Addressing Water Quality Concerns through Nutrient and Water Management

Kevin King
USDA-Agricultural Research Service
Soil Drainage Research Unit
kevin.king@usda.gov
The need for nutrient and water management?

Source

Transport
Fertilizer source/use in the US

Fertilizer use (nutrient pounds per acre of cropland)

- Potash
- Phosphorus
- Nitrogen

Material short tons
- compost
- dried manure
- sewage sludge
- other organic materials

USDA-ERS, 2019


Volumes and intensities of rainfall events are changing

- 4% increase in national precipitation since 1958
- 5-15% in Western Lake Erie Basin region
- Since 1895, 8 of the top 10 wettest years measured since 1990
- 6 of those occurred since 2004
The need for nutrient and water management?

Source

Transport
Risk is a function of the magnitude of source and transport.
Nutrient transport is disproportionately impacted by larger precipitation events

➢ Phosphorus loading is event driven

➢ 80% of phosphorus loading in surface runoff occurs during 10 days per year

➢ 80% of phosphorus loading in tile drainage occurs during 45 days per year

➢ 60% of surface and 40% of tile phosphorus load is generated from precipitation events exceeding 1.25 inches

Williams et al., 2018; AWRA 54:1039-1054
Pease et al., 2018; J. Great Lakes Res. 44:43-53.
4R nutrient stewardship certification program developed to maximize crop uptake and minimize nutrient losses

Vollmer-Sanders et al., 2016:
SMART nutrient management should be the minimum goal for every producer

https://www.farmers.gov/conservation/nutrient-management
Solubility of organic and inorganic sources varies

➢ Inorganic fertilizers are generally more soluble than organic sources

➢ Continued use of organic sources increases soil test phosphorus as well as phosphorus concentrations in discharge

Concentration of dissolved, bioavailable, and total P in surface runoff for rainfall events occurring within 24 hours of broadcasting 100 lb P₂O₅/acre using fertilizer and manure sources to untillled soils with soybean or corn residue (Mallarino et al., 2007)

Mallarino et al., 2007; Smith et al., 2016; Kinley et al 2007
Manures applied at equal rates to inorganic sources tend to slightly increase tile DRP loads

- Preliminary findings suggest statistical, but minor (grams/yr) increase in dissolved reactive phosphorus (DRP) from liquid dairy manure compared to commercial fertilizer
- Similar small increases in DRP from swine manure
- No differences in poultry litter compared to commercial fertilizer

King et al., 2022; unpublished data
Soil testing and adhering to recommended rates reduces potential for nutrient loss

- 90% of fields have crop rotation phosphorus (P) application rates at or below recommendations

- 58% of fields had zero P applied

- Soil test P (STP) above agronomic levels generally poses an environment risk, but STP above agronomic levels does NOT necessarily equal environmental risk

- As P application increases, P load increases

- Late Spring Nitrate Test (LSNT) reduced nitrogen loss by 30%

Smith et al., 2018; King et al., 2018; Duncan et al., 2017; Christianson et al., 2016
Broadcast application leads to stratification and increased losses compared to subsurface placement.

- Broadcast application without incorporation leads to stratification and increased losses (Baker et al., 2017)
- Shallow (3 inches) disk tilling following broadcast application reduced tile drainage P loss by 7-fold (Williams et al., 2016)
- Broadcasting P without incorporation increased field scale dissolved P loss but reduced total P loss (King et al., unpublished data)
- With respect to manure, placement is very important as significantly less losses occur with incorporation when compared to broadcast only
Plot scale studies reveal the importance of subsurface placement

- Injection or tillage incorporation reduced leachate P by ~70% compared to broadcast with no incorporation (Williams et al., 2018)

- 2x2 placement and broadcast plus disk tillage had significantly less losses compared to broadcast only application (King et al., unpublished data)
Fertilizer application followed by rainfall creates potential for large incidental P losses (Johnson et al. Unpublished data)

Prolonging the period between application and rainfall had a decreasing effect for both N and P (Hanrahan et al., 2021)

Several rainfall simulation studies also confirm decreased nutrient loss with delayed rainfall after application (e.g., Smith et al., 2007)
Applications closer in proximity to crop needs tend to have less loss

➢ In-crop manure applications reduced nitrogen (N) loads and marginally increased P loads (Greg LaBarge and Blanchard River Demonstration Network, unpublished data)

➢ Application in winter and/or before precipitation increases loss risk (Mallarino et al., 2015; King et al., unpublished data)

➢ Spring manure applications resulted in less loss compared to fall applications (King et al., unpublished data)
Site specific aspects and regional trends should be considered

Soil quality

Producer capability/resources

Legacy/Variable source area

Local/regional climate change

Change since mid 1970s
Poor soil quality alters natural flow paths that short circuits matrix and natural soil ‘filtering’

- Poor soil quality can reduce infiltration leading to increased surface runoff
- Poor soil quality, related to soil structure can enhance desiccation cracking and preferential flow
- Preferential flow is a direct flow pathway to tile drainage
- Has implications for fertilizer source, placement, and timing
Variable source areas or ‘hot spots’ can disproportionately contribute to field loss

- Variable source areas can vary based on hydrologic connectivity, soil texture, and slope differences and significantly increase field losses

- Legacy P can serve as a chronic source of nutrients for years/decades and mask effects of current conservation efforts

- Management strategies will vary depending on the primary source of P
Producer perception and resources are often cited as reasons for not adopting conservation practices.

- **Barriers to practice adoption**
  - Perceived practice efficacy
  - Financial and time burden

- **Need:**
  - Better cost-benefit information
  - Site-specific decision support tools
  - Technical assistance
Changes in precipitation amounts, intensities and timing may make parts of SMART implementation a challenge.
Water management can reduce hydrologic connectivity and improve water quality

Controlled drainage

Blind inlets

Drainage water recycling

Wetlands

Cover crops

Cropland

Reservoir

Wetland
Drainage water management (controlled drainage) promotes in-field water storage

- Significantly reduced drainage volume
- Significantly decreased nitrate ($\text{NO}_3^-$)
- Mixed results for DRP and TP
- May increase surface discharge as well as nutrient losses but should not negate overall benefits
- Potential increase in crop yield in effective area

King et al., 2022; Ghane et al., 2012; Wang et al., 2020
Blind inlets disrupt surface flow to tile drainage and filter surface runoff

- Slow down movement of water and promote sedimentation
- Variable results for NO3-N
- Phosphorus reduction approximately 50%
- Sediment reduction up to 70%

Smith et al., 2013; Williams et al., 2020
Wetlands have potential to reduce moderate discharge rates and become nutrient sinks

- Reduce both N and P
- Limited in addressing larger discharge rates
- Limited lifetime before transitioning from a sink to a source

Braskerud et al. (2005)

Photo credit: Jed Stinner
Drainage water recycling is an approach to move toward a zero discharge system

- Captures and stores drainage water for later irrigation
- Increases crop production
- Significant N and P reductions to downstream waters
- Other potential benefits include flood control and wildlife habitat

Hay et al., 2021
Cover crops alter field scale hydrology and nutrient delivery

➢ Field scale hydrology
  • Increased Evapotranspiration (ET)
  • 0.5 to 2.0 inches less surface runoff
  • 0.5 to 3.0 inches greater tile discharge

➢ Tile drainage nutrients
  • Significant tile NO$_3$-N reductions
  • Mixed results on tile drainage phosphorus

Photo credit: Jed Stinner

Shedekar et al.: unpublished data; Zhang et al., 2017; Hanrahan et al., 2018; 2021; Christianson et al., 2021
When nutrient and water management are not enough

Phosphorus removal structures

Denitrifying bioreactors

Drainage ditch design

Photo credit: Chad Penn

Photo courtesy of Iowa Soybean Association

Photo credit: Brittany Hanrahan
Phosphorus removal structures are designed and implemented to target high P loss sites

- Surface runoff or subsurface drainage
- Work better with greater P concentrations
- Generally designed to remove 40% over 3-5 yrs
- Design software is available (P-TRAP)
Denitrification bioreactors are an effective means to reduce tile drainage nitrogen

- Generally located at the edge-of-field and seek to target 50 to 80 acres
- Typical footprint: 25’x75’x4’
- Typical carbon source is woodchips
- Nitrogen removal generally in 20-30% range
- Research continues to enhance the efficiency of the bioreactors, especially during cold climates
Drainage ditch design and management has the potential to create nutrient sinks

- Engineered for channel stability
- Promotes sediment deposition on benches
- Increased nutrient retention

Davis et al. (2015); Mahl et al. (2015); Hanrahan et al. (2018)
Stacking practices has the potential to further reduce nutrient loss

- Include two or more in-field practices, edge-of-field, or in-stream practices

- Benefits may not be 100% additive but should provide additional reductions

➢ Include two or more in-field practices, edge-of-field, or in-stream practices

➢ Benefits may not be 100% additive but should provide additional reductions
How do we avoid tradeoffs among pollutants? How does it depend on the ecoregion?
Summary

- Solubility varies between organic and inorganic sources; when applied at equal rates, potential for slight increase in P loads.
- Subsurface placement significantly reduces loss potential.
- Site specific field characteristics and socioeconomic conditions need to be considered.
- Soil testing and adherence to land grant university guidelines reduces potential for loss.
- Awareness of local weather forecasts and application closer to crop utilization generally reduced loss potential.
- Water management is just as important as nutrient management.
- Stacking practices and implementing other EOF and in-stream practices may be necessary to meet nutrient reduction goals.
For more information on this presentation, or more information on nutrient and water management in drained landscapes

Kevin King
USDA-ARS, SDRU
590 Woody Hayes Dr.
Columbus, OH 43210
kevin.king@usda.gov
Citations and Additional Resources for “Achieving Water Quality Outcomes Through Nutrient and Water Management” Conservation Outcomes Webinar, featuring Dr. Kevin King, USDA Agricultural Research Service

Slide 3:

Slide 4:

Slide 7:


Slide 8:

Slide 9:
https://www.farmers.gov/conservation/nutrient-management

Slide 10:
Mallarino et al., 2007: http://www.agronext.iastate.edu/soilfertility/info/
FinalDNR319RunoffProjectReport.pdf Feb 2020


Slide 12:


Slide 13


Slide 14

Slide 15

Smith et al., 2007: Smith, D.R., P.R. Owens, A.B. Leytem, and E.A. Warnemuende. Nitrogen losses from manure and fertilizer applications as impacted by time to first runoff event. Environmental Pollution 147: 131-137.

Slide 16
Labarge et al., 2022: blancharddemofarms.org


Slide 19

Slide 20

Slide 23


Slide 24


Slide 25
Braskerud et al., 2005: [https://doi.org/10.2134/jeq2004.0466](https://doi.org/10.2134/jeq2004.0466)

Slide 26

Slide 27


Christianson et al., 2021: Christianson, R., J. Fox, N. Law, and C. Wong. Effectiveness of cover crops for water pollutant reduction from agricultural areas. Transaction of the ASABE 64:1007-1017.

Slide 29

Slide 31
