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### How Crop Nutrient Removal Trends Affect Agronomics and Economics of Nutrient Management

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#### First Step - brief definitions

- Grain nutrient concentration percentage (%) or part per million nutrient concentration in grain at physiological maturity (harvest)
- Nutrient removal coefficient pounds of nutrient removed per unit of crop harvested (lb  $P_2O_5$  per bushel of corn grain)
- Nutrient removal pounds of nutrient removed per land area (ac or ha)
- Soil-test level extractable nutrient value in ppm or mg/kg
- Soil nutrient buffering capacity pounds of nutrient to increase soil-test levels one ppm (e.g., 7 pounds of K<sub>2</sub>O to increase STK 1 ppm)

#### North Central U.S. Soil-test trends



## Background for this work – Wisconsin K issues



#### Removal in WI rate recommendations

#### Critical concentration range

	Soil test category											
	Very low (VL)	Low (L)	Optimum (0)	High (H)	Excessively high (EH)							
Soil group <sup>a</sup>			soil test P pp	m <sup>b</sup>			Buildu	n	Maintain	Dra	wdown	
Demand level	1: corn grain, soybea	n, clover, small grai	ns (but not wheat), gr	rasses, oilseed crops, j	pasture	5 🛧	Danad	P			in a contra	
Loamy	< 10	10-15	16–20	21-30	> 30	lati			1			
Sandy, Organic	< 12	12-22	23-32	33-42	> 42	end	4.9/81		1	-		
Demand level 2	2: alfalfa, corn silage,	wheat, beans, swee	et corn, peas, fruits			Ĕ	A AN	P. art				-
Loamy	< 12	12–17	18–25	26-35	> 35	5	- ALE PRO OF	Her Has	A Partition	½ Crop	1/4 Crop	-
Sandy, Organic	< 18	18-25	26-37	38–55	> 55	Rec	19:55	7.9 3	12935	Removal	Removal	
Demand level 3	3: tomato, pepper, br	assicas, leafy greens	, root, vine, and truck	crops		ut	Crop Rer	noval+	Crop			
Loamy	< 15	15-30	31–45	46-75	> 75	trie	hands at	ANER .	Removal		1	_
Sandy, Organic	< 18	18-35	36–50	51-80	> 80	2 I	TTAK.	TEX		1435	- PTAN	
Demand level 4	l: potato							100 Mar 1		A State of the second s		
Loamy	< 100	100-160	161-200	> 200			Very Low	Low	Optimum	High	Very High	Exces
Sandy, Organic	< 30	30–60	61–90	91–120	> 120				Soil Test Category		Hi	
anuy, organic	×1V	/ v <sup>_</sup> ivv	101-100	טו עטו-וכו	V(I ~ V/I				Soll lest Category			

Maximizes economic return & builds over 4-yr Laboski (2012)

#### Removal estimates also affect...

- Assumed soil-test draw down values
  - E.g., 18 lb P<sub>2</sub>O<sub>5</sub> to reduce soil-test P 1 ppm (Wisconsin number)
  - May be estimated from build-up rate
  - We will show later how this causes some complications
- Large-scale nutrient budgeting efforts
  - Support regional and national production and water quality estimates



### Specific importance with manure planning (Wisconsin examples)

• Crop nutrient removal and soil buffering capacities embedded in:



HUNTING FISHING PARKS CLIMATE ENVIRONMENT FOR

#### **NUTRIENT MANAGEMENT PLANNING**

A Concentrated Animal Feeding Operation (CAFO) Water Pollutant Discharge Elimination System (WPDES) permit requires a field-specific, <u>phosphorus-based (PDF</u>) nutrient management plan (NMP) that outlines the amounts, timing, locations, methods and other aspects related to land application of manure and process wastewater. Implementation of a NMP helps prevent or minimize manure or other wastewater runoff from fields to surface waters or groundwater. Nutrient management planning also ensures applied nutrients meet crop needs.

Nutrient management planning can be complicated and take a considerable amount of time and effort. One NMP may cover thousands of acres and contain over 100 fields. Planning may be for areas with multiple crops and different soils with different nutrient requirements and limitations. Nutrient management plans require:

- field soil testing reports;
- planned or actual application rates, methods and timing for manure and process wastewater;
- field soil erosion and phosphorus delivery to surface waters calculations;
- nutrient crediting;
- maps showing field-specific spreading restrictions and soils;
- manure spreading field-specific reports and procedures; and
- detailed plan narratives.

https://dnr.wisconsin.gov/topic/CAFO/NutrientManagementPlan.html

#### SNAPPLUS WISCONSIN'S NUTRIENT MANAGEMENT PLANNING SOFTWARE

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#### SNAPPLUS NUTRIENT MANAGEMENT

**SnapPlus** (Soil Nutrient Application Planner) is Wisconsin's nutrient management planning software. The program helps farmers make the best use of their on-farm nutrients, as well as make informed and justified commercial fertilizer purchases. By calculating potential soil and phosphorus runoff losses on a field-by-field basis while assisting in the economic planning of manure and fertilizer applications, SnapPlus provides Wisconsin farmers with a tool for protecting soil and water quality.

#### https://snapplus.wisc.edu/

### Big three questions to address today

- 1. What happens to removal as crop yield and fertility status change?
- 2. What are economic implications of changing removal estimates?
- 3. How will varying removal rates affect soil-test levels?



#### Studies to examine P&K in Wisconsin

- 12 sites/year across Wisconsin
- Corn, soybean, corn silage each year
- No-till and disk/chisel-plow
- 0.7 to 5.8% SOM, silty clay loam to sand surface textures, pH 5.5 to 7.4 (6")
- Full factorial of P & K treatments







#### General discussion direction today

Data trends







Management implications





#### Yield response to soil-test P and K



#### Critical soil-test P&K – fine textured WI sites



Slightly higher than current interpretation class "optimum" for P&K

# Observed grain nutrient concentration ranges – P, K, & N

- Small increases in soybean yield can greatly affects removal
- Though not used for fertilization planning, large amounts of N leave the system in grain



#### Observed grain nutrient removal ranges

 Total removal variability is driven in part by fertility, but also any stress that affects yield



#### Variability in removal coefficients

- Both yield and grain composition affecting this variability
- Upper 75<sup>th</sup> percentiles near or slightly changed from current UW values



#### Soil-test level and grain P



#### Soil-test level and grain K



#### Yield level and grain concentration



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#### Yield level and nutrient removal



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#### Yield level and phosphorus removal



Consider the range of removal for a given yield levels (200bu/a and 75 bu/a)

#### Yield level and potassium removal



 Consider the range of removal for a given yield levels (200bu/a and 75 bu/a)
 Jones (2022)

### Corn silage yield response to P&K

- Grain yield and silage (biomass) respond differently to added K
- Grain P and K responses show clear thresholds
- Biomass will continue to take up K (evidence of this in soybean as well – redistribution of K)



### Corn silage phosphorus removal



- Phosphorus removal in silage affected by P rate, K rate, and P x K interaction
- Implications for total nutrient uptake in grain corn

#### Corn silage potassium removal



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• Implications for total nutrient uptake in grain corn

#### Economics of variable removal

Crop	Nutrient	Yield (bu/a)	Removal range (Ib/a)	Replacement cost (\$/a)
Corn	Р	250	58 to 85	\$29 to 43
	K	250	28 to 48	\$14 to 24
Soybean	Р	75	42 to 65	\$25 to 39
	K	75	78 to 93	\$47 to 56



## Case study field – soybean removal (south central WI field data)

zones	1	2	3	4	5	6	7
Yield (bu/a)	50	55	38	57	69	71	65
static K							
removal	60	66	45.6	68.4	82.8	85.2	78
static field							
average				69			
dynamic K							
removal	64	71.3	46.48	74.22	91.74	94.66	85.9
dynamic field							
average				75			

#### Weather conditions & total uptake



• Years within 5" of 30-yr avg growing season rainfall

• Years < 5" of 30-yr avg growing season rainfall

#### Weather conditions & K uptake/removal



- Years within 5" of 30-yr avg growing season rainfall
- Years < 5" of 30-yr avg growing season rainfall

#### Final topic to cover – removal and soiltest levels

- Some states (WI) define soil nutrient buffer capacity as pound of fertilizer nutrient to increase soil-test 1 part per million.
- This may be applied to drawdown estimates too
  - Assumes that build up and drawdown are equal??
- This definition of buffering capacity is resent in fertilizer rate recommendations (in some form)

**Table 7.3.** Phosphorus (P) and potassium (K)buffer capacities; the rate of fertilizer (oxide basis)required to increase soil test level 1 ppm.

	P buffer capacity	K buffer capacity			
Soil group <sup>a</sup>	(lb P <sub>2</sub> 0 <sub>5</sub> /a per 1 ppm soil test P)	(lb K <sub>2</sub> 0/a per 1 ppm soil test K)			
Loamy	18	6–7			
Sandy	12	6			
Organic	18	5			

#### How fast can I build up soil-tests?



Maintaining optimum STP (16-20 ppm P) was affected by K nutrition

### Soil buffering capacities – highly variable



**Table 7.3.** Phosphorus (P) and potassium (K) buffer capacities; the rate of fertilizer (oxide basis) required to increase soil test level 1 ppm.

i wanter suparity	K buffer capacity		
(Ib P <sub>2</sub> O <sub>5</sub> /a per 1 ppm soil test P)	(lb K <sub>2</sub> 0/a per 1 ppm soil test K)		
18	6–7		
12	6		
18	5		
	(Ib P <sub>2</sub> O <sub>5</sub> /a per 1 ppm soil test P) 18 12 18		

UW A2809

- Single field near Arlington, WI
- Well represented in recommendation dataset

### Why are buffering capacities important?



# Soil buffering capacities vary by initial soil-test level

- More fertilizer is required to increase soiltest levels if the initial level is low
- Remember: this is based on extractable nutrient amounts
- Finding true fate of applied nutrients at higher levels needs other tactics (lab methods)



#### Challenge in Wisconsin: >750 soil series



#### Are build-up and drawdown equivalent?



• Suggests that they are not. Fertilization and nutrient uptake kinetics very different

# Wrapping up – removal varies & affects many system components

- While nutrient concentrations vary, yield will be main driver of spatial and temporal trends in removal
- So, accurate yield estimates or calibrated monitors/data are best to save over-applying removal fertilization
- Can we collect representative field-level grain samples to make precision removal estimates? Does it matter?
- Field-specific "yield" maps of removal and NUE to driving sitespecific decisions
- Finally, soil sampling will tell the real "truth" for fertilizer rate decisions, but in-between accurate removal (yield) is second best

## Thank you!



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