Instrumentation, Measurement and Findings from the USDA-ARS Edge-of-Field Research Network

Kevin W. King
USDA-Agricultural Research Service
Soil Drainage Research Unit
Columbus, OH
USDA-ARS edge-of-field network in Ohio

By the numbers

- 40 paired fields located on 20 farms
- ~90 automated Isco samplers
- Over 200+ site years of data (surface & subsurface)

Typical edge-of-field site

Williams et al. 2016. J. Soil Water Conserv. 71:9-12
Discharge

Volumetric depth (mm)

Month
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

subsurface drainage
surface runoff
precipitation
**DRP Concentration: Surface > Subsurface**

![Box plots comparing DRP concentrations for Surface and Subsurface](image)

- **March to July**
  - Surface: 0.09 mg L\(^{-1}\)
  - Subsurface: 0.05 mg L\(^{-1}\)

- **Annual**
  - Surface: 0.21 mg L\(^{-1}\)
  - Subsurface: 0.08 mg L\(^{-1}\)
  - Target Conc.: 0.05 mg L\(^{-1}\)
DRP Load: Subsurface > Surface

*If 40% load reduction was applied to entire Maumee Basin Watershed

Pease et al. (2018)
If 40% load reduction was applied to entire Maumee Basin

73±26% of total DRP load was from tile drainage
Soil Test P vs Environmental Risk

Soil Test P above agronomic rates poses an environmental risk

BUT Soil Test P above agronomic rates does NOT equal environmental risk

King et al., 2018
Duncan et al., 2017
P balances

Inorganic sources
- atmospheric deposition
- application
- crop removal
- surface runoff loss
- subsurface (tile) loss
- balance (inputs - outputs)

Organic sources

Phosphorus (kg/ha) vs. Site

Site A B C D E F G H I J K L M N O P Q

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Weather plays a major role

![Graph showing the relationship between precipitation, surface discharge, subsurface discharge, surface DRP load, and subsurface DRP load.](image)
Precipitation and Discharge Volume

Statistical Analysis of Event Magnitude

Size of surface runoff events tied to the size of the rainfall event
Larger rainfall event = larger runoff event

Size of tile discharge event tied to antecedent conditions
Higher flows associated with:
– Consecutive rainfall events within 48-h
Lower flows associated with:
– Single events and short duration events
What is the most effective scale to address water quality?
How do we avoid tradeoffs among pollutants? Does it depend on ecoregion?
**Treatment practices**

<table>
<thead>
<tr>
<th>In-field</th>
<th>Edge-of-field</th>
<th>In-stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ 4Rs (source, rate, time, placement)</td>
<td>➢ Drainage water management</td>
<td>➢ Two-stage ditch design</td>
</tr>
<tr>
<td>➢ Organic vs inorganic</td>
<td>➢ Woodchip bioreactors and P filters</td>
<td></td>
</tr>
<tr>
<td>➢ Zero P, half-rate, full-rate</td>
<td></td>
<td></td>
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<tr>
<td>➢ Fall vs spring</td>
<td></td>
<td></td>
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<tr>
<td>➢ Surface vs subsurface</td>
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<tr>
<td>➢ Gypsum as a surface amendment</td>
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<tr>
<td>➢ Cover crop vs no cover crops</td>
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<tr>
<td>➢ Crop rotation</td>
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</tbody>
</table>
Fertilizer Source

Field 1: Liquid dairy manure

Field 2: MAP

Event P concentration (mg/L) vs. Event P load (kg/ha) for Field 1 and Field 2 under Baseline and Treatment Periods:

- **A** Dissolved Reactive P (DRP)
  - Baseline Period
  - Treatment Period
  - Field 1: Liquid dairy manure
  - Field 2: MAP

- **B** Total P (TP)
  - Baseline Period
  - Treatment Period
  - Field 1: Liquid dairy manure
  - Field 2: MAP

- **C** Event P concentration (mg/L)
  - Field 1: Liquid dairy manure
  - Field 2: MAP

- **D** Event P load (kg/ha)
  - Field 1: Liquid dairy manure
  - Field 2: MAP

Supplementary data:

- **S** Source
- **D** Drainage
- **R** Research

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Ohio – Crop Rotation Application Rates

90% of fields have P application at or below recommendations

58% of fields had zero P applied
P losses and time of application

- Greater potential for losses when application is followed shortly by precipitation

King et al., 2018
Evidence of Preferential Flow

Positive correlation between peaks in P concentrations and tile discharge indicate fast flow processes (preferential flow) and connection to surface sources.
P Stratification and management

A

B

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P losses and fertilizer placement

Mean DRP conc. (mg/L)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>(n=7)</th>
<th>(n=7)</th>
<th>(n=8)</th>
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</thead>
<tbody>
<tr>
<td>Broadcast</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inject</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Till</td>
<td></td>
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</tbody>
</table>

Error bars represent ± SE

Variability among lysimeters

Williams et al., 2018
Cover/catch Crop x Rate study

7/6/2017: 7000 gal/ac liquid dairy manure (15.3, 5.4, 13.5)

7/31/2017: 7000 gal/ac liquid dairy manure (15.3, 5.4, 13.5)

<table>
<thead>
<tr>
<th></th>
<th>No Cover Crop</th>
<th>Mustard Cover Crop</th>
<th>No Cover Crop</th>
<th>Mustard Cover Crop</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>7000 gal/acre</td>
<td></td>
<td>14,000 gal/acre</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Precipitation (inches)</th>
<th>Discharge (inches)</th>
<th>NO3-N (lbs/ac)</th>
<th>DRP (lbs/ac)</th>
<th>Discharge (inches)</th>
<th>NO3-N (lbs/ac)</th>
<th>DRP (lbs/ac)</th>
<th>Discharge (inches)</th>
<th>NO3-N (lbs/ac)</th>
<th>DRP (lbs/ac)</th>
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<th>NO3-N (lbs/ac)</th>
<th>DRP (lbs/ac)</th>
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<tbody>
<tr>
<td>Oct</td>
<td>2.94</td>
<td>0.84</td>
<td>3.92</td>
<td>0.04</td>
<td>0.20</td>
<td>1.16</td>
<td>0.00</td>
<td>0.25</td>
<td>1.07</td>
<td>0.00</td>
<td>0.09</td>
<td>0.32</td>
<td>0.00</td>
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<tr>
<td>Nov</td>
<td>5.87</td>
<td>1.74</td>
<td>10.69</td>
<td>0.08</td>
<td>0.70</td>
<td>1.34</td>
<td>0.01</td>
<td>1.83</td>
<td>20.49</td>
<td>0.02</td>
<td>1.19</td>
<td>1.60</td>
<td>0.01</td>
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<tr>
<td>Dec</td>
<td>0.32</td>
<td>0.20</td>
<td>0.27</td>
<td>0.01</td>
<td>0.08</td>
<td>0.04</td>
<td>0.00</td>
<td>0.05</td>
<td>0.06</td>
<td>0.00</td>
<td>0.20</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Total</td>
<td>9.13</td>
<td>2.77</td>
<td>14.87</td>
<td>0.12</td>
<td>0.98</td>
<td>2.54</td>
<td>0.01</td>
<td>2.12</td>
<td>21.62</td>
<td>0.02</td>
<td>1.48</td>
<td>1.92</td>
<td>0.01</td>
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</tbody>
</table>

Preliminary data suggests: Rate and cover crop have a significant impact on NO3-N tile drainage losses but no effect on DRP.
Cover crops

DrP Load from North Tile

NO3-N Load from North Tile

DrP Load from South Tile

NO3-N Load from South Tile

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Ground Cover and Discharge Volume

Statistical Analysis of Event Magnitude

Grass-type crops associated with lower tile discharge
  Includes corn, wheat, forage grasses, and grass-type cover crops

Ground cover had less of an effect on discharge amount than rainfall characteristics
Edge of Field Practices

Drainage Water Management (DWM)

Non-Growing Season

Planting

Growing Season

Harvest
DWM - Case Study

**B2** – free drainage
**B4** – drainage water management

- **Annual discharge reduction:**
  17% to 73% across sites
  41% on average

- **Daily discharge reduction:**
  50% on average during management (Gunn et al. 2015)

- DWM did not significantly affect DRP concentration

- 8-40% reduction in annual DRP load with DWM
Phosphorus Removal Structures
DRP Concentration
Reduction

DRP Concentration (ppm)

Reactor Inlet

Reactor Outlet


Reactor Inlet

Reactor Outlet

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Drainage Ditch Design

Conventional channelized stream

unstable banks

Fertilizer

↓ ↓ ↓

Sediment

NO₃

sub-surface tile drain

Two-Stage Ditch

9 m

3 m

high flow

low flow

floodplain

Restored: After 10 years

Source: Hanrahan 2017
Directionally Correct Practices

- 4Rs of nutrient management (Right source, rate, time, placement)

- Disconnecting hydrologic pathways (DWM, blind inlets, linear wetlands, water storage/increased OM)

- Do not increase erosion potential (subsurface placement)
Fertilizer placement:
- surface
- 2” x 2”
- Deep (3” - 5”)
- surface/disk
Results of Thermal Infrared Drone Survey Conducted Near Spencer, Iowa.

As-Built Map of Field Subsurface Drainage System. Boundary of Drone Survey is Highlighted in Red.

Field Thermal Infrared Orthomosaic from One Day Before 3” Rainfall Exhibiting no Drainage Pipe Responses.

Field Thermal Infrared Orthomosaic from One Day After 3” Rainfall Showing Drainage Pipe Patterns. (Compare to As-Built Drainage Map.)
Contact Information

Kevin King
590 Woody Hayes Dr.
Columbus, OH 43210

kevin.king@ars.usda.gov
Combined Determination of Total P and Total N Using Persulfate Oxidation

- Combined TP and TN determination is required due to number of samples (10,000+ annually)
- USGS method is valid and acceptable method (Patton and Kryskalla, 2003)
- Recovery of total-P is nearly identical in both the alkaline and acidic persulfate oxidation methods
- Excluding P-Pyro and P-ATP, which had bad recoveries for both alkaline and acid methods, total P recoveries ranged from 94% to 108% in lab prepared solutions and 90% to 104% in unfiltered field samples.
- However, recovery of total-N is significantly lower in the acidic method
- USGS method in use since WY2015 (Oct 1, 2014): > 70% of site yrs and > 77% of all water samples to date (9/30/2017)
Observed Total Suspended Solids in EOF

Dayton et al. (2017) SS range

- Minimum SS in Dayton et al (2017) is greater than 50th percentile for observed surface samples and 70th percentile for tile samples.

- Shaded area is typical sediment concentration range for monitored fields (75th percentile for surface and ~90th percentile for tile).

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