Managing Legacy Phosphorus to Sustain Agriculture and Protect Water Quality

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Agriculture and “Legacy Phosphorus”

Phosphorus that has accumulated in soils to values that are of concern for water quality and agricultural sustainability - from historic applications of inorganic fertilizers and organic residuals (manures, biosolids composts…)

[Map of excess manure phosphorus assuming no export of manure from farms, 1997]

[Graph showing Delaware fertilizer sales (1996-2012) with a note on the DE 1999 Nutrient Management Law]

Source: EWG, 2010
Driving Forces to Address the Legacy P Challenge

**Environment (water quality):**
- Increasing regulation of P (TMDLs)
- Growing pressure to eliminate P Index, replace with STP as regulatory tool

**Food security:**
- Agricultural profitability/sustainability
- Natural resource utilization ("peak P")
Total Maximum Daily Loads (TMDLs)
Chesapeake Bay, USA – 2025 Goals

Nitrogen
Simulated Nitrogen Loads Delivered to the Bay by Jurisdiction*

Phosphorus
Simulated Phosphorus Loads Delivered to the Bay by Jurisdiction*

Sediment
Simulated Sediment Loads Delivered to the Bay by Jurisdiction*

* Loads simulated using 5.3.2 version of Watershed Model and wastewater discharge data report by Bay jurisdictions.
Delmarva farm fields hide a pollution time bomb for Chesapeake Bay

May 26, 2013 | 1 Comments

SALISBURY — It's Delmarva's version of the circle of life.

Farmers grow corn and soybeans to feed their chickens. The birds, in turn, create the manure that fertilizes the corn and soybeans.
Global Food Security

Our Nutrient World
The challenge to produce more food and energy with less pollution

(Sutton et al., 2013)
Prepared by the Global Partnership on Nutrient Management in collaboration with the International Nitrogen Initiative

UNEP Global Partnership Nutrient Management, 2013

“Peak P”

Global Production & Reserves of P

(Cordell et al, 2009)

(Scholz and Wellmer, 2013)
Management/Remediation Options for Legacy Phosphorus

**Option #1:**

Cease P applications to “high P” soils, rely on crop removal to slowly deplete “soil P” to acceptable values. Use conservation practices to minimize soil loss, and:

- Establish soil P criteria for problem/success
- Quantify timelines to achieve success, as function of soil type, cropping systems…
- Focus incentives and/or mandates that foster soil P depletion on high P loss areas
Criteria for Success

- **Agronomic:** clear scientific consensus on soil P values needed for *economically optimum* crop production, with low environmental risk

- **Environmental:** continue to be mixed views (scientific, regulatory) on best use of soil P criteria to assess risk of P loss to water

✓ **Approaches:**
  - “Soil test” P (upper limit; e.g., DE = 150 mg M3P/kg)
  - “Soil P saturation” (threshold %)
  - Water soluble P (critical values?)
  - “P Site Index” (site, transport, soil, management)
Cease P Applications?

(Sims et al, 2000; n=465)
Cease P Applications?  
(Arable crops – Maize/Soy)

Average annual crop P removal of ~15 kg P/ha/yr. (Kamprath, 1999; McCollum, 1991)

Soil P depletion slopes based on 14 and 30 year NC field studies with maize and soy.
Managing Legacy Soil Phosphorus in Irish Grassland Soils (Murphy et al., 2013)

Cease P Applications?
UD “Long-Term” STP Depletion Studies

Mehlich 3 P (mg/kg)

- Corn-Soy rotation
- Silt loam soil
- No P added
- M3-P: 93 mg/kg

\[ y = -3.6x + 7222 \]
\[ r^2 = 0.76 \]

Binford, et al., in preparation, 2013

M3-P Critical Values - Chesapeake Bay Watershed
UD “Long-Term” STP Depletion Studies

Binford, et al., in preparation, 2013

Mean Corn Grain Yield: 9.7 Mg/ha (154 bu/ac)
Mean Soybean Yield: 4.4 Mg/ha (65 bu/ac)
UD “Long-Term” STP Depletion Studies

<table>
<thead>
<tr>
<th>STP Target</th>
<th>Corn/Soy Yield (Mg/ha)</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>10/4</td>
<td>21</td>
</tr>
<tr>
<td>30</td>
<td>14/5</td>
<td>15</td>
</tr>
<tr>
<td>50</td>
<td>10/4</td>
<td>15</td>
</tr>
<tr>
<td>50</td>
<td>14/5</td>
<td>11</td>
</tr>
</tbody>
</table>

Binford, et al., in preparation, 2011
Delaware Irrigation Initiative: Improving Nutrient Use Efficiency, Increasing Farm Profitability and Protecting Water Quality by Expanding Irrigation Use

Efficient Irrigated Crop Management Systems
- Stabilize crop yields, increase farm income
- Increase nutrient uptake (N, P)
- Intercept and use groundwater nitrate
- Build soil organic matter (sequester carbon?)

Annual Corn P Removal

<table>
<thead>
<tr>
<th></th>
<th>Grain Yield</th>
<th>P Uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated</td>
<td>16 Mg/ha</td>
<td>41 kg/ha</td>
</tr>
<tr>
<td>Dryland</td>
<td>6 Mg/ha</td>
<td>15</td>
</tr>
</tbody>
</table>

Grain Yield: 16 Mg/ha
P Uptake: 41 kg/ha
Grain Yield: 6 Mg/ha
P uptake: 15

Graph showing annual corn P removal with data points indicating:
- Non-Irrigated Corn-Soy-Corn
- Irrigated Corn-Soy-Corn
- Irrigated Corn-Wheat/Soy-Corn

Graph showing Mehlich 3 P (mg/kg) over years 2010 to 2050 with labels:
- DNMC "High STP"
- UD Optimum STP
Managing Ryegrass-Bermudagrass to Phytoremediate High P Soils

Crop P Uptake

<table>
<thead>
<tr>
<th>Fertilizer N Rate (kg/ha)</th>
<th>Ryegrass</th>
<th>Bermuda</th>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>112</td>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>168</td>
<td>120</td>
<td>80</td>
</tr>
</tbody>
</table>

Soil Test (M3-P)

<table>
<thead>
<tr>
<th>Poultry Litter Rate (2004-2007, Mg/ha)</th>
<th>2007</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>200</td>
<td>120</td>
</tr>
<tr>
<td>18</td>
<td>400</td>
<td>300</td>
</tr>
</tbody>
</table>
Environmental Policy Impacting Agricultural Sustainability?

Trends in soil P status in Ireland between 2007 and 2011 (for soils from commercial farms submitted to Teagasc for analysis).

(Murphy et al., 2013)
Management/Remediation Options for Legacy Phosphorus

**Option #2:**
Continue with “unavoidable” P applications to cropland (manures, biosolids), manage risks associated with all P sources and P transport to water
UD “Long-Term” STP Depletion Studies

- **Manure P Added (kg/ha)**
  - 1998: 84
  - 2000: 132
  - 2002: 68
  - 2004: 65
  - 2006: 67
  - 2008: 46

- **Corn/Soy Yield (Mg/ha)**
  - 2004: 8.2
  - 2008: 8.2

- **Field P Balance (kg/ha)**
  - **No P**
    - Added: 0
    - Crop Removal: 269
    - 10 Yr Balance: -269
  - **+Manure P**
    - Added: 443
    - Crop Removal: 253
    - 10 Yr Balance: +190

Source: Binford, et al., 2011
Conclusions

- Legacy P in soils presents a long-term (decades?) risk to water quality and agricultural sustainability, especially for animal-based agriculture.

- Science-informed strategies to manage legacy P can – and should - be developed and systematically implemented that sustain (increase?) agricultural profitability and reduce water quality impacts.

- SERA-17 will undertake, in 2014, a systematic review – on legacy P management, including potential action items – and encourages your input into our efforts (contact jtsims@udel.edu)!