Fertilizer-use Technologies that Minimize Environmental Impacts

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Who has renewable water resources

FAO & World Resources Institute

km³ water

Brazil, Russia, U.S., China, India, DR Congo

World average
Fertilizer use - million tonnes

FAO & World Bank
Crop yields - tonnes ha$^{-1}$

56% of fertilizer P added to soybean (37%) & maize (19%)

FAO & World Bank
Nitrate in runoff is small - 5%
Crop N harvest ~50%
Total N
Nitrate losses in leachate are large - 25%

Soil N immobilization - 5%

Days/wks
Weeks/mo
Years

Nitrate leaching
Soil erosion & particulate P

Crop P harvest 15%

Release of soil P → dissolved P

Total P - 5%

Soil P immobilization - 80%
Today’s presentation

- Identifying critical source areas
- Nutrient management - 4R’s
  - Right rate, time, place source
- Transport management
  - Runoff & erosion control
- Impact of management legacies
- The future - new 5R’s for P
The Pennsylvania simulator
Dissolved P, mg L\(^{-1}\)

Crop response

FD-36 watershed - PA

R\(^2\) = 0.86

Change point
200 mg L\(^{-1}\)

Mehlich-3 P, mg kg\(^{-1}\)
Risk management
P loss affected by many factors

Soil P - mg kg\(^{-1}\)
Runoff - liters
P loss - kg P ha\(^{-1}\) yr\(^{-1}\)

Tony Buda, ARS, PA
Critical Source Area

Led to the 80/20 rule:
80% of P comes from 20% of land area
Factors in P Index

Source
- Soil P content
- Added P
  - Rate, method, timing of fertilizer & manure
  - Manure P solubility

Transport
- Runoff potential
- Erosion potential
- Leaching potential
- Proximity to stream
Nutrient inputs to the farm
Farm-gate measures

Dietary P mgt. & use of enzymes enhances nutrient absorption & reduces excretion.

Manure additives can reduce P solubility & NH₃ loss.

Manure treatment by solid-liquid separation, struvite, zeolite.
Appropriate rate, method timing, & placement of P can increase crop uptake & decrease runoff loss.

Soil & manure testing to tailor rates of P to apply.

Subsurface injection reduces P runoff & N volatilization.
Transport management
Rotational grazing reduces P runoff & N leached

Stream bank fencing Decreases P deposition in streams

Riparian buffers trap particulate nutrients

Conservation tillage reduces P runoff

Cover crops reduces P runoff

Riparian buffers

Cover crops

Conservation tillage

Rotational grazing

Stream bank fencing

Decreases P deposition in streams

Riparian buffers trap particulate nutrients

Conservation tillage reduces P runoff

Cover crops reduces P runoff

Rotational grazing reduces P runoff & N leached
Stream exclusion

Equal to 12% of ag. P loadings
System legacy drivers

- **Soil processes**
  - Decline in soil P with crop offtake is slow
  - Wetlands trap & can then recycle P

- **Hydro-chemical response**
  - Time for ground water to reach stream can be days to years

- **BMP response**
  - Uptake & release of P by stream & lake sediments

- **Fluvial response**
  - Time for buffers to become effective filters
Hydro-chemical response
Conservation tillage

No-till reduced erosion from wheat 95%

Total P, mg/L


Converted to no-till

Conventional till wheat

Total N, mg/L


Converted to no-till

Conventional till wheat

Sharpley & Smith, 1994 - El Reno, OK
Conservation compromises

Infiltration increased 33%

Runoff - Dissolved P, mg/L

Leached - Nitrate, mg/L

Conventional till wheat

Converted to no-till
Management effects at a larger scale

Maumee River watershed

Sandusky River watershed

Richards et al., 2002
Annual flow-weighted total P, mg/L

50% decrease

Dave Baker & Peter Richards, OH

Trends in P - Maumee River
Adoption of mulch & no-till soybeans, %

Annual flow-weighted dissolved P, mg/L

75% decrease

What happened?

Increased DP input & blooms result of...

- Same annual rainfall but more intense spring rains
  - Prior to 2008 - 12% of annual rains
  - 2008 to 2011 - 30% of annual rains

- Surface soil P buildup with no-till

- Increased tile drainage of soils created more critical source areas
Adaptive management may have reduced nutrient loss

- Incorporation of fertilizer & manure
- Winter cover crops
- Spring fertilization
The reality is ......

- More time-sensitive tasks in spring
- Fertilizer usually costs more in spring
- Less soil compaction on frozen ground
Challenge for scientists

- Esteja para trás e olhar para o panorama geral

Às vezes é difícil ver a floresta para as árvores ...
FAO & IPNI, 2014
Hydrologic lag times

- In-channel (<1 yr)
- Riparian & floodplains (<1 - 1000 yr)
- Groundwater (<1 - 50 yr)
- Lakes (c.5-30 yr)
- Soils & hillslopes (c.5-30 yr)
Dealing with elephants
Dealing with the elephant

É um fã

É uma lança

É uma parede

É uma corda

É uma cobra

É uma árvore
We all view things differently

Há muitas pessoas

Não, é de fertilizantes

Não, é a partir de estrume

Eu quero o meu lago para ser azul

Precisamos de mais árvores

Eu preciso de bifes baratos
The elephants

Public expects blue waters & green pastures

With predicted population growth, 50-100% increase in crops yields on same acreage

- Will increase pressure to intensify & maximize yields
- Likely on less suitable lands
- Economics remains THE driver
The 5R’s for P

- **R**ealign the inputs of P
- **R**euse P from manures & residuals
- **R**ecovery P from wastes
- **R**edefine production systems
- **R**educe P losses to surface waters
In conclusion ..... 

✅ Whatever fertilizer formulation is used, its management is critical to minimizing losses

✅ We must help farmers deal with these issues

✅ Or the elephant will awaken the tiger we call EPA

✅ Who will regulate fertilizer use to protect water quality