Spring Nutrient Flux to the Gulf of Mexico and Nutrient Balance in the Mississippi River Basin

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www.ipni.net
Introduction

- **Hypoxia Task Force Action Plans** - call for a 45% reduction in total N and total P loads via the Mississippi and Atchafalaya rivers to:
  - reduce summer hypoxia in the northern Gulf of Mexico
  - improve water quality throughout the MARB

- **Modeled nutrient loading and hypoxic area**
  - May to June total N load & ocean dynamics ($R^2 = 0.45$)
  - May nitrate-N load, 1978-2004 (included hindcasting; $R^2 = 0.82$)
    - Turner et al. 2006. Predicting summer hypoxia in the northern Gulf of Mexico… Marine Pollution Bull. 52:139-148
  - May nitrate-N load ($R^2 = 0.42$); May streamflow and May nitrate-N and Feb. TP ($R^2 = 0.60$ to 0.80)
  - May nitrate-N load vs. **hypoxic volume** ($R^2 = 0.58$)
Introduction

- Modeled nitrate loading or “yields” vs. nutrient use
  - March-June nitrate delivery to Gulf for 1990-2002 vs. “fertilizer N” runoff (59%), atmospheric nitrate deposition (17%), animal waste (13%), municipal waste (11%) ($R^2 = 0.65$)
  - April-July nitrate delivery ($R^2 = 0.86$)
  - January-June nitrate “yields” (i.e. mass loss per unit area, kg N ha$^{-1}$) for 1997-2006, 8 crops ($R^2=0.82$)
    - Nitrate yield = cm of river flow x ((0.0112 x kg fertilizer N ha$^{-1}$)$^{0.7783}$ + (0.1988 x kg N ha$^{-1}$ consumed by humans) + (0.21750 x fraction of county drained)
    - N inputs were not a good predictor of riverine nitrate N “yields”, nor were other N balances
    - greatest nitrate N “yields” corresponded to the highly productive, tile-drained cornbelt from southwest Minnesota and across Iowa, Illinois, Indiana, and Ohio
      - David et al. 2010. Sources of nitrate yields in the Mississippi River Basin. J. Environ. Qual. 39:1657–1667
Nutrient Loss Reduction Strategies in MARB

- Plans completed in 9 states, pending in 2 others
  - primarily focused on annual total N and total P loss reductions from agricultural and other lands to protect surface (and subsurface) water quality
  - BMP science to reduce annual N and P losses has been/is being evaluated and advocated
- Much of the N and P loss from agricultural fields is associated with peak flows and drainage events that pose risks for summer algae blooms and hypoxia
  - peak runoff and drainage usually occurs during spring in much of the MARB
- Should the agricultural BMP and nutrient loss reduction strategies center more on the **spring** (specifically April, May) nitrate-N and ortho-P losses?
Objectives

• For available data in MARB, 1987 to 2011:
  – compare April, May, and April plus May nitrate-N flux and ortho-P flux to northern Gulf of Mexico against:
    • Total N input (annual)
    • Fertilizer N input (annual)
    • Cropland area harvested
    • Crop harvest removal of N
    • Net annual N balance
    • Net annual N per cropland ha

• Data/information sources for MARB
  • Nutrient flux – USGS (B. Aulenbach et al. using LOADEST AMLE)
  • Crop harvested area – USDA NASS
  • Fertilizer consumption (annual) - AAPFCO & TFI
  • MARB nutrient metrics – IPNI NuGIS (includes 21 crops)
History

- Development began in 2006 (6-yr effort)
- Preliminary NuGIS – Summer of 2010
  - Bulletin & web tool
  - Reviewed and extensively revised
- Final version - Nov. 1, 2011
  - Improved accuracy
  - Export data files and maps
  - Data from 1987-2007; 2008-2011 added
  - Improved procedure for estimating nutrient removal by “other crops”

http://www.ipni.net/nugis
Methods – basic model

A simple partial nutrient balance algorithm

- Farm fertilizer
- Recoverable manure
- Biological N fixation

Not considered:
- Atmospheric deposition
- Nutrients in irrigation water
- Biosolids application
- Soil erosion
- Gaseous N emissions or leaching

1987 to 2007 in 5-yr increments set by Census of Agriculture (COA)
1987 Estimated N Removal to Use Ratio by Hydrologic Region

Nutrient Removal by Crops \( \frac{(\text{adj})}{(\text{Fertilizer} + \text{Recoverable Manure Nutrients} + \text{Legume N Fixation})} \)

<table>
<thead>
<tr>
<th>Hydrologic Region</th>
<th>RatioN</th>
</tr>
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<tbody>
<tr>
<td>#1</td>
<td>0.89</td>
</tr>
<tr>
<td>#2</td>
<td>0.82</td>
</tr>
<tr>
<td>#3</td>
<td>0.47</td>
</tr>
<tr>
<td>#4</td>
<td>0.75</td>
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<tr>
<td>#6</td>
<td>0.73</td>
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<tr>
<td>#7</td>
<td>0.73</td>
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<tr>
<td>#8</td>
<td>0.96</td>
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<tr>
<td>#9</td>
<td>0.83</td>
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<tr>
<td>#10</td>
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<tr>
<td>#11</td>
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<td>#16</td>
<td>0.94</td>
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<tr>
<td>#17</td>
<td>0.81</td>
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<tr>
<td>#18</td>
<td>0.68</td>
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</tbody>
</table>

Legend:
- RatioN 0.0 - 0.30: green
- RatioN 0.31 - 0.50: dark green
- RatioN 0.51 - 0.70: yellow-green
- RatioN 0.71 - 0.90: light yellow
- RatioN 0.91 - 1.10: yellow
- RatioN 1.11 - 1.50: orange-yellow
- RatioN 1.51 - 3.00: orange
- RatioN > 3.00: red
<table>
<thead>
<tr>
<th>Independent variable</th>
<th>NO$_3$-N flux</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>April</td>
</tr>
<tr>
<td>Total N input</td>
<td>--</td>
</tr>
<tr>
<td>Harvest removal of N</td>
<td>--</td>
</tr>
<tr>
<td>Cropland harvested</td>
<td>--</td>
</tr>
<tr>
<td>Net annual N balance</td>
<td>--</td>
</tr>
<tr>
<td>Net annual N per planted cropland hectare</td>
<td>--</td>
</tr>
<tr>
<td>Fertilizer N input</td>
<td>--</td>
</tr>
</tbody>
</table>

* * Slope of the regression is statistically significant at a p-value $\leq 0.05$ or a p-value $\leq 0.01$ (after rounding), respectively, when all data are included; 

* * * Statistical significance of the slope is conditional upon removing either a suspected outlier or a suspected influential point; 

** -- Not significant under either of the cases above
May NO₃-N Flux vs. Total N Inputs: All data considered

- Regression
- 95% Confidence Interval
- 95% Prediction Interval

Adj. R Squared = 0.457
p-value = 0.0273
Y = -107 + 21.027X
Slope 95% Confidence = 21.027 +/- 17.894
## Summary of Regression Analyses:
### MARB Ortho Phosphate-P Flux

<table>
<thead>
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<th>Ortho phosphate-P flux</th>
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<tr>
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<td>April</td>
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<tr>
<td>Total P input</td>
<td>--</td>
</tr>
<tr>
<td>Harvest removal of P</td>
<td>*</td>
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<tr>
<td>Cropland harvested</td>
<td>*</td>
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<tr>
<td>Net annual P balance</td>
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<td>Net annual P per planted cropland hectare</td>
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<td>Fertilizer P input</td>
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Interpretation

• Total fertilizer input, total nutrient input, and nutrient removal with harvest may be useful for explaining nutrient fluxes in May, or April and May combined.

• For P flux only:
  – P removal with harvest may be useful for explaining P flux in April.
  – The amount of cropland harvested may be useful for explaining P flux in April, May, and April and May combined.
Future Plans

• Continue these analyses as the NuGIS database is populated with more annual data

• Work with agribusiness, university, government, and conservation partners to advance 4R Nutrient Stewardship implementation and actions to increase crop yields and in-field nutrient retention

• Monitor trends in nutrient use and management metrics

• Encourage documentation and tracking of nutrient performance by farmers on individual fields and farms