Managing Phosphorus
4R
Crops and Environment

Tom Bruulsema, Phosphorus Program Director
The International Plant Nutrition Institute is supported by leading fertilizer manufacturers.

Formed in 2007 from the Potash & Phosphate Institute, its mission is to develop and promote science for responsible management of crop nutrition.
Outline

1. Sustainable Phosphorus
2. Lake Erie
3. Effective Practices

http://phosphorus.ipni.net
Phosphorus Sustainability Initiatives:
• resource consumption & use efficiency
• trace element loading
• water quality impacts

August 16-20, 2016
Kunming, Yunnan, China

5th Sustainable Phosphorus Summit 2016 (SPS 2016)
Phosphorus Issues

- Eutrophication
- Hypoxia
- Harmful algal blooms
- Deficiencies and excesses

- Finite resource
- Declining quality of reserves
As a sustainability system, 4R Nutrient Stewardship needs METRICS.
Nutrient Stewardship Metrics for Sustainable Crop Nutrition

**Enablers (process metrics)**
- Extension & professionals
- Infrastructure
- Research & innovation
- Stakeholder engagement

**Actions (adoption metrics)**
- Cropland area under 4R [Requires regional definitions of 4R practices]

**Outcomes (impact metrics)**
1. Farmland productivity
2. Soil health
3. Nutrient use efficiency
4. Water quality
5. Air quality
6. Greenhouse gases
7. Food & nutrition security
8. Biodiversity
9. Economic value
4R Outcome Metrics are influenced by 4R and more.
The outcomes of nutrient stewardship are influenced by crop and pest management, and by soil and water conservation practices in the context of changing weather and climate.
High-yield crops take up large amounts of P. Most of it is removed with grain harvest.

Maize grain yield
12 t/ha
Illinois, 2010

2010 data from two sites and six hybrids
Research shows potential for altered P placement needs in high density high yield maize.

Banding P fertilizer 10-15 cm deep

Yield, t/ha
11.7
12.0
13.0

none  15cm beside  under

Dr. F.E. Below, University of Illinois
Crop yield contribution from phosphorus use is very substantial in the long term.

1. Crop removal is increasing with yield.
2. Application rates are falling short of crop removal.
Ontario’s P balance: manure is a bigger proportion of the input than in the Western Lake Erie watershed.
Ontario has more soils very high in P than Ohio

http://soiltest.ipni.net
Ontario soil test P is declining

http://soiltest.ipni.net
Soil test P stratifies when moldboard plowing stops

Soil test P distribution with depth in a long-term tillage experiment on a poorly drained Chalmers silty clay loam soil near West Lafayette, Indiana. Moldboard and chisel plots were plowed annually to a depth of 20 cm. Data from Gál (2005) and Vyn (2000). Fertilizer P applied broadcast.
Soil P stratification after 25 years in PA


Duiker and Beegle, 2006
Soil P stratification after 25 years in PA


Duiker and Beegle, 2006
Environmental Impact

• Eutrophication
• Hypoxia
• Harmful Algal Blooms

Photo credit: Carrie Vollmer-Sanders, The Nature Conservancy
Lake Erie total P loads 1967-2013

Total P load does not explain the increase in algal blooms since ~1995

Maccoux MJ et al J Great Lakes Res (2016), http://dx.doi.org/10.1016/j.jglr.2016.08.005
Lake Erie mean DRP loads 2009-2013

Maccoux MJ et al J Great Lakes Res (2016), http://dx.doi.org/10.1016/j.jglr.2016.08.005
Western Lake Erie: dissolved P trends increasing since 2002

1. David Baker & Laura Johnson, National Center for Water Quality Research, Tiffin, OH
Fertilizer P is Soluble P

- MAP (11-52-0) has water solubility of 370 g/L
  - = 84 grams P per litre
  - = 84,000 mg P per litre

- Maumee river target for DRP = 0.047 mg P per litre

- Targets for Lake Erie:
  - Western Basin – 0.012 mg/L
  - Central Basin – 0.006 mg/L
  - Eastern Basin – 0.006 mg/L
Ohio P loss monitoring at edge of field

Funding Sources:
4R Research Fund
USDA-ARS: USDA-Agriculture Research Service
CEAP: Conservation Effects Assessment Project
EPA: DW-12-92342501-0
Ohio Agri-Businesses
Ohio Corn and Wheat Growers
CIG: 69-3A75-12-231 (OSU)
CIG: 69-3A75-13-216 (Heidelberg University)
MRBI: Mississippi River Basin Initiative
The Nature Conservancy
Becks Hybrids/Ohio State University
Ohio Soybean Association

Kevin King, USDA-ARS, Columbus, Ohio
**Right Rate**

**Spring (Mar through Jul)**

- DRP load (kg/ha)
- TP load (kg/ha)

**Water Year (Oct through Sep)**

- DRP load (kg/ha)
- TP load (kg/ha)

Kevin King, USDA-ARS, Columbus, Ohio
When is the right time?

Kevin King, USDA-ARS, Columbus, Ohio
Right Timing

- Greatest potential for surface and tile losses occurs with fall and winter application.
- Applying P in spring or after wheat harvest seems to minimize surface and tile losses.

Kevin King, USDA-ARS, Columbus, Ohio
1. Intense rainstorms following broadcast of P can generate high P concentrations in runoff even though losses are small relative to amount applied.

2. As the time intervals increase between surface broadcast P applications and runoff-producing rainfall events, DRP concentrations spike less.
Broadcast? at the right time to avoid runoff
Right Place – in the soil, not on the soil

**Soil type:** Silt loam  
**Tile depth:** 90 cm  
**Soil test P:** 30 ppm Mehlich-3P  
**Tillage:** No-till

### 2014 management

- **May 6th** – Applied MAP @ 45 kg P/ha
- **May 8th** – Tilled field TD1 (disc)  
  (TD2 remained no-till)

Compared P transport out of the tile drains

1. Broadcast P incorporated versus
2. Broadcast P not incorporated

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*Williams and King, USDA-ARS, Columbus, Ohio*
Before P application & tillage (April 28th)

Discharge (mm)

After P application & tillage (May 12th)

P incorporated  P not incorporated

Discharge (mm)

Incorporating reduced DRP loss from 0.27 to 0.04 lb P$_2$O$_5$ per acre

Williams and King, USDA-ARS, Columbus, Ohio
Some growers fertilize all their crops in bands near the seed.
Fall
Strip-till Banding

- Puts the P in the soil
- Keeps residue on the soil
- RTK GPS for precision planting

Greg LaBarge, Ohio State University Extension
Strip tillage with granular placement puts P in the right place – and controls erosion.
Defining 4R phosphorus practices at the continental scale.
4R P Practices - Participating Scientists

1. Brian Arnall, Oklahoma State U
2. Doug Beegle, Penn State U
3. Don Flaten, U of Manitoba
4. Laura Good, U of Wisconsin
5. Kevin King, USDA-ARS, Columbus, OH
6. Quirine Ketterings, Cornell U
7. Josh McGrath, U of Kentucky
8. Antonio Mallarino, Iowa State U
9. Rao Mylavarapu, U of Florida with input from other colleagues.
10. David Mulla, U of Minnesota
11. Nathan Nelson, Kansas State U
12. Keith Reid, Agriculture and Agri-Food Canada
13. Nathan Slaton, U of Arkansas
14. Charles Shapiro, U of Nebraska
15. Andrew Sharpley, U of Arkansas
16. Doug Smith, USDA-ARS, Temple, TX
17. Ivan O’Halloran, U of Guelph
18. Deanna Osmond, North Carolina State U
19. David Tarkalson, USDA-ARS, Kimberly, ID
Regions and Cropping Systems

1. Western Corn and Soybean
2. Eastern Cereals and Oilseeds
3. Wheat in the Great Plains
4. Irrigated Potatoes in the Northwest
5. Rice
6. Irrigated vegetables

4R Phosphorus Practices for Eastern Crops (including Ontario)

• Basic
  – Source: known or guaranteed analysis
  – Rate: recommended soil sampling and soil test interpretation, no more than 3 years crop removal
  – Timing: avoid frozen and snow-covered soils
  – Placement: subsurface band for no-till; on surface only when risk index is low

• Intermediate
  – Source: manure sampled for nutrients
  – Rate: as in basic, plus: P index used when recommended, no more than 2 years crop removal
  – Timing: close to or at planting, P Index
  – Placement: use starter where recommended, P Index
4R Phosphorus Practices for Eastern Crops (including Ontario)

- Advanced
  - Source: as in intermediate
  - Rate: as in intermediate, plus: zone-specific based on loss potential and crop response, no more than current crop’s needs, P Index
  - Timing: as in intermediate, plus: follow P Index
  - Placement: as in intermediate, plus: follow P Index

ADAPTIVE MANAGEMENT
- Decisions are site-specific and adaptive to changing conditions. Not everything can be written down.
## 4R efficacy for reducing P loss, % reduction
- ranges found in field experiments across the USA and Canada

<table>
<thead>
<tr>
<th>Practice</th>
<th>Dissolved P</th>
<th>Particulate P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Rate</td>
<td>60 to 88%</td>
<td>negligible</td>
</tr>
<tr>
<td>Time</td>
<td>41 to 42%</td>
<td>negligible</td>
</tr>
<tr>
<td>Place</td>
<td>20 to 98%</td>
<td>-60% to NS</td>
</tr>
<tr>
<td>Soil inversion</td>
<td>NS to 92%</td>
<td>-59% to NS</td>
</tr>
<tr>
<td>Conservation tillage</td>
<td>-308 to -40%</td>
<td>-33 to 96%</td>
</tr>
</tbody>
</table>


1. Wide range of efficacies demands more site-specific focus.
2. Trade-off between dissolved and particulate is important.
37 CERTIFIED BRANCH FACILITIES

1,960,000 ACRES IN WLEB

850,000 ACRES OUTSIDE WLEB

32 BRANCH COMMITMENTS

2,810,000 TOTAL ACRES

3,870 CLIENTS SERVICED IN WLEB

1,700 CLIENTS SERVICED OUTSIDE WLEB

5,570 TOTAL CLIENTS

4R NUTRIENT STEWARDSHIP CERTIFICATION PROGRAM

Western Lake Erie Basin - Ohio, Michigan & Indiana

Voluntary program for agricultural retailers & nutrient service providers implementing the 4Rs
Phosphate Rock Reserves and Quality

- Grade, $P_2O_5$ content, trace elements
- Phosphogypsum
- Peak phosphorus by 2033? Cordell & White, 2009:

![Peak phosphorus curve](image-url)
Map of World P Resources
250 billion tonnes
in >100 countries

Sources: IFDC; USGS (2002, 2013)
“No matter how much phosphate rock exists, it is a non-renewable resource”
IFDC, 2010

<table>
<thead>
<tr>
<th>Country</th>
<th>2014-15 Production</th>
<th>Reserves</th>
<th>R/P ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morocco</td>
<td>30</td>
<td>50,000</td>
<td>1670</td>
</tr>
<tr>
<td>South Africa</td>
<td>2</td>
<td>1,500</td>
<td>750</td>
</tr>
<tr>
<td>Jordan</td>
<td>7</td>
<td>1,300</td>
<td>186</td>
</tr>
<tr>
<td>Russia</td>
<td>12</td>
<td>1,300</td>
<td>108</td>
</tr>
<tr>
<td>USA</td>
<td>26</td>
<td>1,100</td>
<td>42</td>
</tr>
<tr>
<td>China</td>
<td>100</td>
<td>3,700</td>
<td>37</td>
</tr>
<tr>
<td><strong>World Total</strong></td>
<td><strong>220</strong></td>
<td><strong>69,000</strong></td>
<td><strong>314</strong></td>
</tr>
</tbody>
</table>

Source: USGS, 2016
Summary

• Site-specific 4R phosphorus practices can limit dissolved losses
• 4R practices need to be synergized with conservation practices controlling particulate losses.
• With 4R, agri-retailers can engage the sustainability movement to build social trust.
• Opportunity to work with growers to document:
  1. trends in right place, right time, right rate;
  2. the resulting impact on things that matter.