Tri-State Fertilizer Recommendations

Why update?
- Water Quality Concerns In Ohio
- Tri-State Fertilizer Recommendations
  - *2020 Update to Tri-State Recs* – *expect publication early winter*
- Tools to reduce nutrient loss

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Ohio Water Quality Impairments

- Sediment
  - Blocks waterways, carries nutrients
- Excessive Plant Growth from N & P
  - Hypoxia
  - Harmful Algal Blooms
- Health Warnings
  - Microcystin
  - Nitrate Concentration

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Ohio Nutrient Management Law

- SB 150 - 2014
  - The applicator *certification* law – if farm more than 50 acres and apply fertilizer to a crop for sale
  - State wide – on September 30, 2017
- SB1 - 2015
  - The nutrient application *restriction* law for western Lake Erie basin
  - State wide: Anyone applying manure from concentrated animal feeding facility must have fertilizer certification
- SB 299 – 2018
  - $23 million assistance through SWCDs for nutrient management programs in the WLEB
    - Working Lands Program, VNMP development, Cost Share to purchase technological improvements
- HB 7 – 2019
  - H2Ohio – provides funding to improve water quality.
  - Up to $100 million per year.

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Nutrient Reduction Goals: Lake Erie

Source: International Joint Commission

- 40% reduction in Total P loading to 6,000 metric tons
  - The goal is to reduce Hypoxic zone in central Lake Erie
- 40% reduction in soluble reactive phosphorus loads
  - The goal is to reduce Harmful Agal Blooms in western Lake Erie
  - By reducing soluble phosphorus from these waterways

US Rivers	Canadian Rivers
Maumee River - US	Thames River - Canada
River Raisin - US	Leamington Tributaries – Canada
Portage River – US	
Toussaint Creek – US	
Sandusky River - US	
Huron River, OH – US	

FYI
The *Microcystis* cyanobacteria bloom in 2019 had a severity index (SI) of 7.3, indicating a relatively severe bloom.
http://coastalscience.noaa.gov/research/habs/forecasting

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Nutrient Reduction Goals: Ohio River
(Mississippi River Basin)

Goal is to reduce Hypoxic zone to 5,000 square kilometers (1.2 million acres)

FYI, in 2019 the Gulf hypoxia area was 6,952 square miles, 8th largest on record*

- 45% reduction in Total P loading
  - Attain a 20% reduction by 2025
- 45% reduction in Nitrogen loading
  - Attain a 20% reduction by 2025

Source: Gulf Hypoxia Task Force 1/2015
* https://www.noaa.gov/media-release/large-dead-zone-measured-in-gulf-of-mexico

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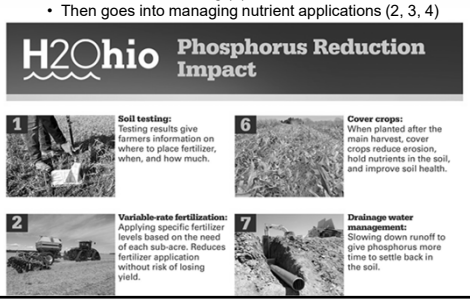
H2Ohio
November 2019

- Outlines ten ideas to reduce phosphorus loss
  - It starts with soil testing (1)
  - Then goes into managing nutrient applications (2, 3, 4)



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2020

Update to the Tri-State Fertilizer Recommendations for Corn, Soybean, Wheat and Alfalfa

- Steve Culman, Kurt Steinke, Jim Camberato
  - Ohio State University, Michigan State University, Purdue University
  - Contributing authors
    - Anthony Fulford, Bethany Herman, Nicole Hoekstra, Peter Thomison, Rich Minyo, Laura Lindsey, Anne Dorrance, Harold Watters, Greg LaBarge, Ed Lentz, Ryan Haden..
- Funding from OCWGA, OSC and many others

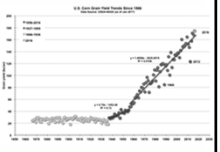
Changes for 2020 Tri-State Fertilizer recommendations

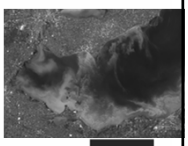
What are they?

- Nutrient extractant and procedures –
  - now Mehlich-3 for P, K, etc.
- Critical level & maintenance range
  - Reduced reliance on CEC in potassium recommendations
- Crop removal rates
  - Have changed as crops are now more efficient
- Fertilizer philosophy change
  - P_2O_5 recommendation is crop removal
  - K_2O recommendation is crop removal + 20
- Lime recommendations previously updated
  - Based on Effective Neutralizing Power
- Nitrogen recommendations updated 2018
  - MRTN model for corn (CNRC)
  - Ohio wheat recommendations typically are yield goal based

Update to the Tri-State Fertilizer Recommendations

- Farming has changed over past 25 years
  - Increased yields
    - plant nutrient use
  - Greater use of conservation tillage
  - Reduced rotations
- In OH-IN-MI, majority of farmland is rented
- Water quality issues have put a spotlight on nutrient management and agriculture





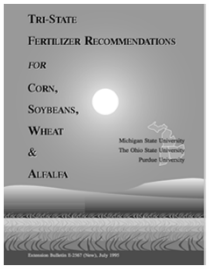
1995 Tri-State Fertilizer Recommendations

for Corn, Soybean, Wheat & Alfalfa

Originally Published in 1995

Unified N, P, K recommendations for corn, soybean, wheat and alfalfa across Ohio, Indiana & Michigan

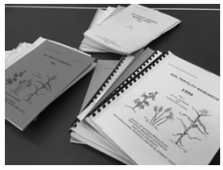
Served as a cornerstone of fertilizer management in the region

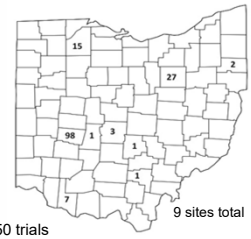


Original Ohio Tri-State Data

Annual Soil Fertility Reports: 1976 – 1993

- 68 P trials conducted
- 92 K trials conducted



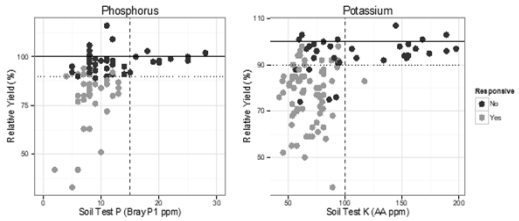


9 sites total

Between 1995 and 2014 – about 50 trials conducted: P, N, manure, Lake Erie

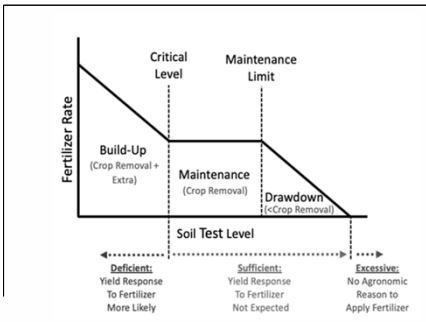
Ohio Tri-State Data (1976-1993)

(Corn, Soybean and Wheat)



Tri-State Fertilizer Recommendations – published 1995
Set the critical point for phosphorus and potassium

Build, maintain, drawdown philosophy of the 1995 Tri-State Fertilizer Recommendations



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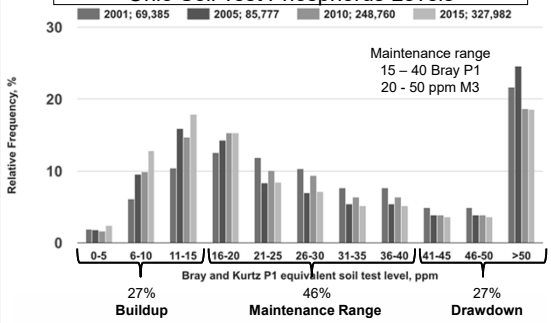
Ohio Soil Test Phosphorus Levels



Source: International Plant Nutrient Institute

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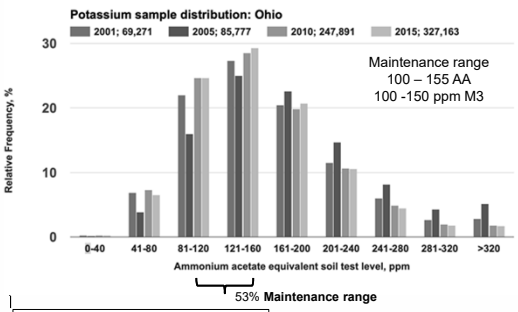
Ohio Soil Test Potassium (K) levels



Source: International Plant Nutrient Institute

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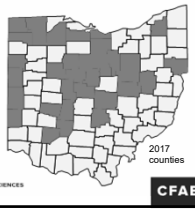
From 2014 to 2018 - over 300 on-farm trials conducted across Ohio

- Evaluated corn, soybean and wheat response to N, P and K fertilizer.
- Worked with retail, crop consultants, Extension
  - Replicated; 3-4 times
  - Pre-trial soil samples (8 inch depth)
  - Tissue analysis as well
- Included some Sulfur work
- In 39 counties across Ohio



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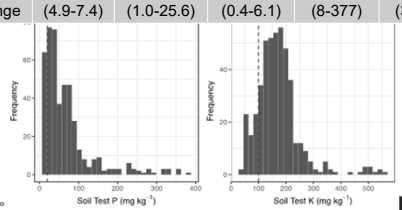
Soil Test P & K Distributions Across Trials

	pH	CEC ($cmol_c\ kg^{-1}$)	OM (%)	Mehlich 3 P (ppm)	Mehlich 3 K (ppm)
Mean	6.4	11.3	2.3	68	170
Median	6.4	11.4	2.1	47	161
Range	(4.9-7.4)	(1.0-25.6)	(0.4-6.1)	(8-377)	(39-563)



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Extractants

measure available nutrient over a cropping season

Estimate of available phosphorus to the crop

- Bray-Kurtz P_1 – weak HCl/amm. F (1945)
- Mehlich-3 – acetic acid, amm. NO_3, amm. F, nitric acid, EDTA (1984)
- Olsen – sodium bicarbonate (1954)

Estimate of exchangeable potassium to the crop

- Ammonium acetate (1940s-1960s?)
- Mehlich-3 (1984)

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What soil test extractant will we use going forward?

- Will move to Mehlich-3 as the accepted soil test for future recommendations
  - Calibrated yield against Mehlich-3 test
  - Slight numeric modification to maintenance range going forward
    - Generally M3 times 0.75 = Bray P1
      - When soil tests are in the agronomic range
    - For M3 potassium, close enough to the AA test
- Lime recommendations based on buffer pH
  - Moved from SMP (1961) buffer to Sikora modified (2006)

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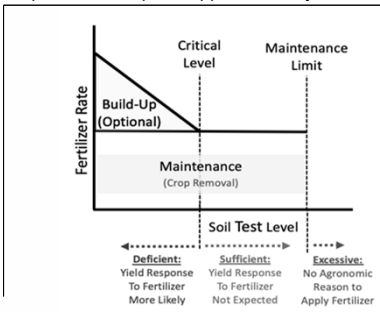
Slightly different recommendation philosophy – 2020 optional buildup, no application beyond maintenance limit



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Yield response if soil test was in maintenance range?

- Yield responses to P and K fertilizer in soils in the current maintenance range were very rare from recent data.
- And compares with information contained in the 1995 Tri-State Recommendations

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Long term trials have been conducted at university research stations since 2006

Long-term data from

- three sites - Clark, Wayne, Wood counties
  - University research farm sites
- show that when Ohio soils are in the current maintenance range,
  - *they supply sufficient P and K to meet corn and soybean demand for many growing seasons without fertilization.*

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Long Term P & K Trial Findings

- 9 years of trials (at 3 sites for 27 site years)
- Fertilization increased grain yields in 9 out of 42 comparisons
- Soil test P and K started in maintenance range
- Treatments – fertilizer application at 0, 1 and 2x removal
- No indication that recommendations are too low
- Only 21% of time did we show a response

  4 in P (15%), 1 in K (4%) for corn

  1 in P (4%) , 3 in K (11%) for soybeans
- Revision of leaf tissue guidelines is likely necessary
- *Fulford and Culman, Agronomy Journal, 2018*

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Corn, soybean and wheat are yielding more grain with less nutrients

- Nutrient removal per bushel of grain is lower than it was 25 years ago.

Table 11. Nutrients Removed in Harvested Grain

Crop	Grain Nutrient Removal Rate	
	lbs P_2O_5/ bushel	lb K_2O/ bushel
Corn	0.35	0.20
Soybean	0.80	1.15
Wheat	0.50	0.25

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Ohio Grain Nutrient Removal (lb/bu) comparison 2020 to 1995

Nutrient	Current Data	1995 Tri-State	*% decrease*
Corn			
P_2O_5	0.35	0.37	*5%*
K_2O	0.20	0.27	*26%*
Soybean			
P_2O_5	0.80	0.80	--
K_2O	1.15	1.4	*18%*
Wheat			
P_2O_5	0.50	0.63	*21%*
K_2O	0.25	0.37	*32%*

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Forages and nutrient removal

less work was done over this recent period

- Nutrient removal from forages.
  - Source International Plant Nutrition Institute (2014).

Table 12. Nutrients Removed in Harvested Forage Biomass

Crop	Grain Nutrient Removal Rate	
	lbs P_2O_5/ ton	lb K_2O/ ton
Corn silage	3.1	7.3
Alfalfa	12.0	49

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What are the new Maintenance Ranges?

	Maintenance Range		
	Phosphorus (Mehlich-3 P)	Potassium (Mehlich-3 K)	
Crop		Loam & clay soils (CEC >6 meq/ 100g)	Sandy soils (<6 meq/ 100g)
Corn, Soybean	20 – 40 ppm	100 – 150 ppm	90 – 130 ppm
Wheat, Alfalfa	30 – 50 ppm**	100 – 150 ppm	90 – 130 ppm

**Wheat and alfalfa require greater levels of soil test P than corn and soybean. Therefore, if growing wheat or alfalfa in rotation and soil test levels are below 30 ppm, apply maintenance rates of P fertilizer before these crops are grown.

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Overview of Build-up and Maintenance Phases and Associated Fertilizer Recommendations

Assess-ment	Phase	Rate to Apply	When to Apply
Deficient	Build-Up (below critical level)	Crop removal + additional fertilizer to build soil test levels	Immediately, before next crop
Sufficient	Maintenance (above critical level, below maintenance limit	Approximate crop removal	Sometime within the rotation
Excessive	Above maintenance limit	Do not fertilize	Do not fertilize

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Remarks on the new Recommendations

Phosphorus - 20 to 40 ppm for Corn & Soybean
And 30 - 50 ppm for wheat and forages
Potassium - 100 to 150 ppm

- If soil test levels are above maintenance range, then no annual nutrient application (P_2O_5 and/or K_2O) is needed.
- Sample and retest every three to four years.
- If P level is below the critical level, then make an annual application.
  - A band application of P_2O_5 can be beneficial when P test is below maintenance range.
- If CEC is low (<6 meq/100g) and soil test K levels are low, then an annual K_2O application may be warranted.

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Recommended fertilizer rate when soil test P and K are in the maintenance range for grains.

Crop	Yield	Recommended Fertilizer Rate	
	(bushel/ acre)	lbs P_2O_5/ acre	lb K_2O/ acre
Corn	150	53	50
	200	70	60
	250	88	70
	300	105	80
Soybean	30	24	55
	50	40	78
	70	56	101
	90	72	124
Wheat	50	25	33
	75	38	39
	100	50	45
	125	63	51

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Recommended fertilizer rate when soil test P and K are in the maintenance range for forages.

Crop	Yield	Recommended Fertilizer Rate	
	(tons/ acre)	lbs P_2O_5/ acre	lb K_2O/ acre
Corn Silage	20	62	166
	25	78	203
	30	93	239
	35	109	276
Alfalfa	4	48	216
	6	72	300
	8	96	300
	10	120	300

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Do the math

Equations used for calculating new fertilizer recommendations.

NRR is Nutrient removal rate
CL is the Critical level

Phosphorus (lbs P_2O_5/ acre to apply)	
Maintenance range	Yield × NRR
Build-Up range	(Yield × NRR) + [(CL – STP) x 5]
Potassium (lbs K_2O/ acre to apply)	
Maintenance range (grain crops)	(Yield × NRR) + 20
Maintenance range (forage crops)	[(Yield × NRR) + 20] - [((YP × NRR) + 20) x (STK – CL)/50]
Build-Up range	[(Yield × NRR) + 20] - [(CL – STK) × (1 + (0.05 x CEC))]

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Thank you!

- Questions or Comments?

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Lime recommendations
And corn nitrogen recommendations
were updated before the 2020 Tri-State Fertilizer update

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pH and Lime recommendations for Ohio

- Updates were made earlier and follow state lime regulations

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Recommended Soil pH levels for Field Crops

	Mineral soils		
Crop	Subsoil pH < 6.0	Subsoil pH > 6.0	Organic soils
	----------Target pH ----------		
Corn	6.5	6.0	5.3
Soybean	6.5	6.0	5.3
Wheat and small grains	6.5	6.0	5.3
Alfalfa	6.8	6.5	5.3
Other forage legumes	6.8	6.0	5.3

From - Soil Acidity and Liming for Agronomic Production (AGF-505): https://ohioline.osu.edu/factsheet/AGF-505-07

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Liming materials

Table 3. Total neutralizing power (TNP), fineness, water content, and ENP of common liming materials.

Grade	TNP (%)	Fineness % passing mesh size				Water (%)	ENP (lbs/ton)
		8	20	60	FI		
Aglime superfine	100	100	100	100	100	0	2000
Dolomitic hydrated aglime	140	100	99	76	90	0	2520
Calcitic aglime	99	99	60	37	59	0	1168
Dolomitic aglime	105	97	95	90	93	0	1953
Waste water lime	102	100	100	100	100	74	530
Pelletized lime	93	100	100	100	100	0	1860

These are liming materials available in the state of Ohio. Depending upon source, lime characteristics will vary.

From - Soil Acidity and Liming for Agronomic Production (AGF-505): https://ohioline.osu.edu/factsheet/AGF-505-07

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Table 4. Tons of liming material (ENP of 2000 lbs/ton) needed to raise the soil pH to the desired pH level based on the SMP (Shoemaker-McLean-Pratt) buffer and an incorporation depth of 8 inches (adapted from Tri-State Fertilizer Recommendations, 1996)

We now use the modified SMP buffer – aka Sikora

Buffer pH[1]	Desired pH levels				
	Mineral soils			Organic soils	
	6.8[2]	6.5[3]	6.0[4]	Soil pH	5.3
	tons agricultural limestone/acre				tons/acre
6.8	0.9	0.8	0.7	5.2	0.0
6.7	1.6	1.4	1.1	5.1	0.5
6.6	2.2	2.0	1.6	5.0	0.8
6.5	2.9	2.5	2.0	4.9	1.3
6.4	3.6	3.1	2.5	4.8	1.7
6.3	4.2	3.6	3.0	4.7	2.1
6.2	4.9	4.2	3.4	4.6	2.5
6.1	5.6	4.7	3.9	4.5	2.9
6.0	6.2	5.3	4.4	4.4	3.3

[1]To compute LTI multiply buffer pH by 10.
[2]For desired pH of 6.8: lime recommendation = -6.8*buffer pH + 46.8
[3]For desired pH of 6.5: lime recommendation = -5.6*buffer pH + 39.1
[4]For desired pH of 6.0: lime recommendation = -4.6*buffer pH + 31.8

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Soil pH correction

- Soil pH should be corrected by liming when the pH in the zone of sampling falls 0.2 to 0.3 pH units below the recommended level.
- Liming rate recommendations target the desired pH level, but the exact pH is not always achieved.
- Applications of less than 1 ton/acre often may not be practical.
- When the lime recommendation exceeds 4 tons per acre, apply the lime in a split application, and do not apply more than 8 tons of lime in one season.
- Large applications of lime without thorough mixing may cause localized zones of high alkalinity, reducing the availability of some essential nutrients.

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Lime recommendations on weakly buffered soils

(e.g. sandy soils)

- Because sandy soils (<6 meq/100 g soil) are often weakly buffered, there is concern about lime requirements determined by the SMP or Sikora buffer tests.
- These soils may have a pH below the desired range for optimum crop growth but the buffer pH does not indicate a need for lime.
- This occurs because weakly buffered soils do not have sufficient capacity to lower the pH of the buffer solution.
- When this situation occurs, growers may consider using:
  - 1 ton of lime per acre when the soil water pH is more than 0.3 pH units below the desired soil pH and
  - 2 tons per acre when the soil water pH is more than 0.6 pH units below the desired soil pH.

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Recommended Corn N Rates updated 2018

- Based on maximizing farmer profitability, not maximizing yields (MRTN).
- Ohio-based research
  - Mostly on-farm trials
  - 280 sites over past 10 years
- Current hybrids are more efficient – make more bushels with less N

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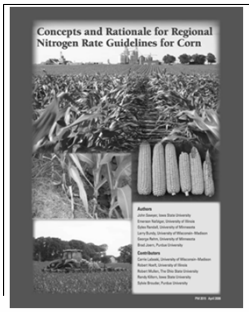
Maximum Return to Nitrogen (MRTN)



- Unified framework for N rate recs across the Midwest corn-belt
- Economic model focused on maximizing profitability, not yield
- As N rates increase, rate of yield increase declines

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Seven-state model based at Iowa State University as the Corn Nitrogen Rate Calculator
http://cnrc.agron.iastate.edu/

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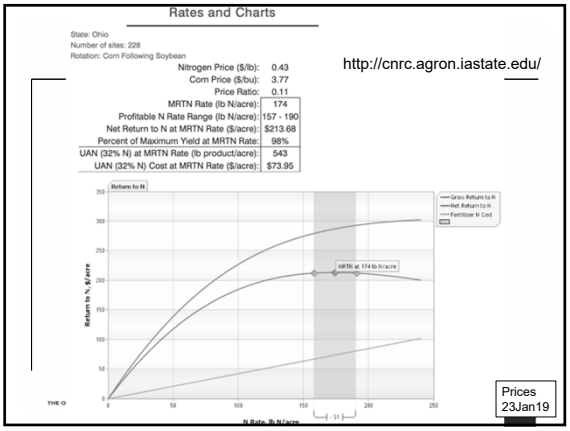

http://cnrc.agron.iastate.edu/

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New Ohio Corn N Rates – Economic model focused on maximizing profitability

	Price of Nitrogen Fertilizer ($/ lb)				
Price/ bushel corn	$0.30	$0.35	$0.40	$0.45	$0.50
$3.25	185	176	168	162	155
$3.50	187	180	173	166	160
$3.75	191	184	176	170	164
$4.00	195	186	180	174	168
$4.25	199	190	184	177	171
$4.50	200	193	185	180	175

http://go.osu.edu/corn-n-rate

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Take Home Points – from current work

1. From 2014 – 2018, 300+ trials conducted across Ohio
2. Yield response to P and K fertilizer additions,
   - *in soils in the current maintenance range, were very rare.*
3. Data shows that when Ohio soils are in the maintenance range,
   - *they supply P and K to meet corn and soybean demand for many growing seasons without annual fertilization.*
4. Recommended corn N rates were updated and are
   - *based on maximizing farmer profitability.*
5. Corn, soybean and wheat today
   - *yield more grain with less nutrients on a per unit basis*

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Changes for 2020 Tri-State Fertilizer recommendations

- Nutrient extractant and procedures –
  - now Mehlich-3 for P, K, etc.
- Critical level & maintenance range
  - Reduced reliance on CEC in potassium recommendations
- Crop removal rates
  - Have changed as crops are now more efficient
- Fertilizer philosophy change
  - P_2O_5 recommendation is crop removal
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Thank you!

- Questions or Comments?

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Three ways to reduce risk of P loss

- Updated Tri-State Fertilizer Recommendations
  - https://soilfertility.osu.edu
- Updated Ohio P-Risk Index
  - https://nutrientmanagement.osu.edu
- Application forecast tools
  - Ohio Applicator Forecast (ODA)

https://www.agri.ohio.gov/wps/portal/gov/oda/divisions/plant-health/resources/ohio-applicator-forecast

  - OSU Field Application Resource Monitor (F.A.R.M.) can give past (and present) forecasts

https://farm.bpcrc.osu.edu

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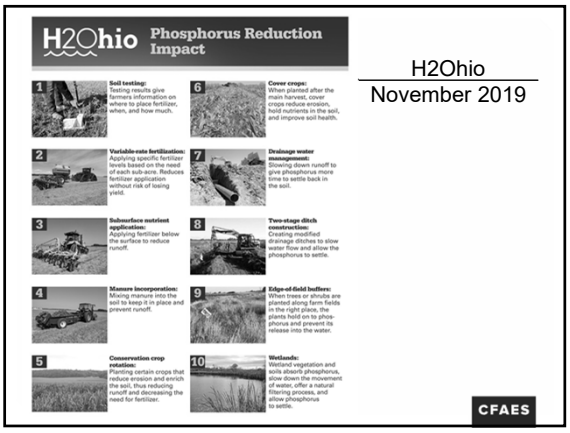

H2Ohio
November 2019

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Management Options to Reduce Lake Erie Algal Blooms (and to reduce P loss across the state)

- Reducing Harmful Algal Blooms (HABs) is challenging.
- The U.S. and Canada have set a goal of reducing the nutrients that cause HABs by 40% by 2025.
- A lot of different strategies have been proposed and debated for reducing the nutrients that go into Lake Erie.
- But will these management options really work?
- Before spending millions of dollars on nutrient management strategies, a research team of 5 institutions (Ohio State University - FABE Jay Martin, Heidelberg University, University of Toledo, University of Michigan, and LimnoTech) looked to see how effective they would be at meeting this 40% reduction goal.

http://kx.osu.edu/project/environment/habri-multi-model

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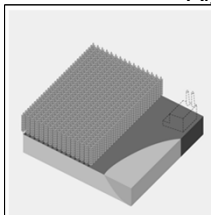
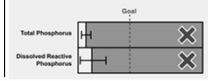
Management Options to Reduce Lake Erie Algal Blooms



Will eliminating nutrients from **all** point sources work?

Point sources of nutrients are known places along the water that pollution and nutrients come from, and we know exactly where the pollution or nutrients were created. Examples of point sources include waste pipes from factories, power plants, wastewater treatment plants, and other sources that go directly into the water. Agriculture is not considered a point source.

Eliminating 100% of nutrients from point sources WILL NOT achieve the 40% nutrient reduction goal.



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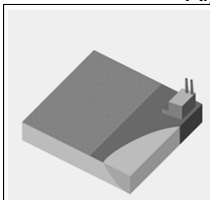
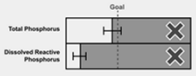
Management Options to Reduce Lake Erie Algal Blooms



Will planting **all** farmland with winter cover crops work?

Fertilizers that contain phosphorous help agricultural crops grow. After harvest, and before the next seasons' planting, rains and weather can cause phosphorous that remains in the soil to run off into local waterways and eventually into Lake Erie. Planting fall and winter cover crops, like cereal rye, can help keep the nutrients from running off.

Planting cover crops on 100% of the agricultural acres in the Maumee watershed will not achieve the 40% nutrient reduction goal, but it does come close.



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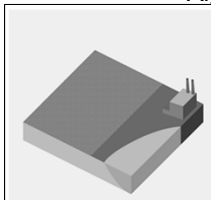
Management Options to Reduce Lake Erie Algal Blooms

There is no silver bullet



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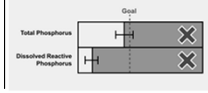

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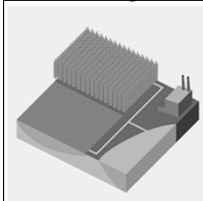
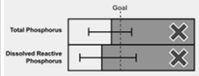
Management Options to Reduce Lake Erie Algal Blooms – bundle practices



Will bundling management practices together work?

The first bundle tested is a combination of improved drainwater management on 15% of acres, no-till agricultural adoption on 50% of acres, cover crops installed on 50% of acres, and injection of fertilizers directly into the soil, instead of being spread on top of fields on 60% of acres.



Will this combination reach the 40% reduction goal?

This combination moves us closer to the 40% reduction on average across all models but does not get us all the way there. A few models predict this combination can achieve the 40% reduction.

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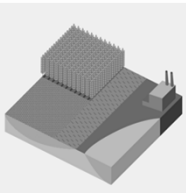
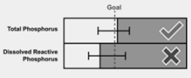
Management Options to Reduce Lake Erie Algal Blooms – bundle practices



Will bundling management practices together work?

This bundle tested a combination of edge-of-field buffer strips installed on 78% of acres, cover crops installed on 58% of acres, and subsurface injection of fertilizers on 50% of acres.



Will this combination reach the 40% reduction goal?

Finally some success. This bundle of practices achieves the 40% reduction in Total Phosphorous on average across all the models run. It doesn't quite reach the goal for Dissolved Reactive Phosphorous on average, but it comes the closest of all the bundles tested.

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Thank you!

- Questions or Comments?

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937 604-2415

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