Nutrients and Gulf Hypoxia

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What is the problem?

• both local and downstream water quality problems from nitrate and total P
  - local: algal production due to P; drinking water for N
  - downstream: hypoxia in the Gulf of Mexico

• USEPA - nutrient criteria in surface waters
Hypoxic zone, 2014

Bottom-water Dissolved Oxygen – 2014

Distribution of bottom-water dissolved oxygen July 27-August 1 (west of the Mississippi River delta), 2014. Black line indicates dissolved oxygen level of 2 mg/L.

Data source: Nancy N. Rabalais, LUMCON, and R. Eugene Turner, LSU
Funding sources: NOAA Center for Sponsored Coastal Ocean Research and U.S. EPA Gulf of Mexico Program
Size of bottom-water hypoxia in mid-summer

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Funding sources: NOAA Center for Sponsored Coastal Ocean Research and U.S. EPA Gulf of Mexico Program
Gulf Hypoxia Action Plan 2008
for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and Improving Water Quality in the Mississippi River Basin
Progress?

• 2008 Action Plan had target date of 2015 for reaching a 2,000 square mile dead zone
  - driven by 45% nutrient load reductions

• on Feb. 12, 2015 new strategies were released
  - extended target date to 2035
  - to track progress and spur action, 20% reduction in nutrient loads by 2025
Mississippi River Basin Nitrogen
Spring nitrate (April, May, June)

Graph 1: Mississippi River at Grafton
- Water Flux (cm)
- Riverine Nitrate-N Flux (million metric tons N)

Graph 2: Ohio River at Grand Chain, IL
- Water Flux (cm)
- Riverine Nitrate-N Flux (million metric tons N)
Spring nitrate (April, May, June)

Spring Nitrate (tons N yr$^{-1}$)

- MRB
- Grafton and Ohio
Mississippi River Basin P

Water Flux (million m$^3$)

Riverine P Flux (million metric tons yr$^{-1}$)

Total P

Soluble reactive P

Annual N Fertilizer Applications

<table>
<thead>
<tr>
<th>Fertilizer (kg N ha(^{-1}))</th>
<th>from David et al. (2010)</th>
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<tbody>
<tr>
<td>0.0 – 11.2</td>
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<tr>
<td>11.3 – 27.2</td>
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<td>27.3 – 45.4</td>
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<td>45.5 – 65.9</td>
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<td>66.0 – 107.1</td>
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Tile drainage is concentrated in the corn belt

From David et al. (2010)
Drainage by tiles and ditches
Patterned tile systems
Nitrification

$\text{NH}_3 \rightarrow \text{NO}_3^-$

Transport in tile water
Surface Runoff
Embarras River - Camargo
<table>
<thead>
<tr>
<th>Water year</th>
<th>Nitrate N (mg N L$^{-1}$)</th>
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<tbody>
<tr>
<td>1993</td>
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<td>1995</td>
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<td>2011</td>
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<td>2013</td>
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<td>2015</td>
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Modeled January to June Nitrate Export

Best model includes fertilizer, sewage effluent, and tile drainage
Fate of N

- limited in-stream losses of nitrate during high flow periods
  - Lake Shelbyville
  - Saylorville Reservoir
- retention times too short
- spring nitrate, headed to Gulf
What can we do in agriculture?

• conservation practices that could help
  - nutrient-use efficiency (4Rs)
    • right source, rate, time, place
  - in-field management
    • less tillage, cover crops, perennials, land retirement
  - edge-of-field measures
    • buffers, bioreactors, wetlands, drainage
      water management, saturated
      buffers, modified channels
Annual ryegrass and radish - aerial seeding 09-08-12
Woodchip bioreactors
Biofuels reduce nitrate

Nitrate (mg N L$^{-1}$)

- C-C-S
- Miscanthus
- Switchgrass
- Prairie

Date

Jan-08    Jul-08    Jan-09    Jul-09    Jan-10    Jul-10    Jan-11    Jul-11    Jan-12    Jul-12    Jan-13    Jul-13    Jan-14    Jul-14    Jan-15
What’s making it difficult

• more intensive tile drainage
• warmer winters
• more intense winter/spring precipitation
• fall N in Illinois, Indiana, Ohio
• the intensity of corn/soybean agriculture across the Cornbelt
• many practices to reduce nutrient loss don’t increase yield
Job ahead for us to reduce nutrient losses

• 45% reductions in N and P will be quite difficult in upper MRB
• we haven’t really started
• variety of methods and costs
  - many or most unrelated to yields
• scale of problem is impressive
  - we want increased corn and soybean yields with limited nutrient losses