2011</td>
<td>6.8</td>
<td>8.0</td>
<td>7.6</td>
<td>24.8</td>
<td>31.6</td>
<td>28.3</td>
<td>16.0</td>
<td>17.4</td>
<td>16.5</td>
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<tr>
<td>2012</td>
<td>0.9</td>
<td>1.0</td>
<td>1.2</td>
<td>2.9</td>
<td>5.2</td>
<td>6.5</td>
<td>13.7</td>
<td>23.6</td>
<td>23.2</td>
</tr>
<tr>
<td>2013</td>
<td>6.0</td>
<td>10.8</td>
<td>9.7</td>
<td>42.0</td>
<td>93.1</td>
<td>55.7</td>
<td>31.0</td>
<td>38.0</td>
<td>25.4</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
<td>12.1</td>
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<td>46.6</td>
<td>34.1</td>
<td>16.8</td>
<td>20.4</td>
<td>17.9</td>
</tr>
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### 5-Year Averages

- **Water Yield**: 7.5 in, 12.1 in, 9.7 in
- **Nitrate Losses**:
  - 3T: 25.8 lb/ac/yr, 46.6 lb/ac/yr, 34.1 lb/ac/yr
  - 4T: 16.8 mg/L, 20.4 mg/L, 17.9 mg/L

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Iowa State University

Agricultural and Biosystems Engineering
Nitrate loss context and “carryover”

Harvested N assumes corn-soybean rotation; 15.5% and 13% moisture contents, 1.2% and 6.2% N content, respectively (Christianson et al., 2012)
Nitrate loss context and “carryover”

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Context of nitrate concentrations

- Relationship with fertilizer application

Lawlor, 2008

Iowa Nutrient Reduction Strategy, 2013
Context of nitrate concentrations

• Relationship with fertilizer application

Lawlor, 2008

Iowa Nutrient Reduction Strategy, 2013
Summary

- Patterns downstream follow same pattern as small, tile-drained watersheds

- Water yield (not necessarily rainfall) is primary driver

- Highest 10% of flows move 59% of nitrate!
- Highest 50% of flows move over 98% of nitrate!

- Nitrogen supply also important
  - Crop yields, fertilizer application, soil N cycle
Summary & Segway

- Monitoring revealed differences between tiles:
  - Flow, NO$_3$ conc, and loads highest at LCR4T
  - Lowest at LCR3T

- Why?
  - Natural variations?
  - Agronomic differences?
    - Tillage, fertilizer application, crop rotations
  - Different tile characteristics?
    - Depth, extents, spacing, surface inlets, etc.
42 km² watershed in Boone River basin
90% corn and soybean cultivation
Three drainage districts investigated:
1. LCR3T (600 ha)
2. LCR4T (250 ha)
3. LCR5T (1096 ha)

Objective: What is the suitability of using Lyons Creek in a paired watershed study to test the effectiveness of BMPs in tile-drained landscapes?
Intrinsic variability

Standard deviation increased with additional samples collected in 2011 and 2012
Cumulative correlation

<table>
<thead>
<tr>
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<th>3T-5T</th>
<th>4T-5T</th>
</tr>
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<tbody>
<tr>
<td>Total period</td>
<td>0.399</td>
<td>0.597</td>
<td>0.814</td>
</tr>
<tr>
<td>Mar-Jul</td>
<td>0.769</td>
<td>0.865</td>
<td>0.934</td>
</tr>
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</table>
Relation between sample pairs was improved during March to July period
Minimum Detectable Change

- MDC is the change needed to discern a significant difference before and after BMP implementation
- It is a function of the number of observations and the variance between treatment and control pairs
- We used the MDC in two ways: 1) assumed balanced design for MDC; 2) estimate number of samples to observe a 10% change
## MDC in NO$_3$-N Concentrations

<table>
<thead>
<tr>
<th>Control</th>
<th>Treatment</th>
<th>n</th>
<th>MDC (%)</th>
<th># of samples needed to see 10% change</th>
<th># of years to monitor (26 samples/yr)</th>
<th>n</th>
<th>MDC (%)</th>
<th># of samples needed to see 10% change</th>
<th># of years to monitor (13 samples/yr)</th>
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<tr>
<td>LCR3T</td>
<td>LCR4T</td>
<td>103</td>
<td>11.8</td>
<td>224</td>
<td>8.6</td>
<td>50</td>
<td>12.4</td>
<td>150</td>
<td>11.5</td>
</tr>
<tr>
<td>LCR3T</td>
<td>LCR5T</td>
<td>109</td>
<td>12.9</td>
<td>474</td>
<td>18.2 (subset)</td>
<td>50</td>
<td>10.5</td>
<td>61</td>
<td>4.7</td>
</tr>
<tr>
<td>LCR4T</td>
<td>LCR5T</td>
<td>103</td>
<td>7.0</td>
<td>35</td>
<td>1.3</td>
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- **Lowest MDC value**: The lowest MDC value is highlighted with a red circle.
- **MDC values are lower with fewer samples if Mar-Jul period used**.
- **High MDC = many years to detect 10% change**.
Lack of correlation affects the ability to detect changes

Correlation of 0.4 = MDC of 11.8%

Correlation of 0.81 = MDC of 6.9%
Why the variability?

- Variable fertilizer and manure applications
- Surface intakes
- Climate variability – extended period of drought in 2011 and 2012
- Proximity and size of the basins used
Paired basin selection and BMPS

- Utilizing LCR5T as control and LCR3T and LCR4T as treatment basins minimized MDC (avg. 7.8%)
- What BMPs are capable of producing a 7.8% change in nitrate concentration?
  - N fertilizer reductions (10-15%)
  - Cover crops (31%)
  - Treatment wetlands (52%) and bioreactors (43%)
  - Land use change (41-85%)
Conclusions from Paired Watershed Study

- Drainage districts are amenable to paired watershed analysis
- A sufficient calibration period has been conducted
- Lack of correlation among some treatment-control pairs will affect ability to detect change
- Focusing sample collection in Mar-Jul period will improve correlation and reduce MDC
- Future studies should wait to select treatment and control basins after calibration period
- Detecting 8% change in NO3-N will be possible in Lyons Creek districts with several BMPs
Headwater areas, including drainage districts, are the source of water for downstream areas. Nitrate concentrations decrease downstream in a predictable manner.
Contributions from headwater areas anchor the starting concentrations. A relatively minor reduction from the source results in major improvements downstream. This is good news.
Nitrate-Nitrogen Export: Magnitude and Patterns from Drainage Districts to Downstream River Basins

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Chris Jones (Iowa Soybean Association)
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