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Bringing K Back into the Conversation

2025 Advanced Crop Advisers Workshop

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Topics to Cover

- How we talk about K
- The role of K in crop growth
- Forms of soil K and K cycle
- Clay mineralogy and K
- Soil sampling and K levels
- K-fertility management

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First Things First…

K^+

- Ionic form
- Available for plant uptake
- How K actually occurs in the soil
- Reported in soil tests

K_2O

- Basis for fertilizer measurement
- Relic of previous chemical techniques

Converting between the “Ks”

- $K_2O \times 0.83 = K$
- 1 ppm soil K = 8 to 10 lb K_2O/ac

K in Plants

TABLE 1.8 Relative and Average Plant Nutrient Concentrations

Plant Nutrient	*Relative Concentration*	*Average Concentration**
H	60,000,000	6.0%
O	30,000,000	45.0%
C	30,000,000	45.0%
N	1,000,000	1.5%
K	400,000	1.0%
Ca	200,000	0.5%
Mg	100,000	0.2%
P	30,000	0.2%
S	30,000	0.1%
Cl	3,000	100 ppm (0.01%)
Fe	2,000	100 ppm
B	2,000	20 ppm
Mn	1,000	50 ppm
Zn	300	20 ppm
Cu	100	6 ppm
Mo	1	0.1 ppm

*Concentration expressed by weight on a dry matter basis.

Source: Havlin et al. (1999)

Source:https://ndsuspectrum.com/sunflower-remains-important-crop-in-north-dakota/

K function in Plants

- K is not part of compounds formed in the plant
- Mediates plant processes
  - Enzyme activation
  - ATP synthesis
  - Nutrient transport
  - Plant water regulation
  - Conversion of N to protein

Agronomic Implications

- Decreased productivity
- Affects crop quality characteristics
  - Protein and carbohydrate production
  - Shriveled/misshapen seed

Agronomic Implications

- Small grains may tiller excessively
- Increased disease incidence
- Increased lodging
- Decreased winterhardiness of forage crops

Source:https://www.agric.wa.gov.au/mycrop/diagnosing-potassium-deficiency-canola

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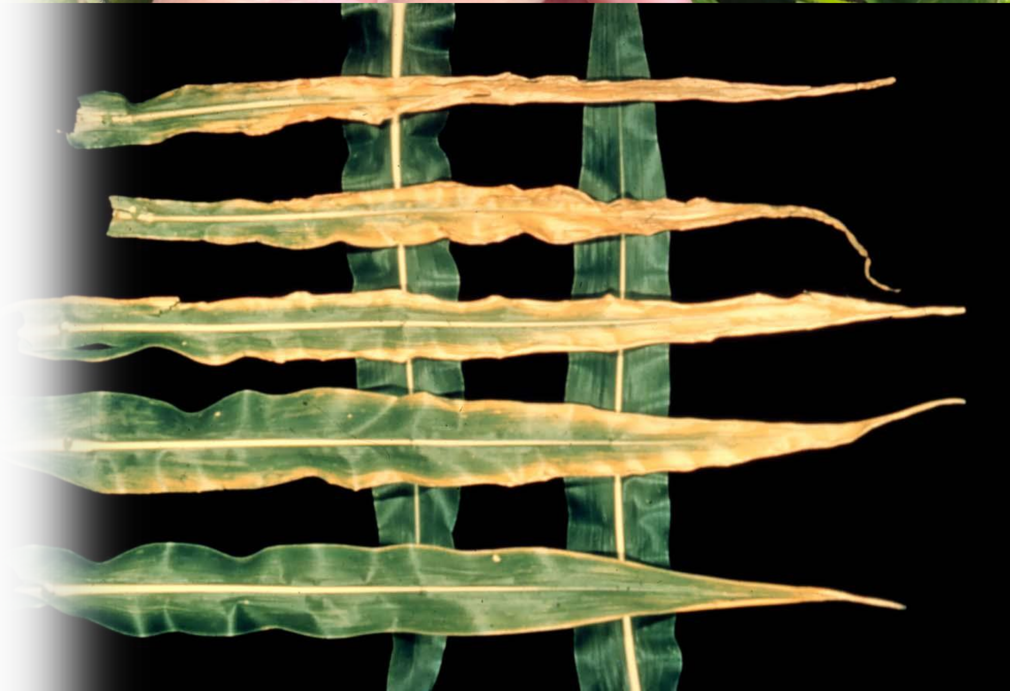
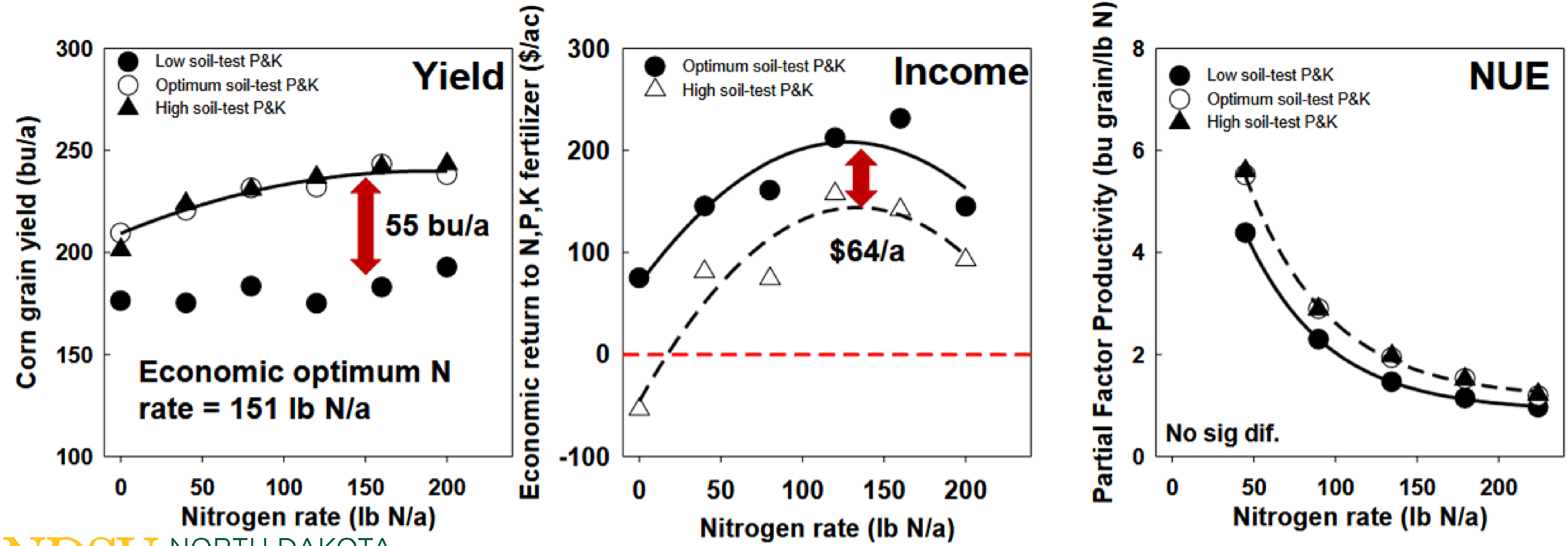
Deficiency Symptoms

- Mobile plant nutrient—older leaves show symptoms first (usually)
- Yellowing and scorching along leaf margins



Agronomic Implications

- Optimum K levels are required to maximize N efficiency



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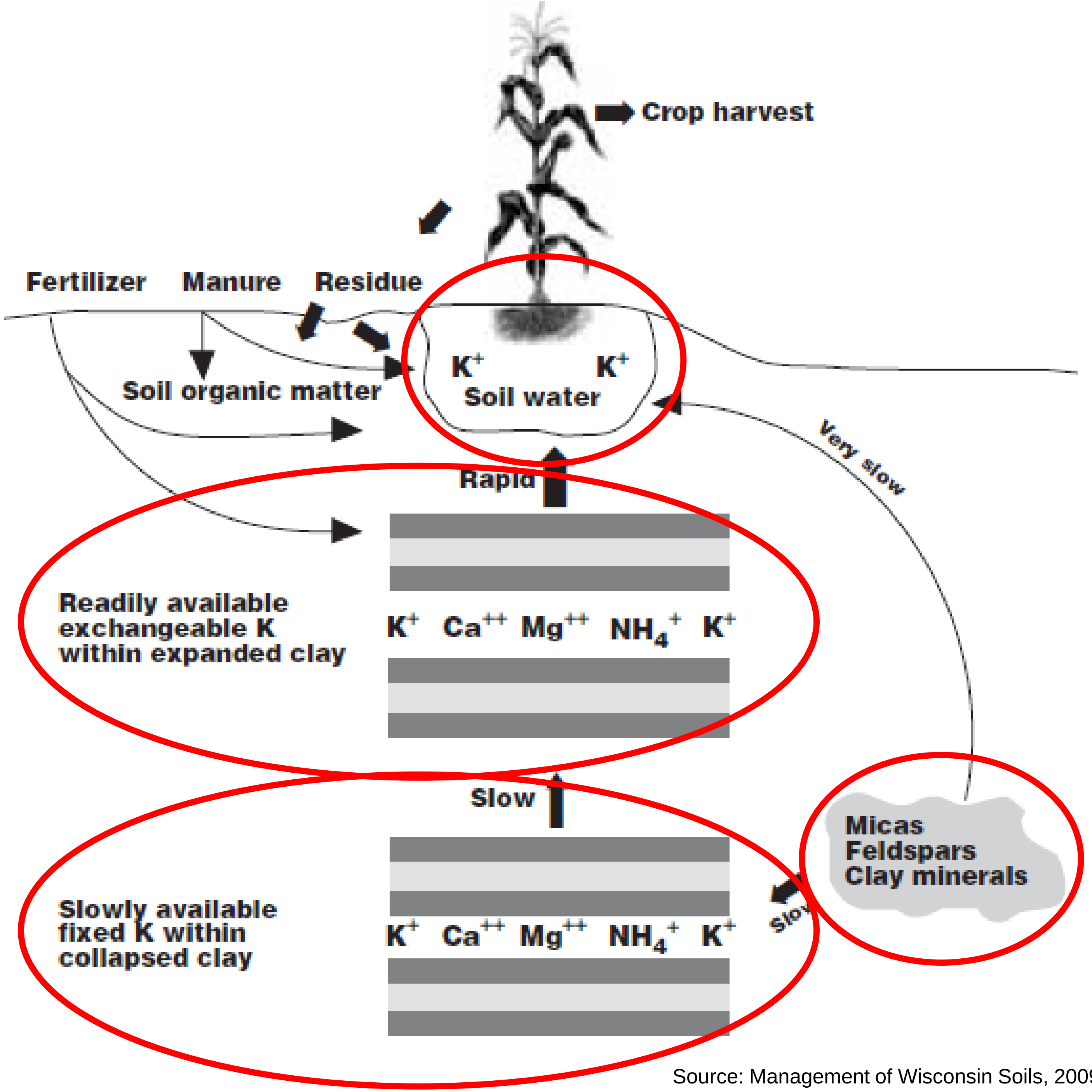
Source: https://cropsandsoils.extension.wisc.edu/files/2023/01/05_Jones_Improved-Phosphorus-and-Potassium-Management.pdf

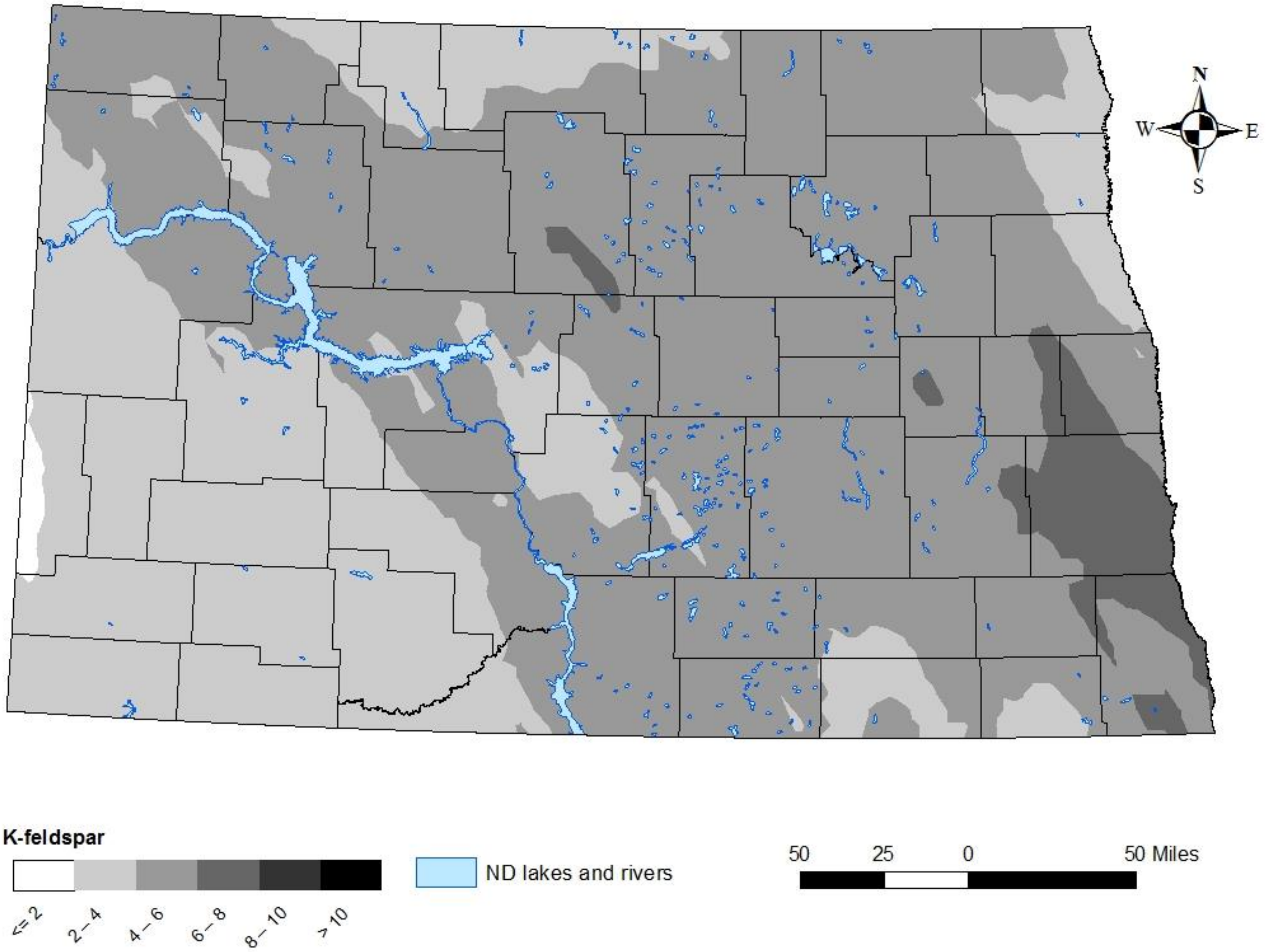
- Mineral
- Non-Exchangeable
- Exchangeable
- Solution



Source: Management of Wisconsin Soils, 2009

Unavailable K

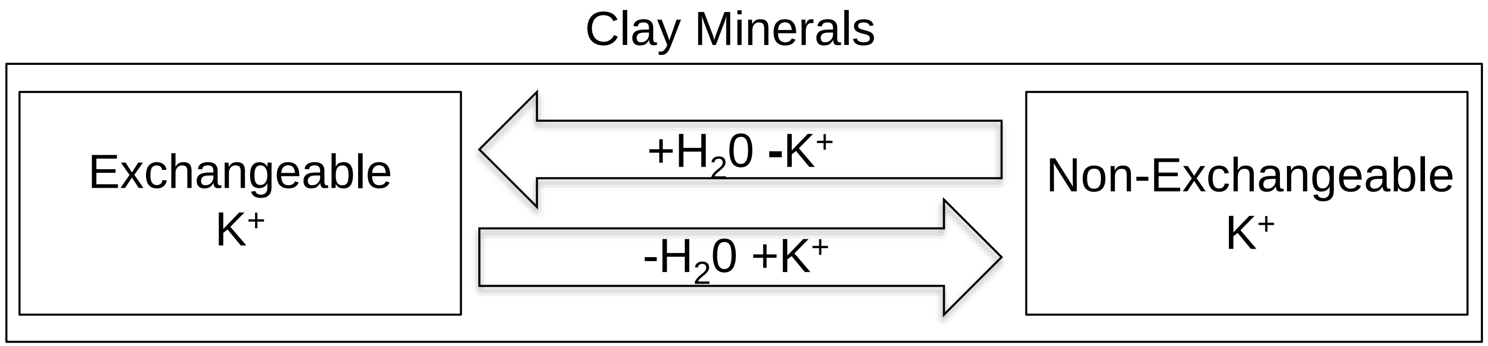
- Also called **primary** or **mineral K**
- Contained within the crystalline structure of rocks and minerals
- 20,000-45,000 lb/ac/6 in
- Insoluble and non-plant available
- Weathered over geologic time into K^+



Source: NDSU-Extension Publication SF1881

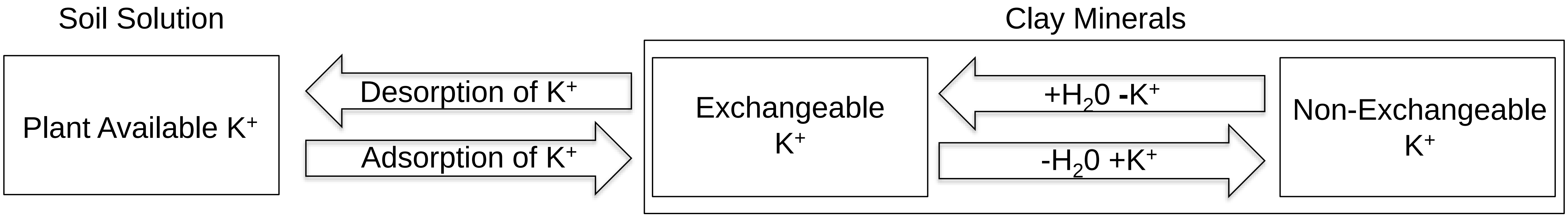
Non-Exchangeable K

- Also called **fixed** or **slowly available K**
- Fixed or “stuck” between layers of certain clays
- Amount of non-exchangeable K depends on clay type and content of soil
- 200-1500 lb/ac/6 in



Exchangeable and Solution K

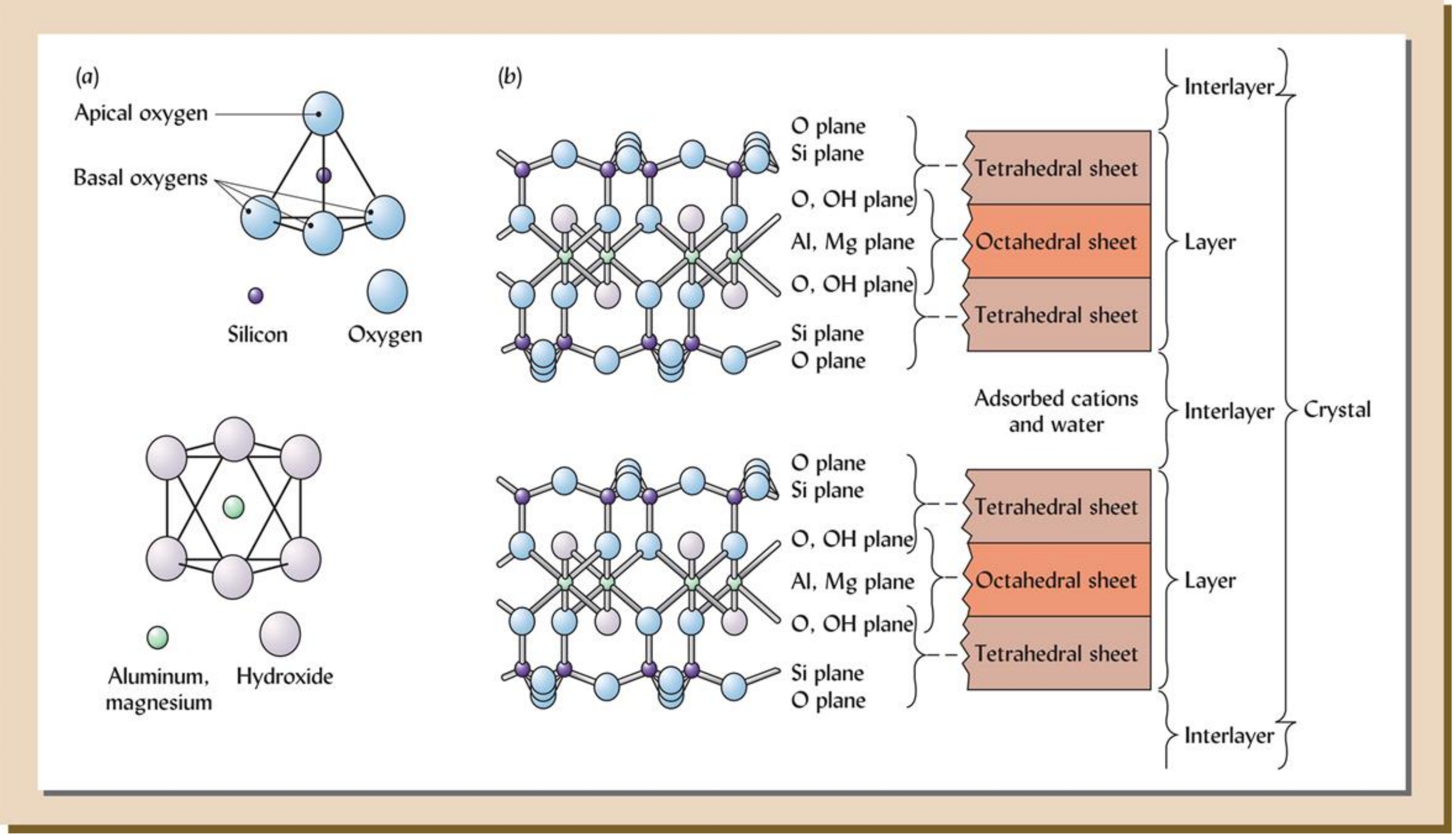
- Exchangeable K, also called **readily available K,** becomes solution, K through cation exchange processes
- Exchangeable and solution K are measured in soil test



Factors affecting K availability

- Root growth
- Rate of soil/mineral weathering
- Wetting and drying cycles
  - *Increases* availability in soils with low exchangeable K
  - *Decreases* K availability in soils with high exchangeable K
- Soil clay and OM content

Clay Mineralogy



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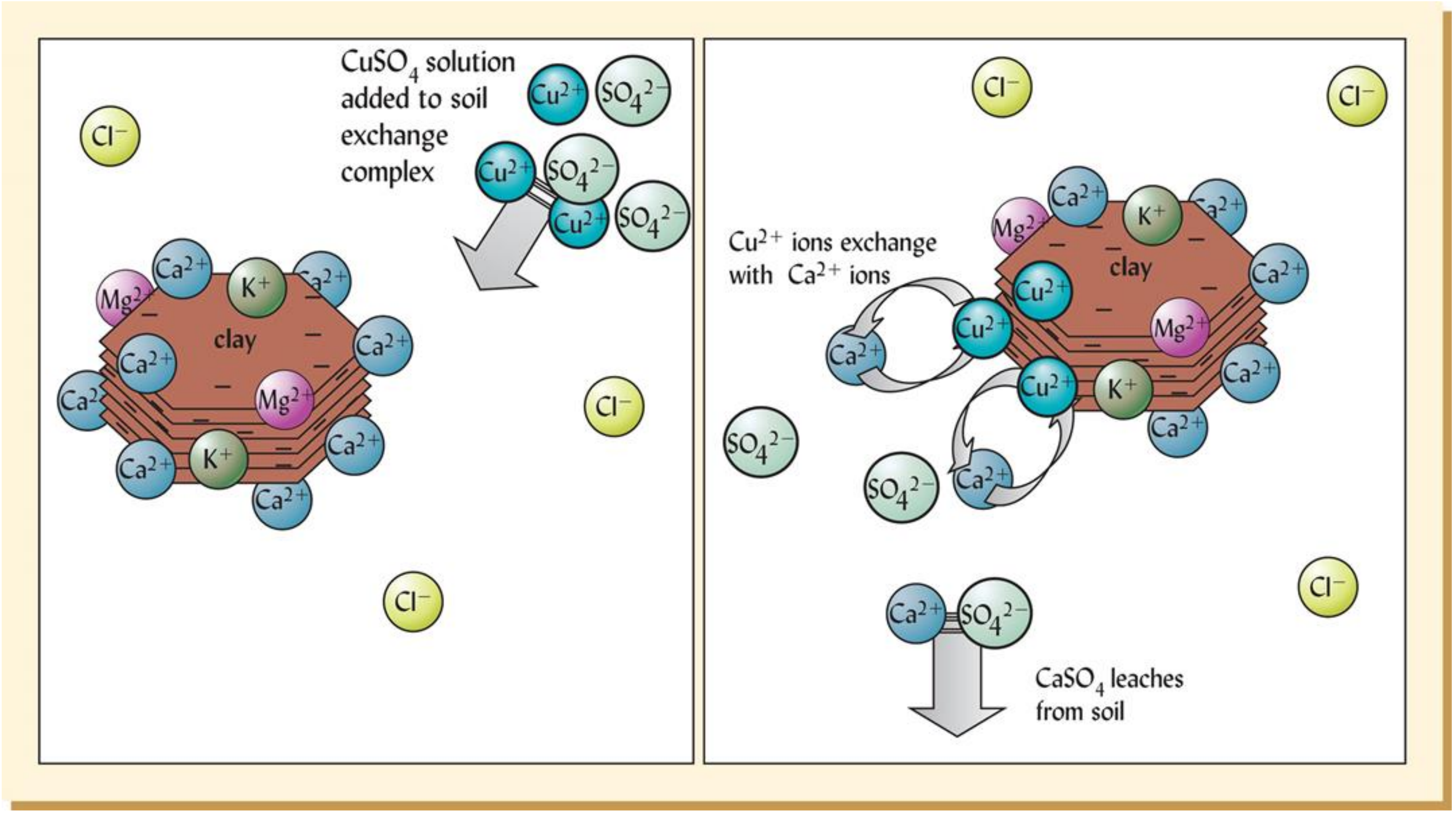
Source: The Nature and Properties of Soil, 15th Ed.

Clay Mineralogy



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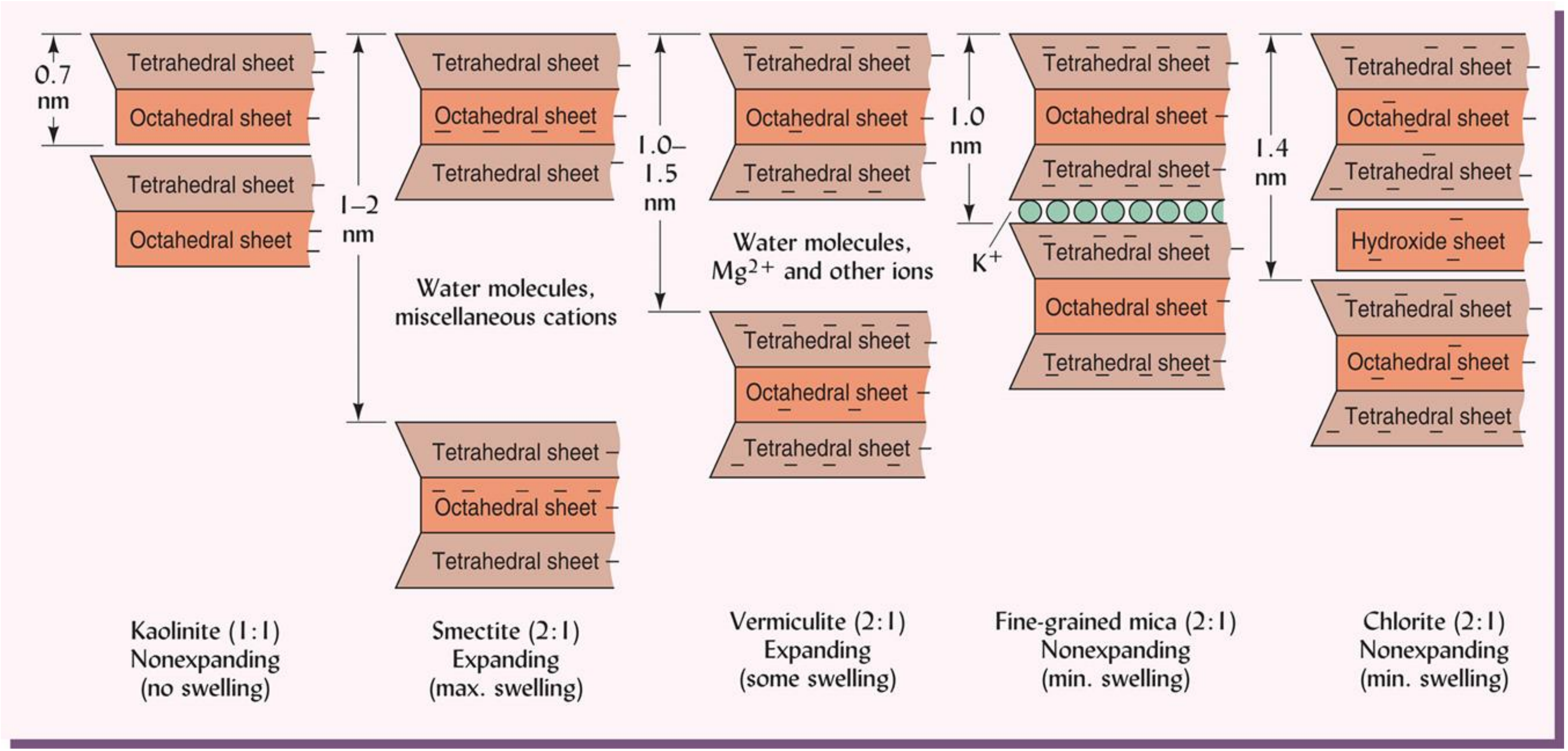
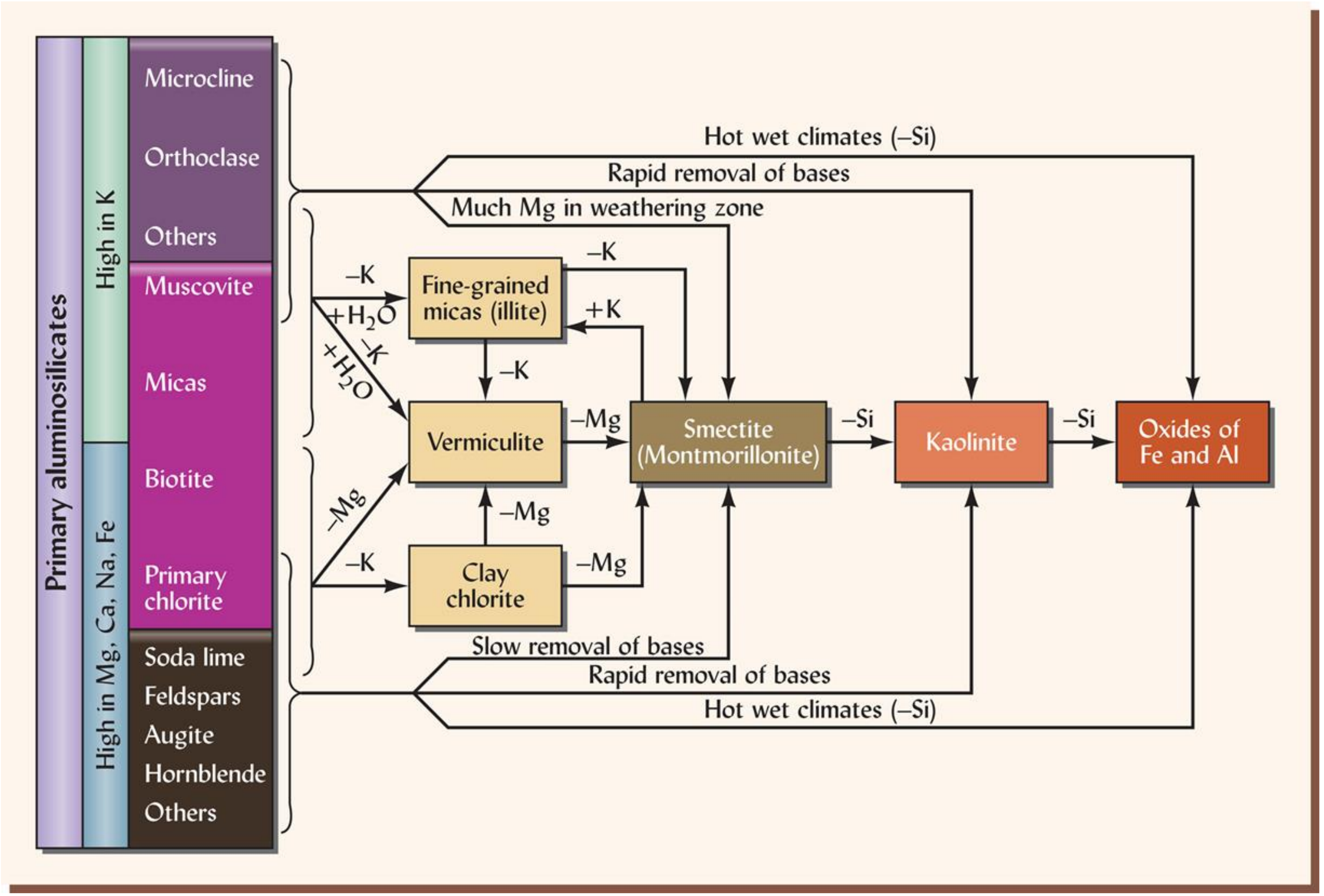
Source: The Nature and Properties of Soil, 15th Ed.

Clay Mineralogy



Source: The Nature and Properties of Soil, 15th Ed.

Clay Mineralogy



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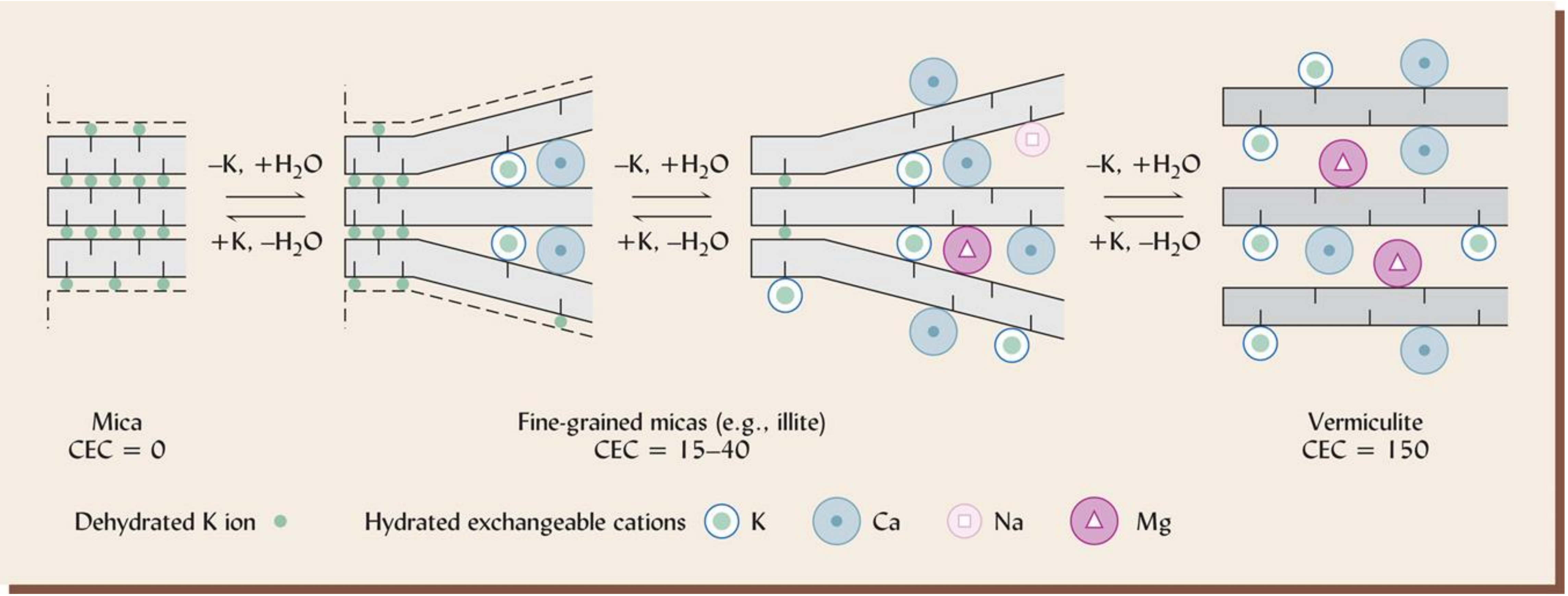
Source: The Nature and Properties of Soil, 15th Ed.

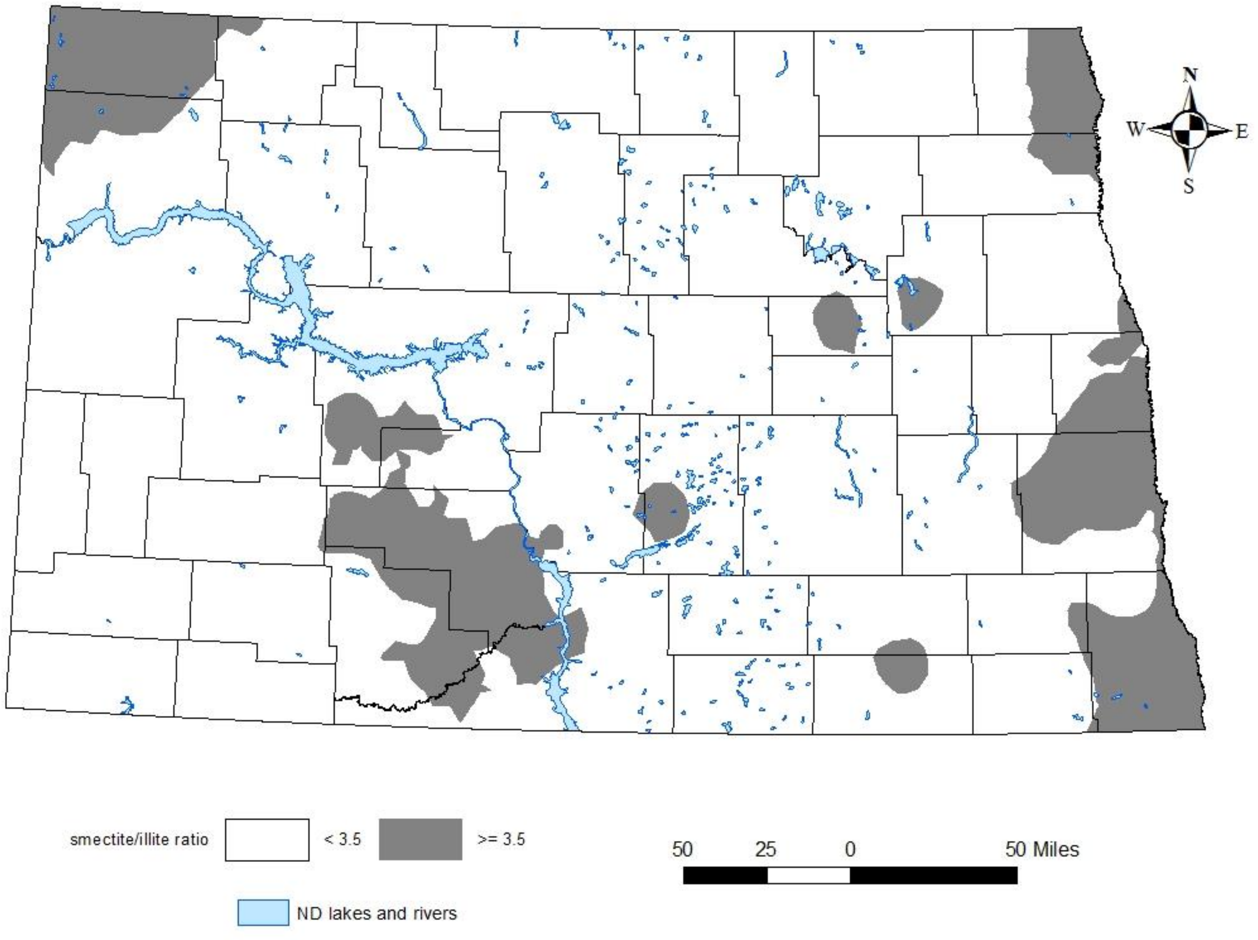
Clay Mineralogy



Source: The Nature and Properties of Soil, 15th Ed.

Clay Mineralogy in Respect to K

- Smectite
  - 2:1 expanding
  - High CEC
  - Traps K when dry
- Illite
  - 2:1 non-expanding
  - Moderate CEC
  - Layers bonded with K



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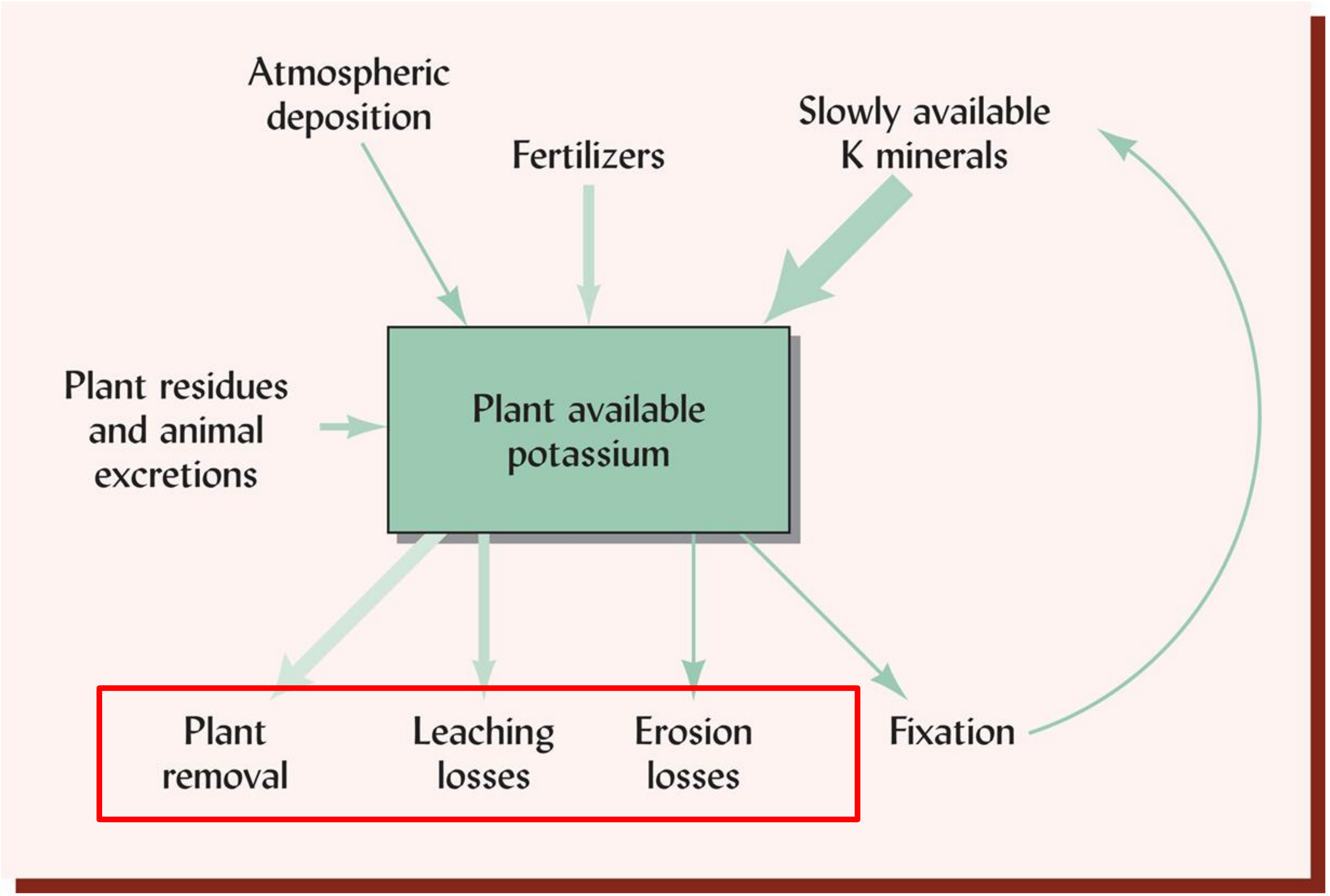
Source: NDSU-Extension Publication SF1881

K Removals and Losses



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Source: The Nature and Properties of Soil, 15th Ed.

K Removal

Crop	Average Yield[1]	K Removed[2] (lb/ac)
Soybean	35.5 bu/ac	55
Corn	143 bu/ac	40
Wheat (grain)	48 bu/ac	20
Wheat (grain+straw)	48 bu/ac	75
Canola	1,810 lb/ac	20
Sunflower	1,998 lb/ac	45
Flax	21 bu/ac	20
Dry Beans	1600 lb/ac	45
Potato	300 cwt/ac	168

Source: [1]USDA-NASS, [2]UW-Extension Publication A2809

K Leaching

- K^+ is protected from leaching in high CEC soils
  - Silty, clayey, and high OM soils
- Sandy, low CEC soils (<10 meq/100g) are prone to K leaching
  - Very sandy fields may not reach critical soil test levels and will not build up K levels
  - Careful yearly fertilization is necessary

Fertility loss due to erosion

- Most K^+ in the soil is associated with clay and OM
  - These are the primary fractions lost when soil is allowed to erode


Photo credit: Ryan Odenbach, NDSU

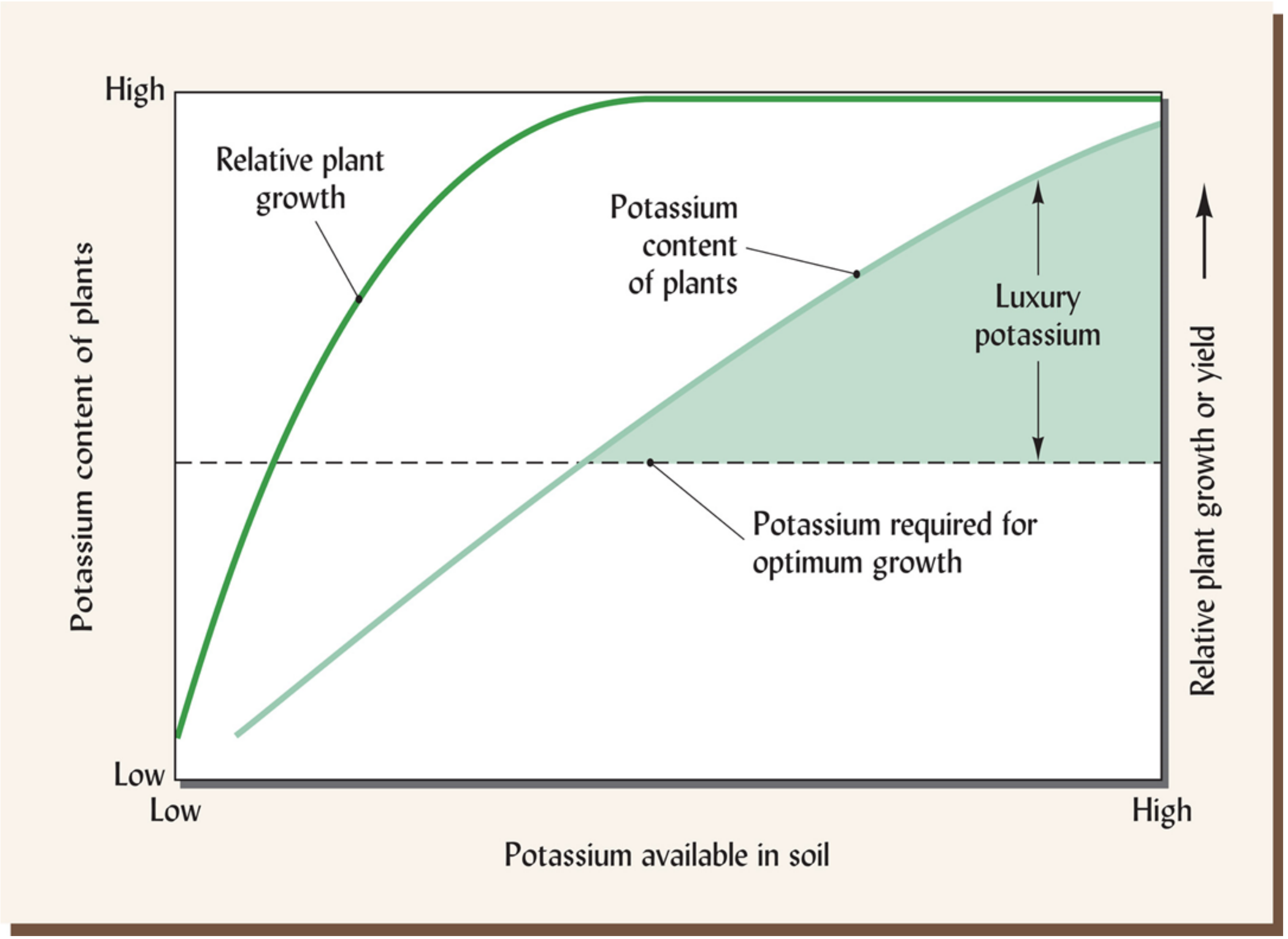
The Cost of Soil Erosion

Estimated available and organic matter-associated nutrients lost in ¼ inch of eroded topsoil with 3% organic matter.

Soil Nutrient	Soil Test Level	Nutrient Lost	Fertilizer Replacement
N	35 lb/ac	125 lb/ac	272 lb/ac Urea
P	12 ppm	30 lb P2O5/ac	62 lb/ac MAP
K	175 ppm	33 lb K2O/ac	55 lb/ac potash

At current wholesale fertilizer prices: $93/ac in loss fertility

Critical Soil Test Levels



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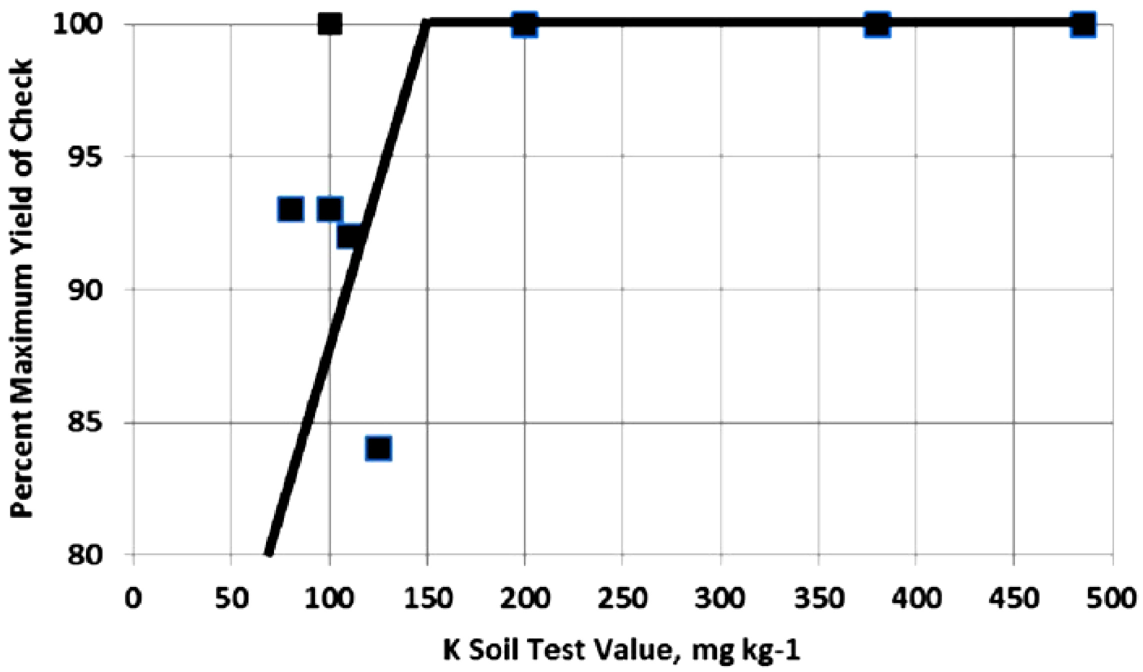
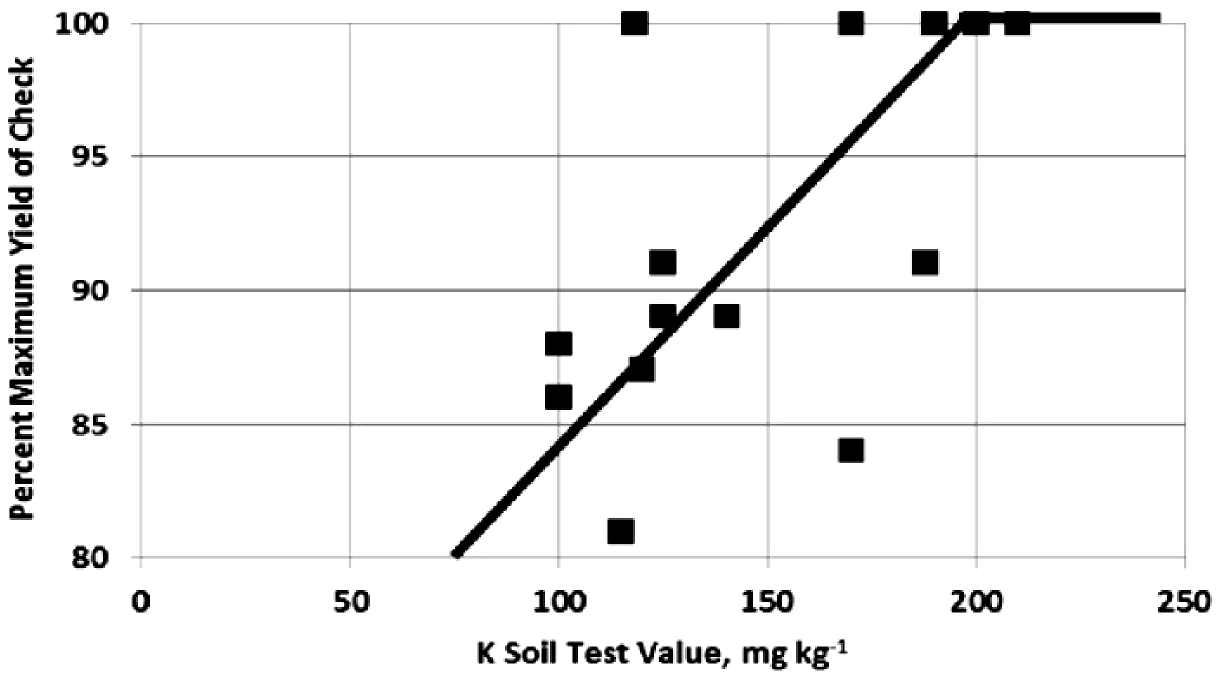
Source: The Nature and Properties of Soil, 15th Ed.

Critical Soil Test Levels

Smectite/illite ratio > 3.5



Smectite/illite ratio < 3.5



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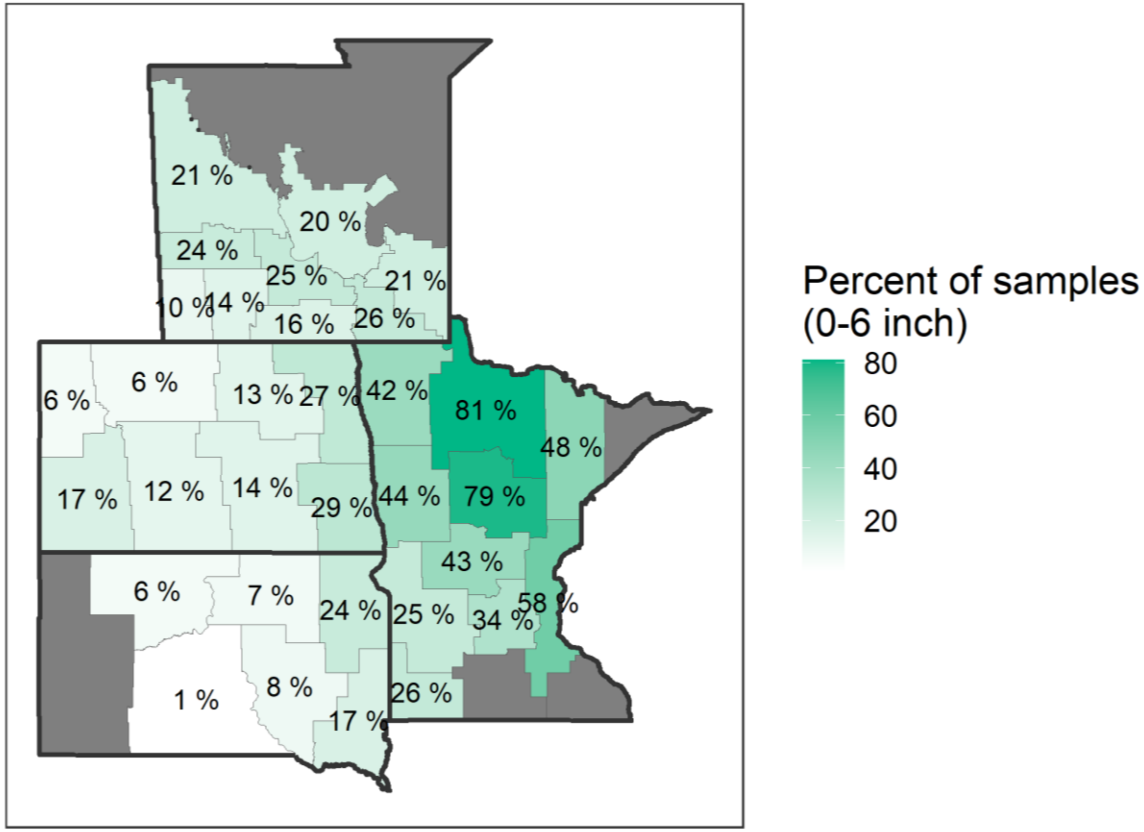
Source: D. Franzen

Critical Soil Test Levels

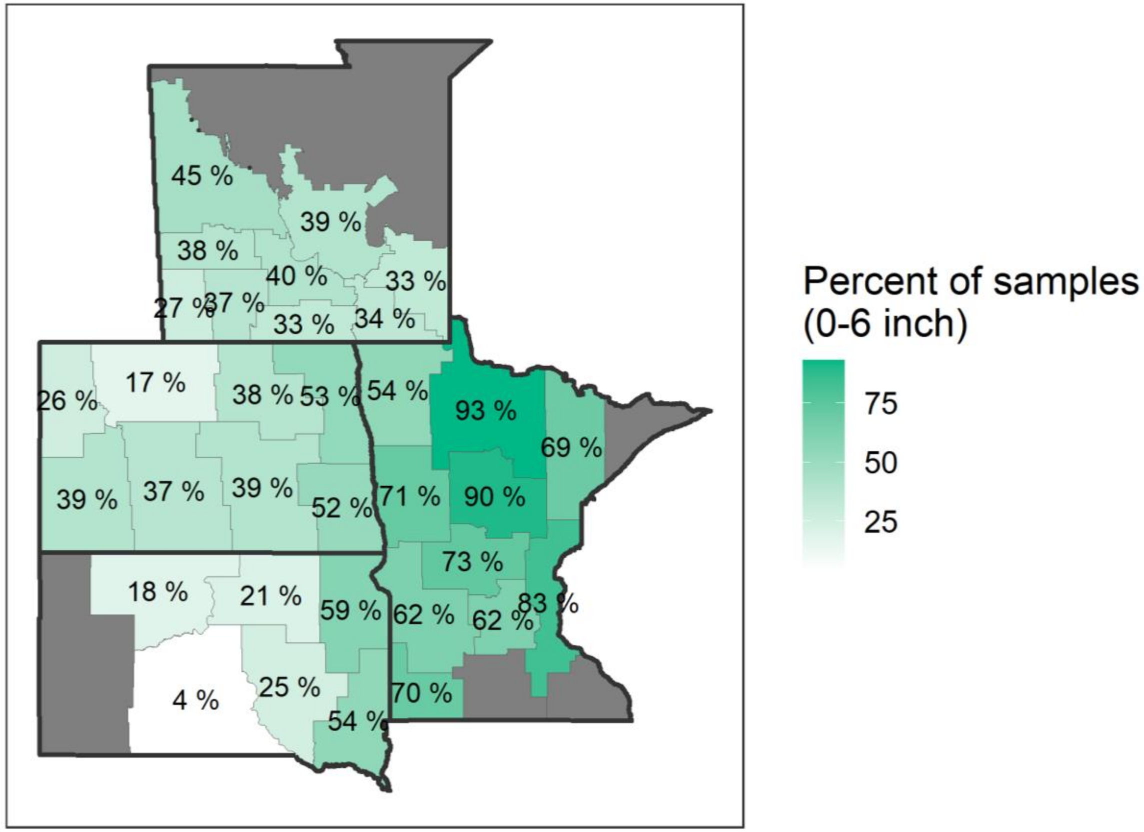
- Smectite-to-illite ratio
  - >3.5 → 200 ppm critical K level
  - <3.5 → 150 ppm critical K level
- Soil test values below the given critical level will likely respond to added nutrients
- Building nutrients above critical levels will likely show no agronomic benefit, but it is “money in the bank”

Soil samples with soil test potassium below 150 ppm in 2024



Data not shown where n< 100
AGVISE Laboratories, Inc.

Soil samples with soil test potassium below 200 ppm in 2024



Data not shown where n< 100
AGVISE Laboratories, Inc.

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Source: https://www.agvise.com/resources/soil-test-summaries/

Soil test K levels vary in both *space* and *time*

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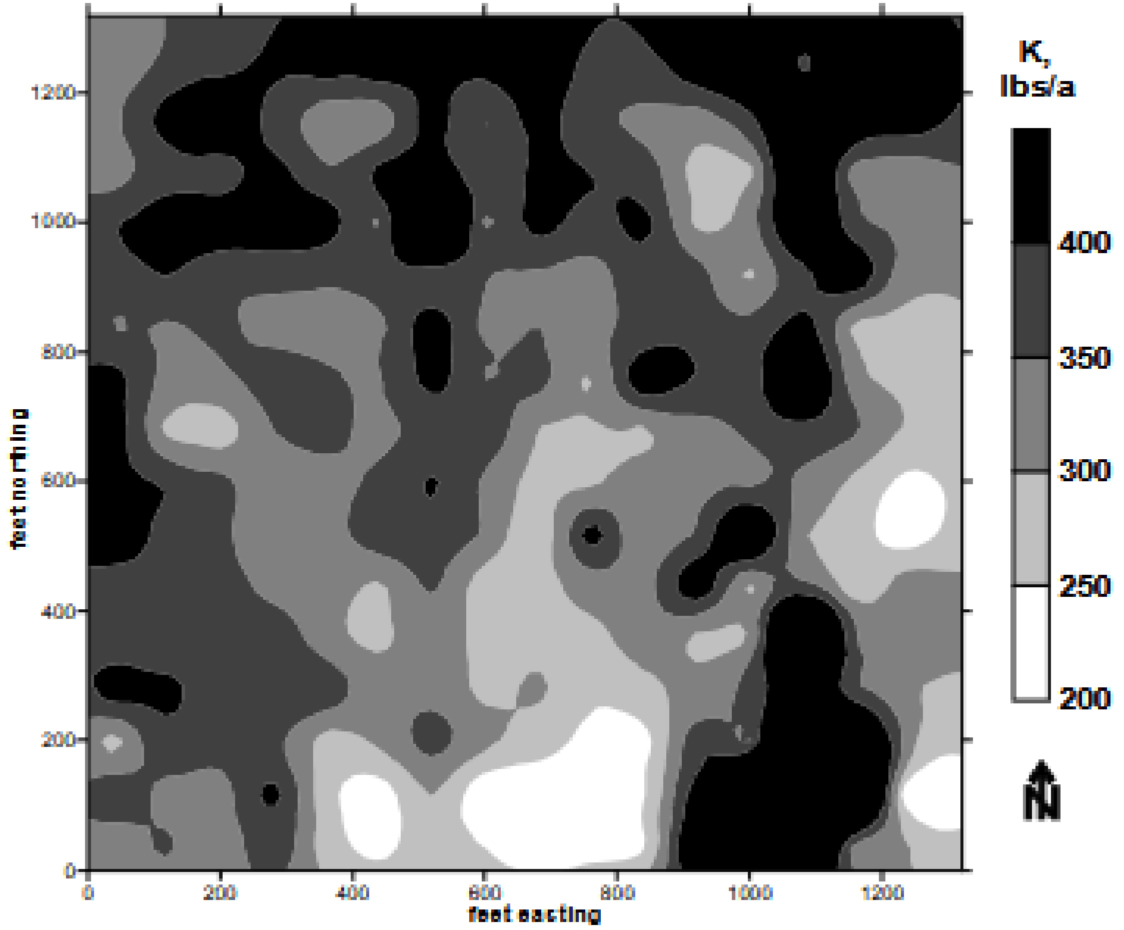
Field K Variability



Thomasboro, IL soil K, 1987.

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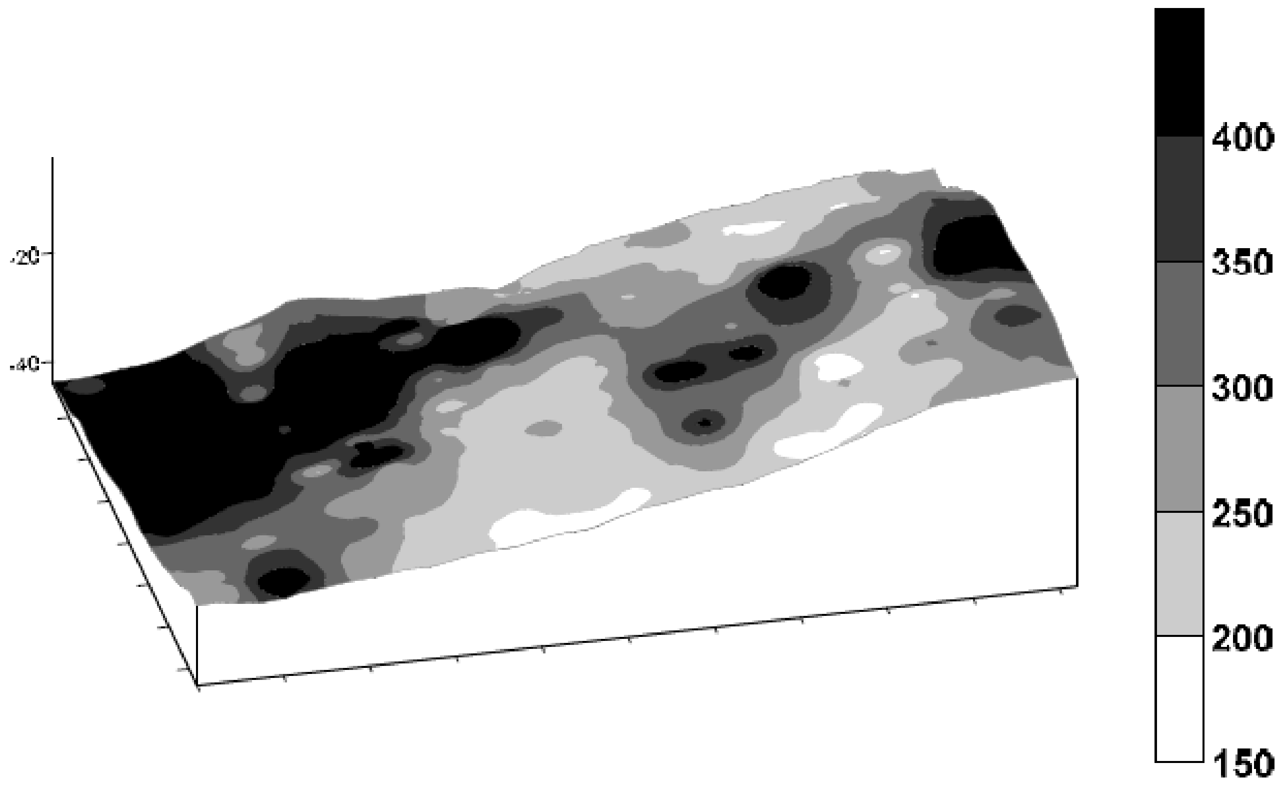
Source: D. Franzen, *Summary of Grid Sampling Project on Two Illinois Fields*

Field K Variability

- Blanket K applications are not efficient
- <10% of the field requires K application

Spatial variability of K soil test, near Valley City, ND



Source: D. Franzen


Photo Credit: B. Goettl, NDSU

NUTRIENT LEVEL IN CROP

ppm		Analysis in Percent								Analysis in Parts Per Million					
P_2O_5-P Phosphate	NO_3-N Nitrate	N Nitrogen	P Phosphorus	K Potassium	S Sulfur	Ca Calcium	Mg Magnesium	Na Sodium	Cl Chloride	Zn Zinc	Fe Iron	Mn Manganese	Cu Copper	B Boron	Al Aluminum
		6.20	0.51	0.33	0.30	1.89	1.28	0.01		36	144	128	7	60	
		H	H	D	S	S	H	S		S	S	H	S	H	

D = Deficient L = Low S = Sufficient H = High V = Very High

NUTRIENT SUFFICIENCY RANGE

		4 TO 5.5	.26 TO .5	1.7 TO 2.5	.2 TO .6	.36 TO 2	.26 TO 1	0 TO 0.1		21 TO 50	50 TO 350	21 TO 100	7 TO 29	20 TO 55	

D.R.I.S. INDEX VALUES

		24	41	-279		39	116			0		38	-3	25	

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Results from Agvise, submitted by J. Stachler, NDSU

- K critical level 150-200ppm
- Cl critical level 40 lbs/ac

NUTRIENT IN THE SOIL			INTERPRETATION (V LOW / LOW / MED / HIGH)
Nitrate N	0- 6"	5 lb/acre	***
Phosphorus	Olsen	15 ppm	************************
Potassium		77 ppm	***********
Chloride	0- 6"	1 lb/acre	*
Sulfur	0- 6"	6 lb/acre	******
Boron		0.1 ppm	**
Zinc		1.09 ppm	********************
Iron		84.6 ppm	****************************
Manganese		17.4 ppm	****************************
Copper		0.62 ppm	********************
Magnesium		368 ppm	*************************
Calcium		1973 ppm	*************************
Sodium		17 ppm	***
Organic Matter		5.2 %	**********************
Carbonate (CCE)		0.2 % CCE	**
Soluble Salts	0- 6"	0.08 dS/m	**

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Results from Agvise, submitted by J. Stachler, NDSU

What factors were at play?

- No K had been applied in 8+ years
- Historically-eroded side hills have lower inherent fertility
- Uneven residue spreading created “higher” K strips

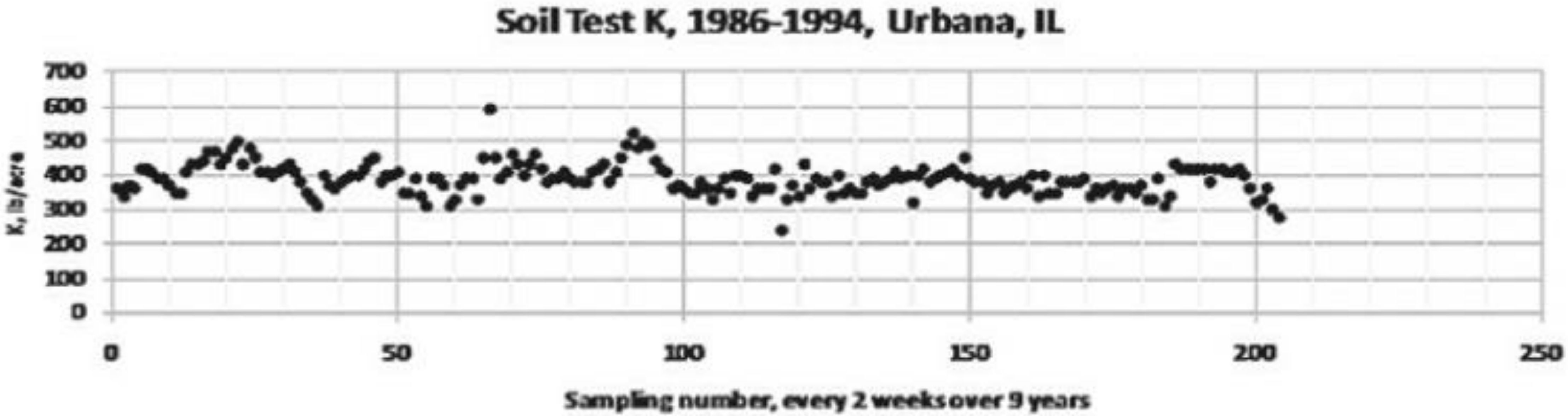

Figure 7. Soil test K in one experimental plot sampled every 2 weeks for 9 years (from Peck and Sullivan, 1995). The first sampling date is April 1.

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Source: Franzen (2011) and Peck and Sullivan (1995)

Freezing and Thawing

- Increases K availability in soils with low exchangeable K
- No effect for soils with high exchangeable K
- Soil test values are generally higher in spring than in fall
  - Freezing and thawing promote the release of fixed K
  - K from plant residues

Soil test K levels vary in both *space* and *time*

- Take advantage of VR technologies
- Keep Sampling timing consistent

Sources of K – Fertilizer

- Potassium chloride (0-0-60)
  - Provides chloride
  - High salt index (116)
    - Care should be taken when applying with the seed
- Potassium sulfate (0-0-50-18)
  - Lower salt index (46)
  - More expensive

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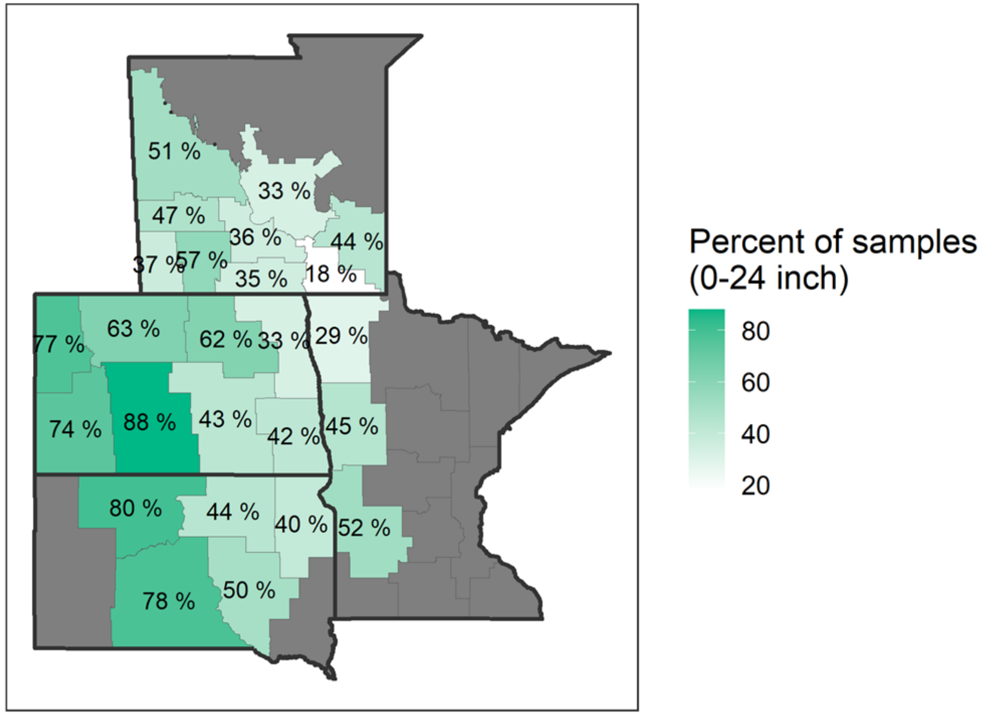
Source:https://krugercommodities.com/product/potash-fertilizer-south-africa-1ton/

Potash and Cl

- Cl deficiency may appear in fields without a history of KCl application
- Most states have no record of Cl deficiency due to regular KCl application
  - ND is not one of these states…

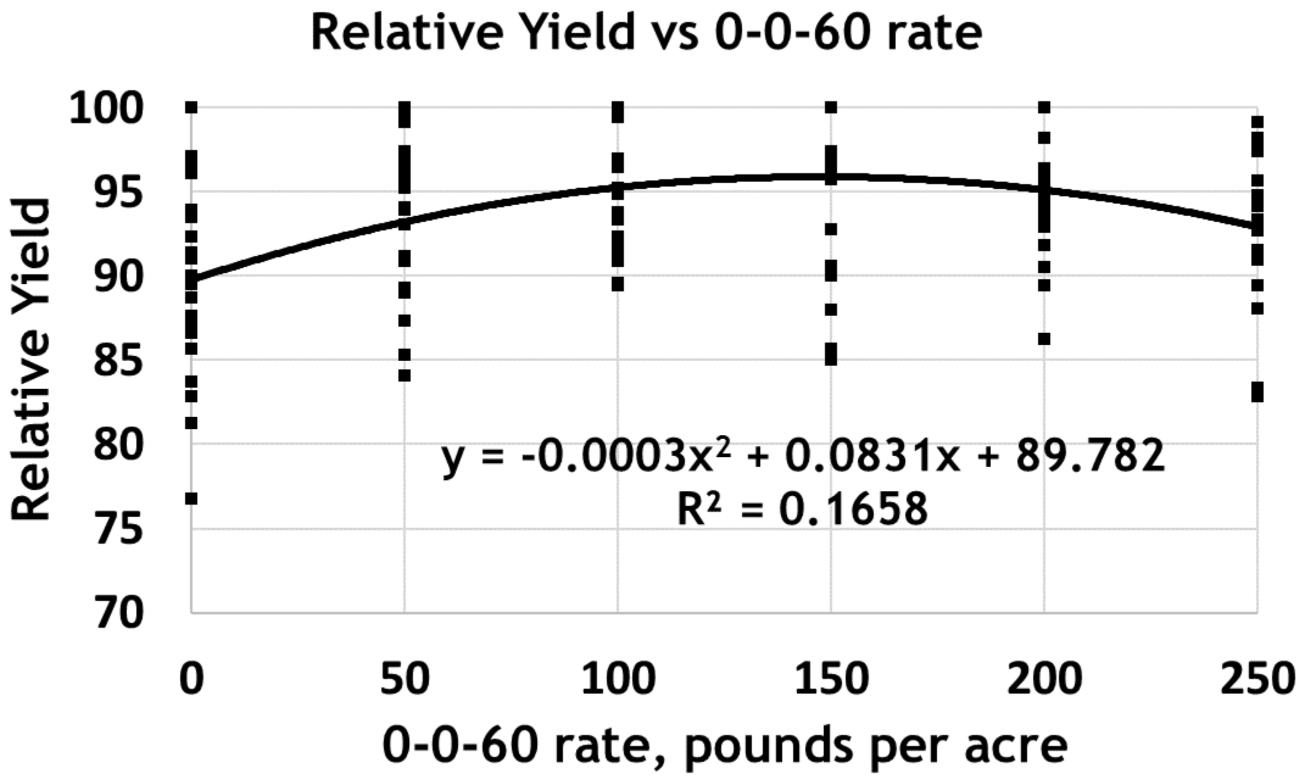
Soil samples with soil test chloride below 40 lb/acre in 2024



Data not shown where n< 100
AGVISE Laboratories, Inc.

Too much of a good thing?

- Reduction in corn yield noted in 0-0-60 rates >200 lb/ac
- Broadcast K recommendations are capped at 200 lb/ac/yr



Source: D. Franzen

Sources of K – Manure

- Approximately 80% of K is available the first year of application
  - 9-30 lb k/ton in solid manure
  - 12-30 lb/1000 gal in liquid manure
- *Remember—forage crops remove high amounts of K, returning the manure can offset the costs of fertilizer*

Practical K Management

- Fertilizing fields over critical level only serves to replace crop removal
  - Unless there is a proven yield response…
- Low CEC fields may not reach critical levels, fertilization for crop needs each year is necessary
- Clay type and climate will impact crop response to K

Small Grain K Fertility

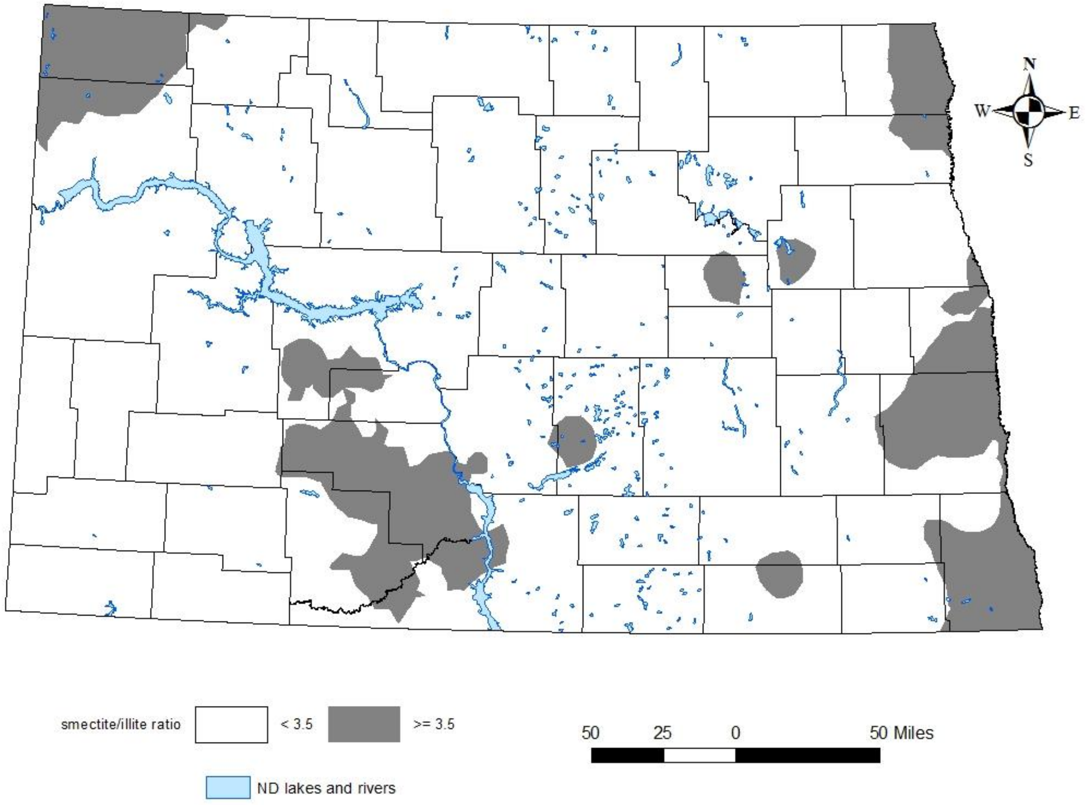
Potassium Recommendations

Soils with smectite-to-illite clay chemistry ratio of 3.5 or less (Figure 3)

- Soil test K > 150 ppm, no additional K required.
- KCl (0-0-60-50Cl) may be applied if soil Cl levels are less than 40 pounds of Cl in a 2-foot depth.
- Soil test K 150 ppm or less, apply 50 pounds/acre KCl (25 pounds/acre K_2O)

Soils with smectite-to-illite clay chemistry ratio more than 3.5 (Figure 3)

- Soil test K > 100 ppm, no additional K required.
- KCl (0-0-60-50Cl) may be applied if soil Cl levels are less than 40 pounds Cl/2-foot depth.
- Soil test K 100 ppm or less, apply 50 pounds/acre KCl (25 pounds/acre K_2O)



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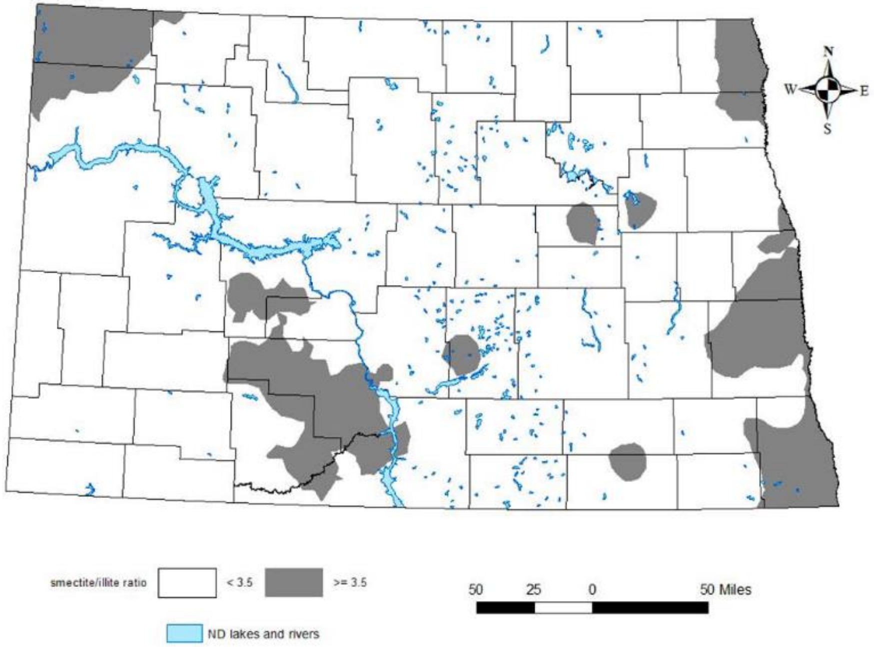
Source: NDSU-Extension Publication SF712

Soybean K Fertility

Table 22. Soybean.

	Olsen Soil Test Phosphorus, ppm					Soil Test Potassium, ppm					
Total N*	VL 0-3	L 4-7	M 8-11	H 12-15	VH 16+	VL/VL 0-40	L/L 41-80	M/M 81-120	H/M 121-150	VH/H 151-200	VH/VH 201+
0	52	26	0	0	0	90/90†	60/90	60/60	30/60	0/60	0/0

† Split K recommendation, left is for soils with smectite-illite ratio < 3.5; right for soils with smectite-illite rate > 3.5



Sunflower K Fertility

- Similar to P, sunflower response to K is minimal
  - However, K removal is higher
- To compensate for removal in low soil test K fields 60 lb K_20/ac is recommended in fields testing <150 ppm K

Source:https://ndsuspectrum.com/sunflower-remains-important-crop-in-north-dakota/

Corn K Fertility

- Corn K recommendations are economic based

Table 15. Potassium recommendations for corn in soils with clay chemistry having a smectite-to-illite ratio less than 3.5 and soil test K levels 100 ppm or less.

Corn price, $ per bushel	Price per pound K_2O, $ per pound									
	0.125	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
	Recommended pounds K_2O per acre									
2	90	90	90	90	60	60	0	0	0	0
3	90	90	90	90	60	60	60	60	60	0
4	90	90	90	90	90	90	90	90	90	60
5	90	90	90	90	90	90	90	90	90	90
6	120	120	120	120	90	90	90	90	90	90
7	120	120	120	120	120	120	120	120	120	90
8	120	120	120	120	120	120	120	120	120	120
9	120	120	120	120	120	120	120	120	120	120
10	120	120	120	120	120	120	120	120	120	120

North Dakota
Corn Potassium Recommendation Calculator

About | Calculator

Select each parameter value below to conduct corn potassium calculation. All fields are necessary.

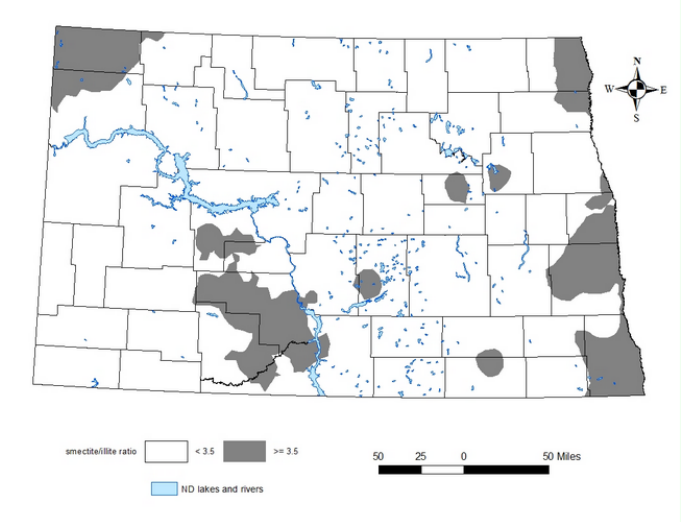
Smectite-to-Illite Ratio
◉ < 3.5 ○ >= 3.5

Soil Test K Level (unit: ppm)
◉ <= 100 ○ 101-149 ○ >= 150

Closest corn price ($/bushel):
2

Closest K_2O price ($/pound)
(or 0-0-60 fertilizer price ($/ton)):
0.125 (150)

Recommended K_2O (pounds/acre)
90



(Click the map to view its bigger size)

Smectite-to-illite ratio of surface soils in North Dakota from a soil sampling conducted in spring 2017. Dark gray regions are equal to or greater than 3:5. White areas are less than 3:5.

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Source: NDSU-Extension Publication SF712

Take-Home Points

- Available K levels in ND are decreasing
- K is below critical levels on 6-52% of submitted samples
- Critical K levels range depending on crop and clay mineralogy
- Consistency is key when sampling, especially when comparing years
- Care should be taken when applying potash to prevent salt injury

Bonus Information

Managing Soil Fertility in Dry Years with Tight Margins

Dr. Brady Goettl

Assistant Professor of Extension Soil Science

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Topics to Cover

- Extension Soil Science updates
- Economic fertility management
- Practical cuts to fertility

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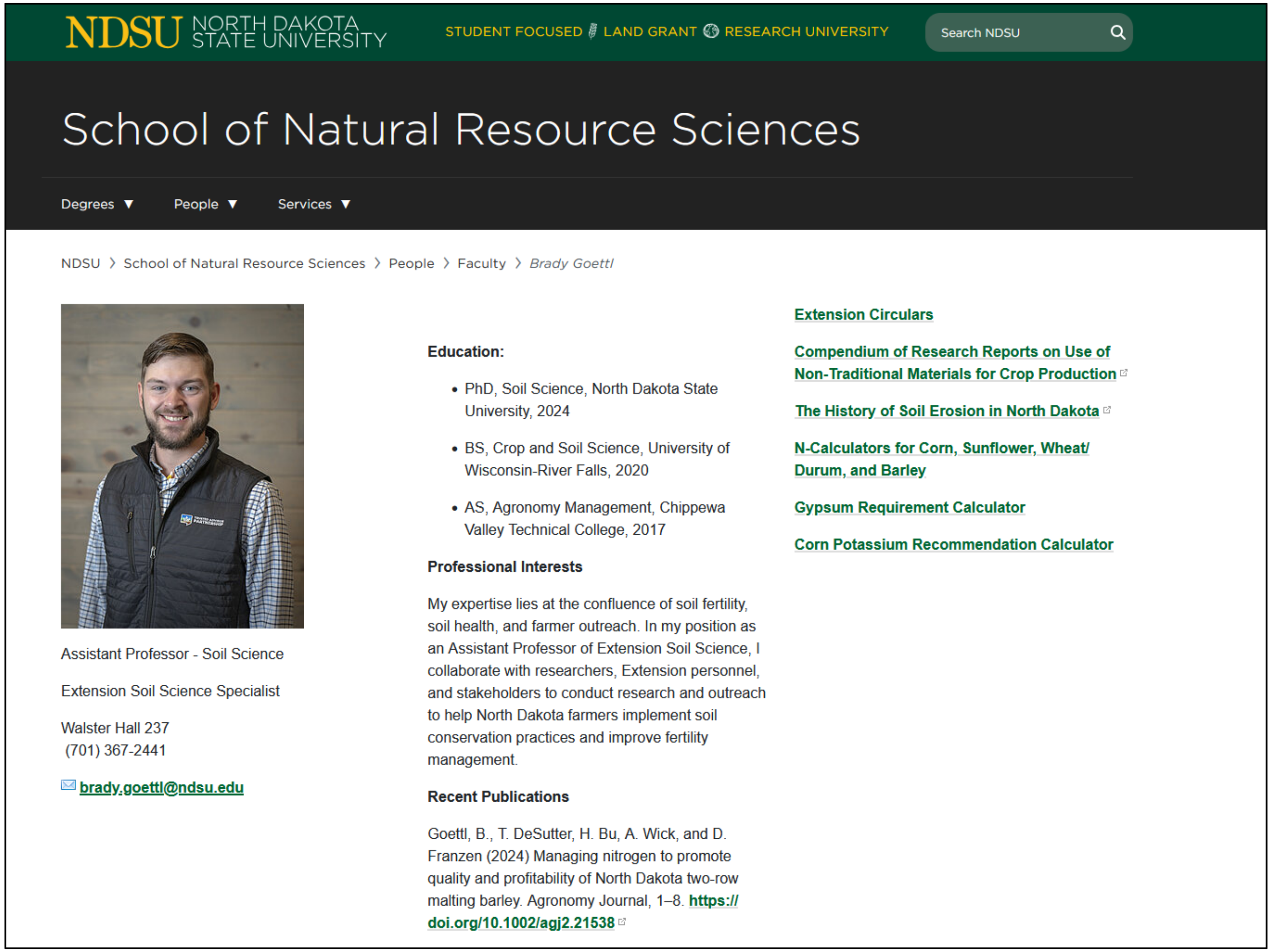
Publications

- Managing Saline Soils in North Dakota
- Land Judging in North Dakota
- Compatibility of North Dakota Soils for Irrigation
- North Dakota Fertilizer Recommendation Tables and Equations

App and Desktop Calculators

- N-Calculators for Corn, Sunflower, Wheat/Durum, and Barley
- Gypsum Requirement Calculator
- Corn K Recommendation Calculator

- Google “Goettl NDSU”
- Choose the School of Natural Resource Sciences



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Fertility Points to Remember

- The *only* way to know is to sample
- N recommendations are based on economics, not yield
- Take the credits you have coming

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Fertility after a drought year

- Have the field zone-sampled for soil nitrate-N, as it will be variable
- Sample each field-not just a ‘representative’ field
- Soil P, K will not vary much from year to year

“Soil sampling makes dollars and sense”

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Understanding Soil Test Levels

Table 1. Soil test calibration levels used in North Dakota.

		Categories				
Nutrient	**Analysis**	**Very low**	**Low**	**Medium**	**High**	**Very High**
		----------	----------	ppm	----------	----------
Phosphorus (P), ppm	Olsen	0-3	4-7	8-11	12-15	16+
Potassium (K), ppm* low SI ratio	Ammonium	0-40	41-80	81-129	121-150	151+
Nitrogen (N)	H_2O Extract			See tables		
Sulfur (S), lb/a-2 feet‡	Monocalcium phosphate	no categories				
Chloride (Cl), lb/a-2 feet¶	H_2O Extract	10-20	20-30	30-40	40+	

Very Low (VL) - In this category, the probability of getting a response to applied nutrient is greater than 80%.

Low (L) - Crops growing on fields in this category will respond to applied nutrient 50% to 80% of the time.

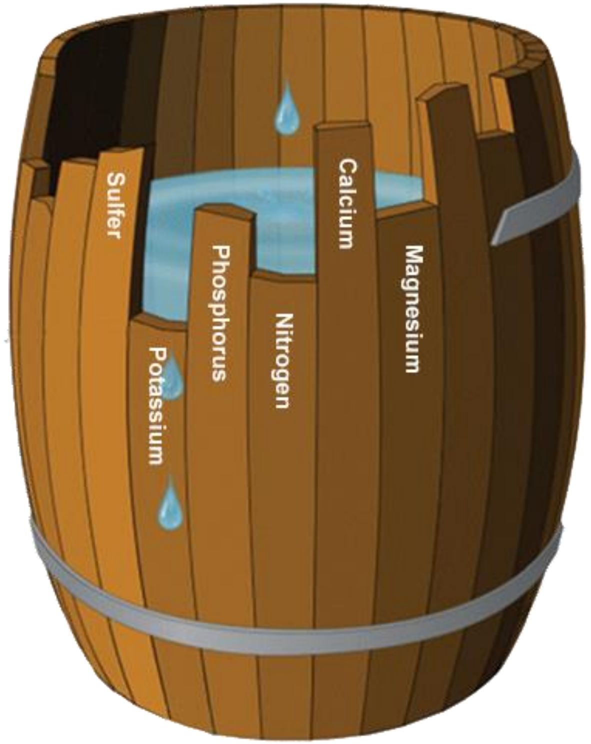
Medium (M) - The probability of getting a response to applied nutrient is 20% to 50%.

High (H) - In this category, crops will respond to applied nutrient about 10% to 20% of the time.

Very High (VH) - The probability of getting a response to applied nutrient is less than 10%.

Yield is proportional to the amount of the most limiting nutrient, whichever nutrient it may be.

Liebig's Law of the Minimum



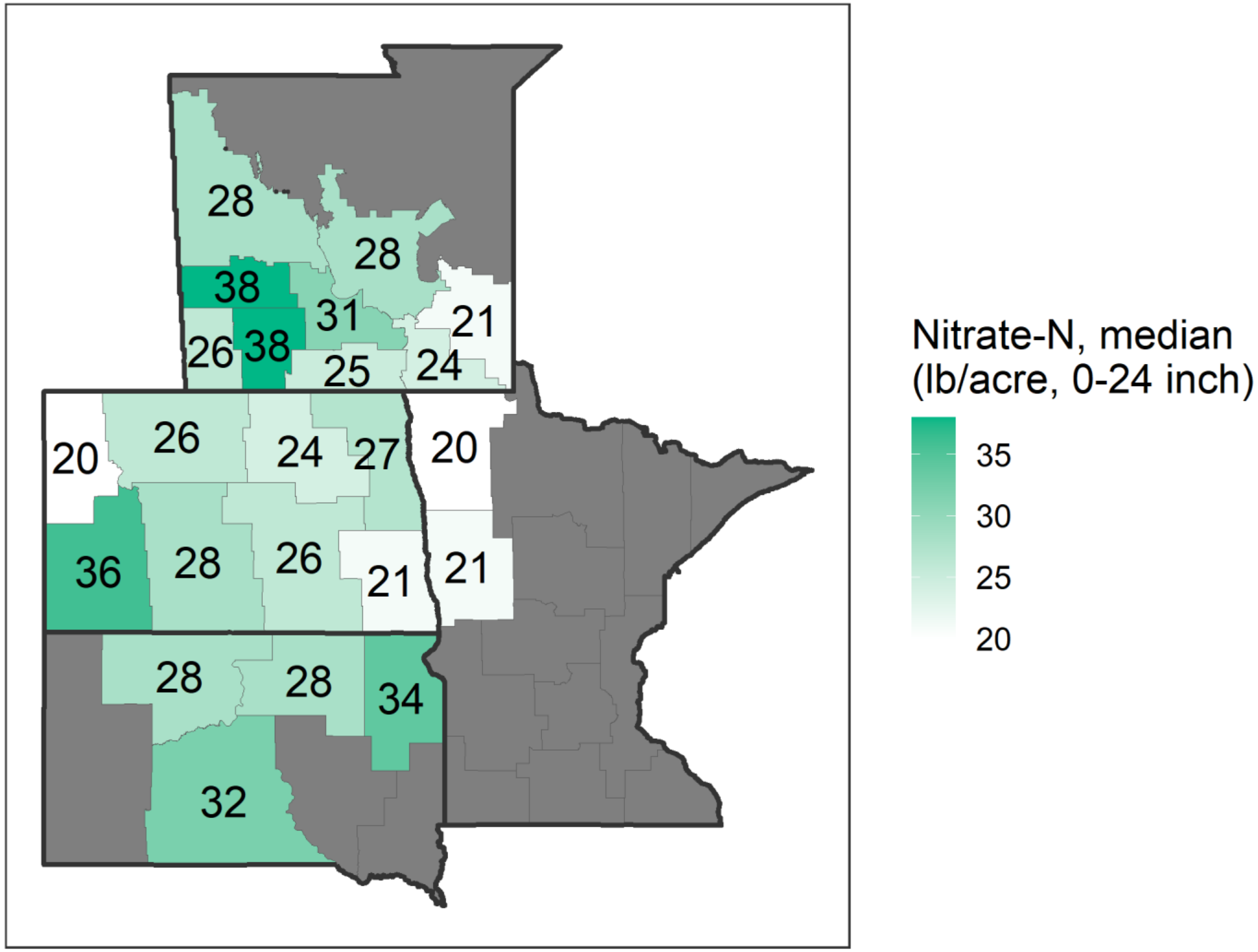
https://nutrien-ekonomics.com/news/liebigs-law-of-the-minimum/


NPK
Source: https://golfcourselawn.store/cdn/shop/articles/Lawn_Fertilizer_Numbers_Explained_900x.jpg?v=1710419362

N Considerations

- Generally most limiting nutrient
  - Focus on N if other nutrients are adequate
- Yearly nitrate-N tests are essential to profitable N management
- NDSU recommendations are created to maximize profit
- Urease and nitrification inhibitors are your friend

Residual nitrate following wheat in 2024



Data not shown where n< 100
AGVISE Laboratories, Inc.

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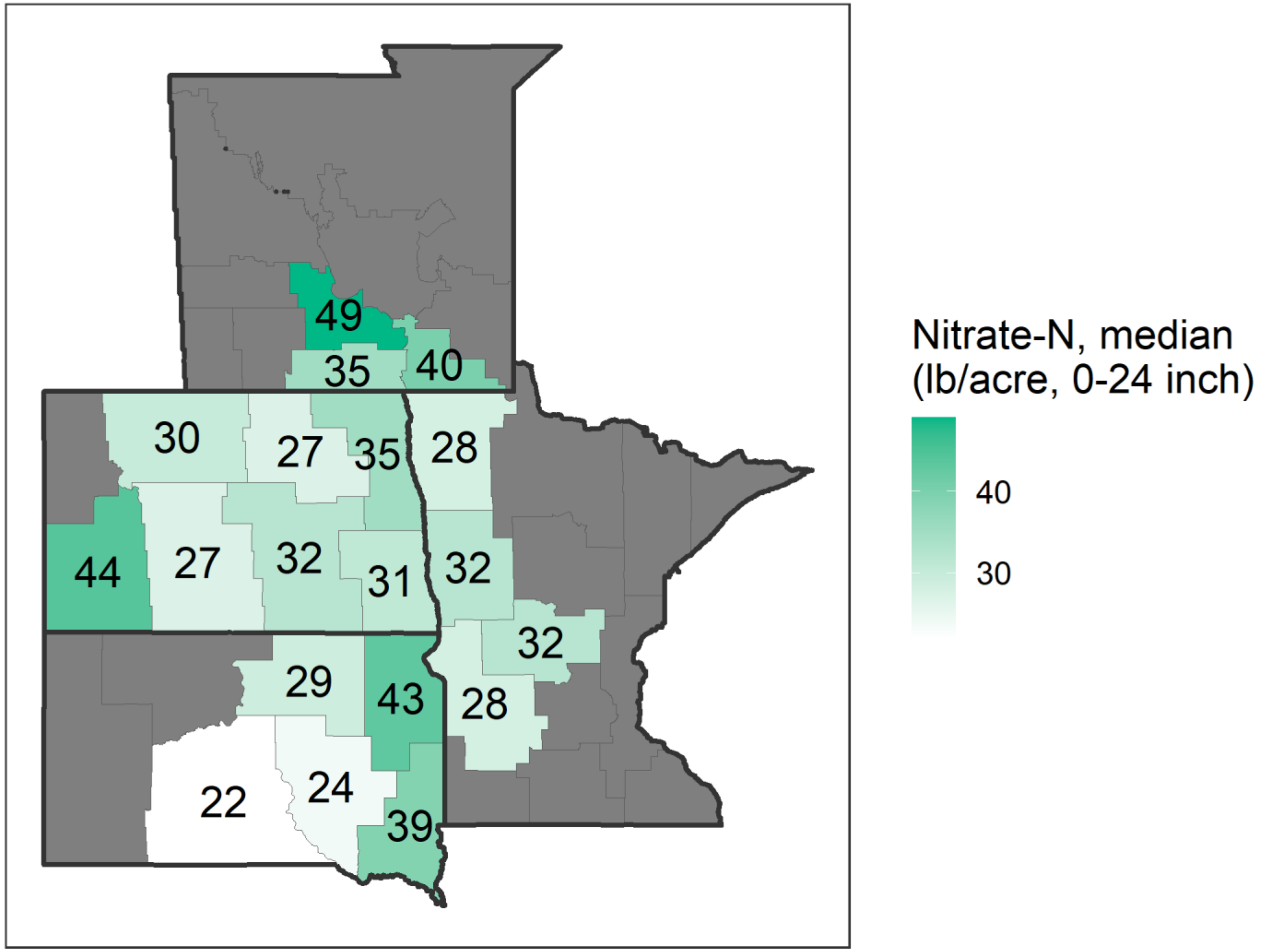
Source: https://www.agvise.com/resources/soil-test-summaries/

Residual nitrate following corn in 2024



Data not shown where n< 100
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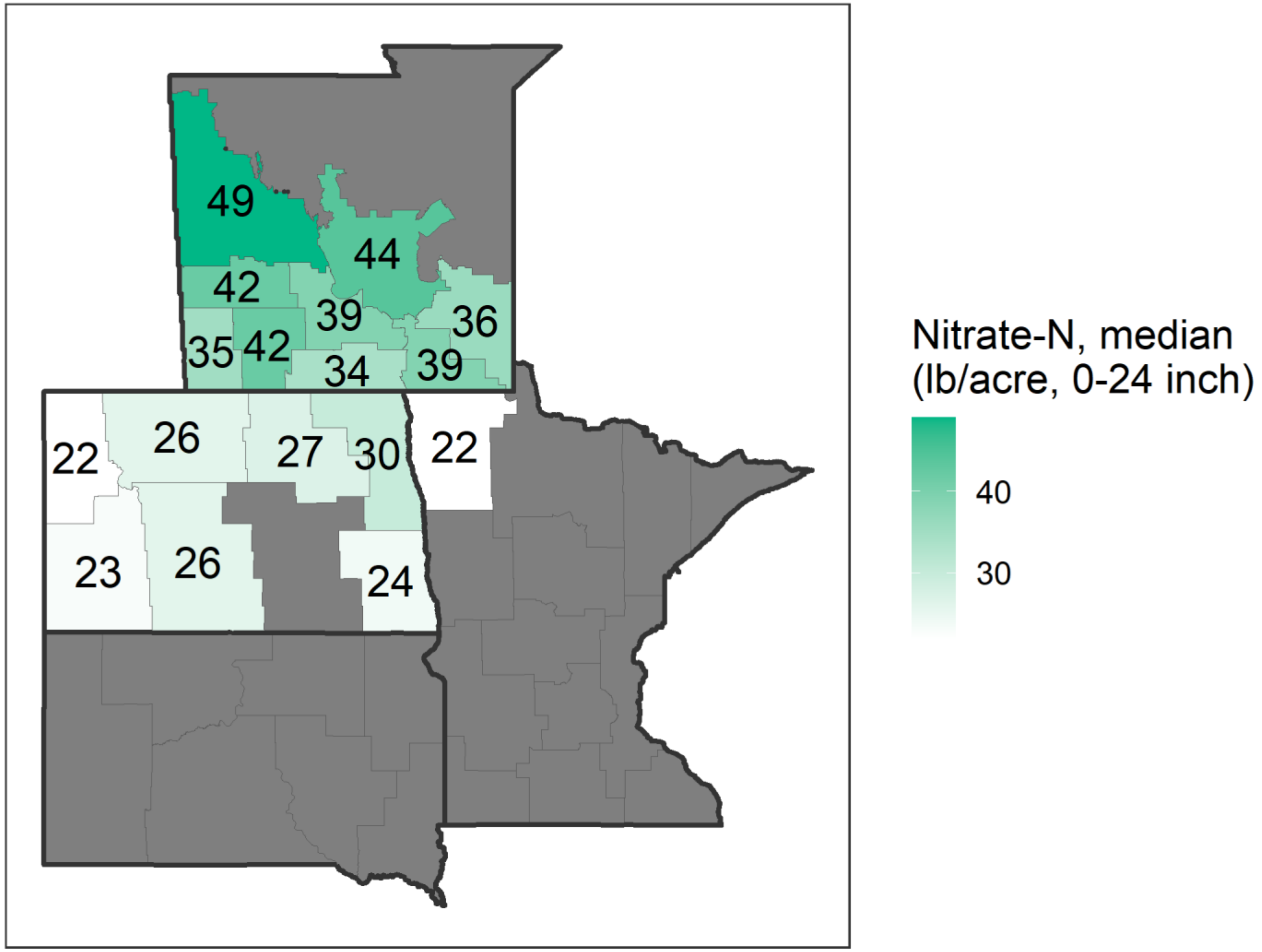
Source: https://www.agvise.com/resources/soil-test-summaries/

Residual nitrate following canola in 2024



Data not shown where n< 100
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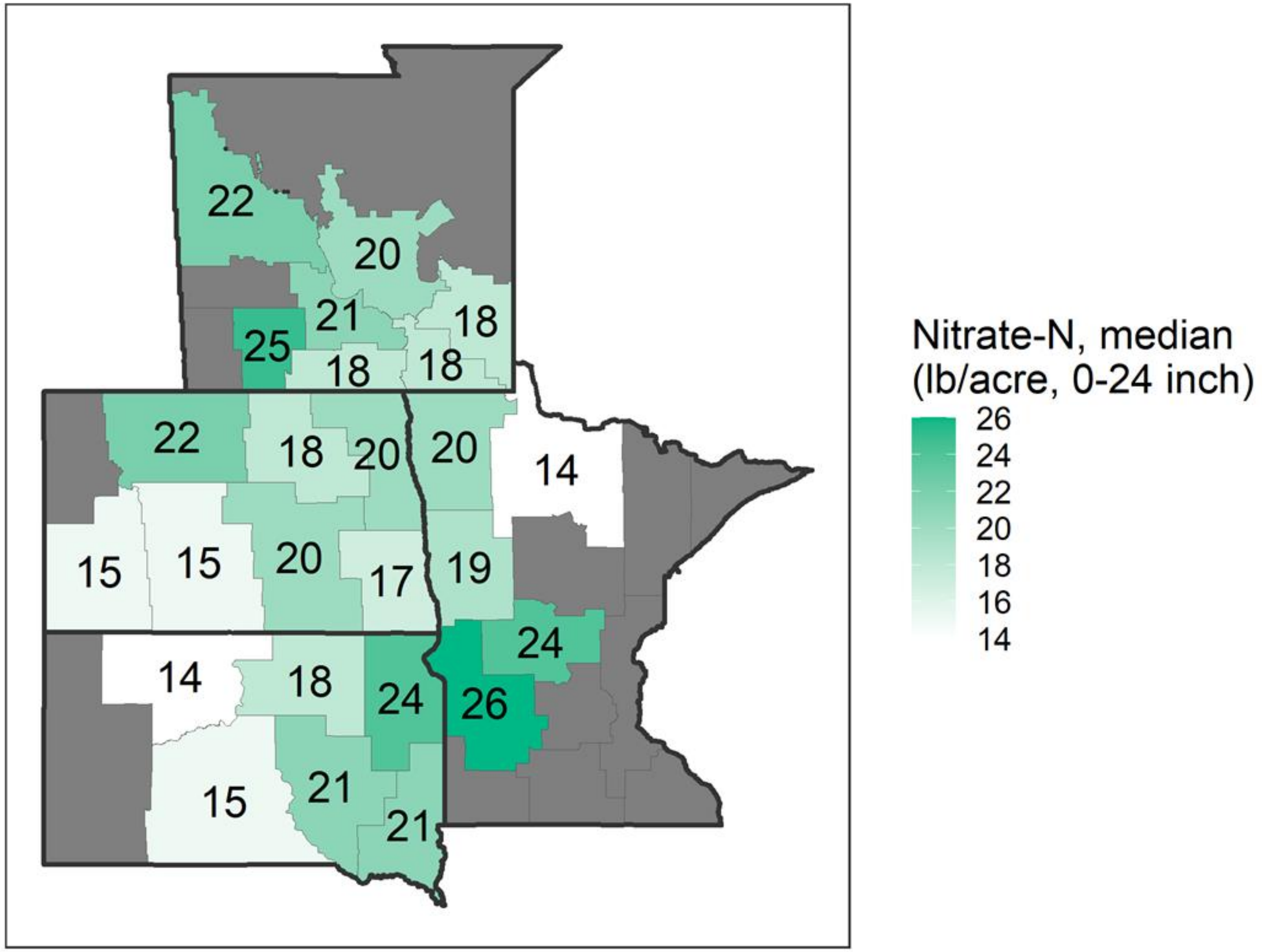
Source: https://www.agvise.com/resources/soil-test-summaries/

Residual nitrate following soybean in 2024



Data not shown where n< 100
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Source: https://www.agvise.com/resources/soil-test-summaries/

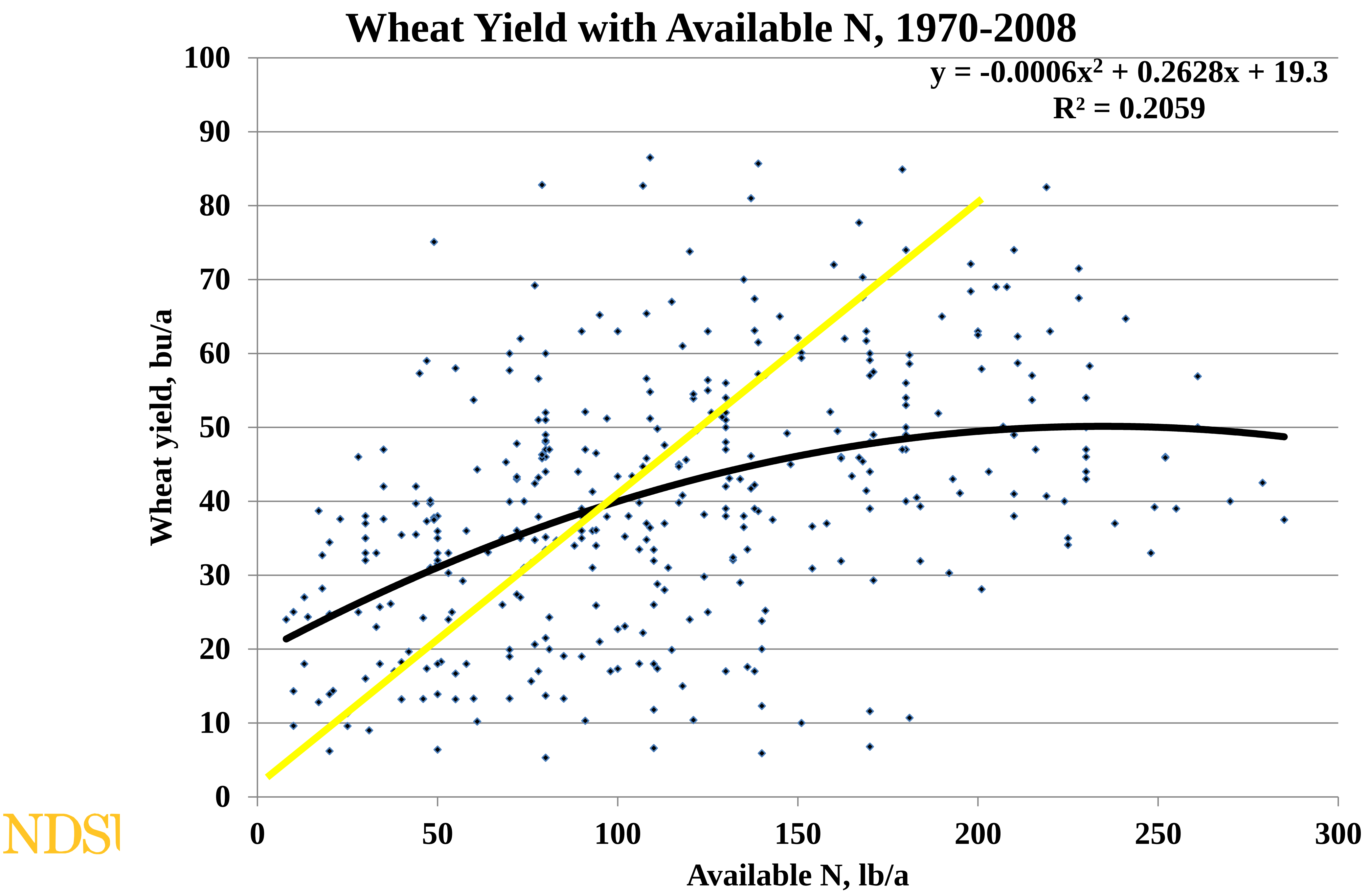
N Recommendations 30 years ago…

- Crop yields were lower than current production
- N was relatively cheap and prices not very volatile
- Grain prices were low and not very volatile.
- Site-specific N application was not practiced.

$$(N_f = n(Y_{GOAL}) - N_{credits})$$

Yield Goal Approach

- Used to develop land grant university recommendations for majority of the last century
- Attempted to relate yield directly to N availability
  - Later, equations also considered additional N sources/credits

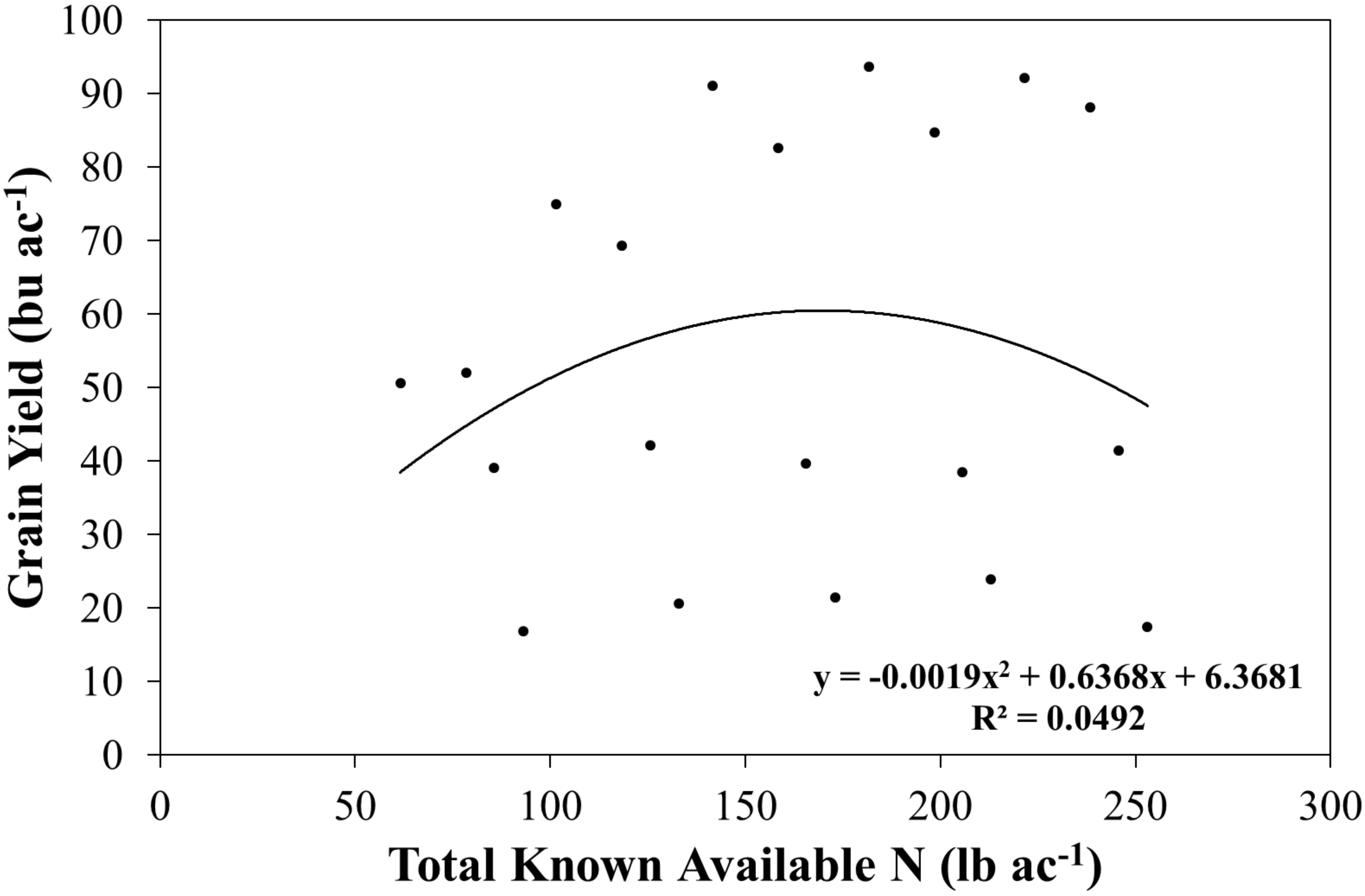

Wheat Yield with Available N, 1970-2008
y = -0.0006x2 + 0.2628x + 19.3
R² = 0.2059
Wheat yield, bu/a
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
Available N, lb/a
NDSU

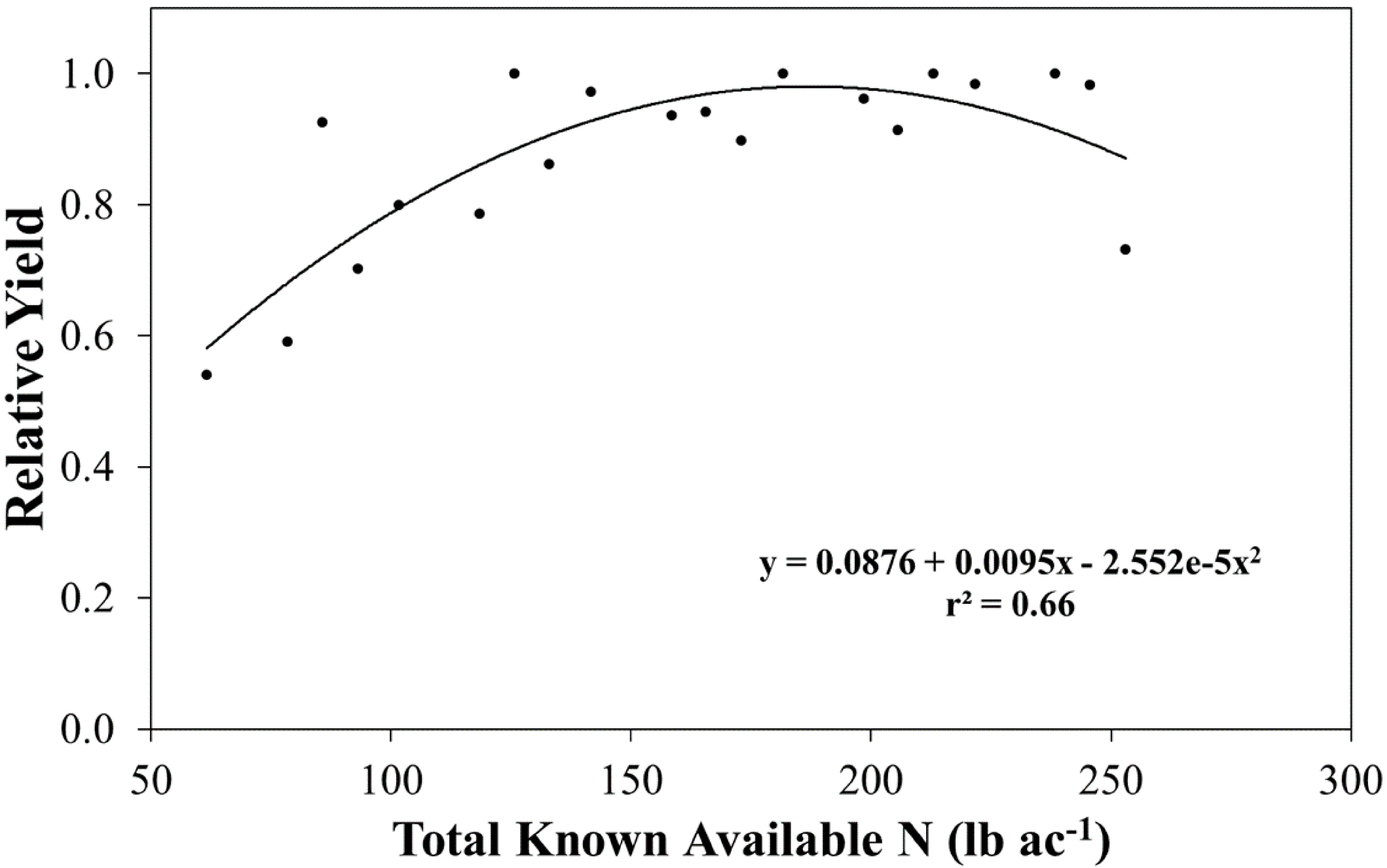
Total Known Available N

- Total *quantifiable* N available to a plant during the growing season

$$TKAN = N_{PC} + N_{TC} + N_S + N_{Fert}$$

  - N_{PC}: Prior crop N credit
  - N_{TC}: N credits from tillage system
  - N_S: Soil nitrate to 2 feet
  - N_{Fert}: N added as fertilizer

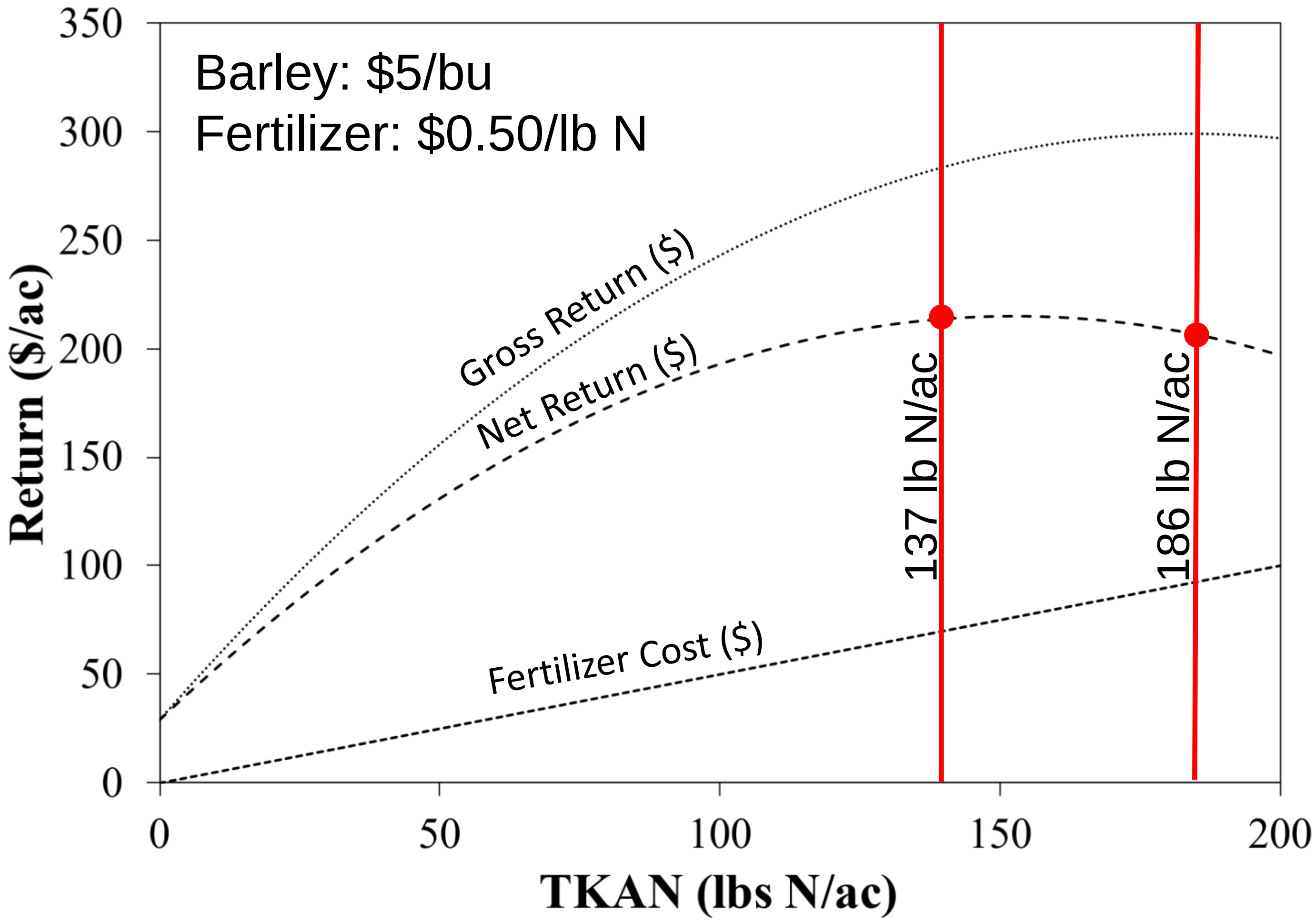

100
90
80
70
60
50
40
30
20
10
0
Grain Yield (bu ac-1)
0
50
100
150
200
250
300
Total Known Available N (lb ac-1)
y = -0.0019x² + 0.6368x + 6.3681
R² = 0.0492


Relative Yield
1.0
0.8
0.6
0.4
0.2
0.0
50
100
150
200
250
300
Total Known Available N (lb ac-1)
y = 0.0876 + 0.0095x - 2.552e-5x2
r2 = 0.66

Economic Rates

Economic Optimum N Rate (lbs TKAN/ac)											
	N Cost ($/lb N)										
Barley Price ($/bu)	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20
3	145	138	131	125	117	110	104	97	89	82	75
4	148	144	137	132	127	122	117	111	106	101	96
5	150	146	142	137	133	129	125	121	117	112	108
6	151	148	144	141	137	134	131	127	124	120	117
7	152	149	146	146	140	137	135	132	129	126	123
8	153	151	148	148	143	140	137	135	132	130	127
9	154	152	149	149	144	142	140	137	135	133	131
10	154	152	150	150	146	144	142	140	137	135	133

A Tale of Two N Rates



Rec Rate:	137	lbs TKAN/ac
Legume Credit:	40	lbs N/ac
Soil Nitrate-N:	- 45	lbs N/ac
Fertilizer:	52	lbs N/ac

186 lbs TKAN/ac → $200/ac
137 lbs TKAN/ac → $213/ac

What about variations?

Low Yield Environments

- Drought or too wet
- Sandy or clayey texture

⇩

- Lower NUE
- Less N mineralization
- Potential denitrification

High Yield Environments

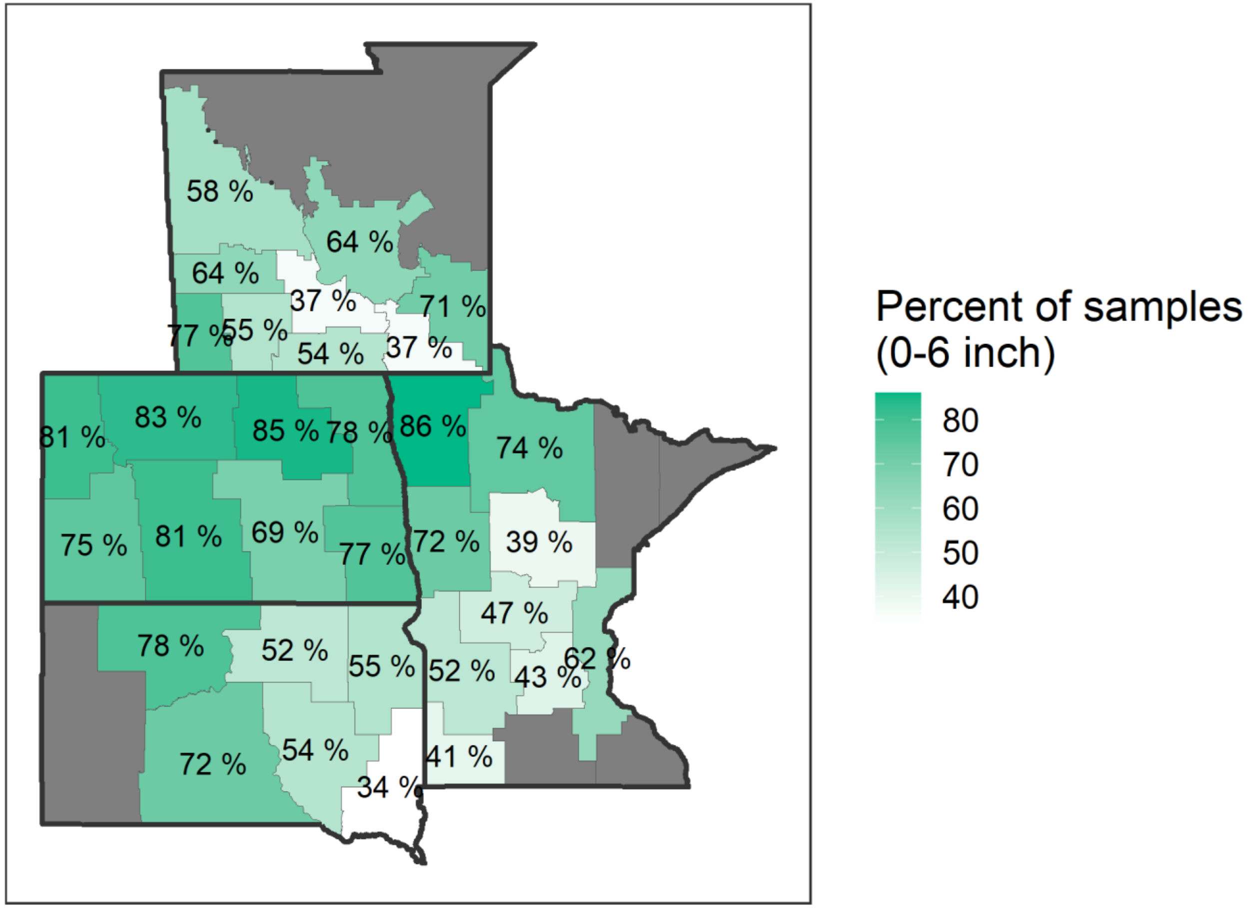
- Ideal moisture
- Favorable soil texture
- “A good year”

⇩

- Higher NUE
- Greater N mineralization

Regardless of environment, rate to produce maximum relative yield is similar.

Soil samples with soil test phosphorus below 15 ppm (Olsen P) in 2024



Data not shown where n< 100
AGVISE Laboratories, Inc.

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Source: https://www.agvise.com/resources/soil-test-summaries/

P Considerations

- P levels move slowly, *if erosion is minimized*
- Focus on banded or in-furrow P to maximize yield response and reduce rate
  - Corn, canola, and small grains
  - No P is needed for sunflowers
  - Soybean fertilizer should be broadcast
- Don't be afraid to back off broadcast P rates this year*

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Source:https://www.ndtourism.com/articles/brighten-your-day-amazing-sunflower

Wheat Phosphorous Fertility

- Published recommendations are for broadcast application
  - Banded P: reduce rates by 1/3 for similar crop response (will not build up low soil test levels!)

Table 11. Broadcast fertilizer phosphate recommendations for North Dakota for spring wheat and durum based on soil test (Olsen sodium bicarbonate).

Soil Test Phosphorus, ppm				
VL 0-3	L 4-7	M 8-11	H 12-15	VH 16+
Pounds P_2O_5/acre				
90	60	35	20	15*

* Wheat seeding always should include a small amount of starter fertilizer in a band regardless of soil test. If starter fertilizer banding is not used, rates in H and VH categories should be zero.

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Source: NDSU-Extension Publication SF712

Corn Phosphorous Fertility

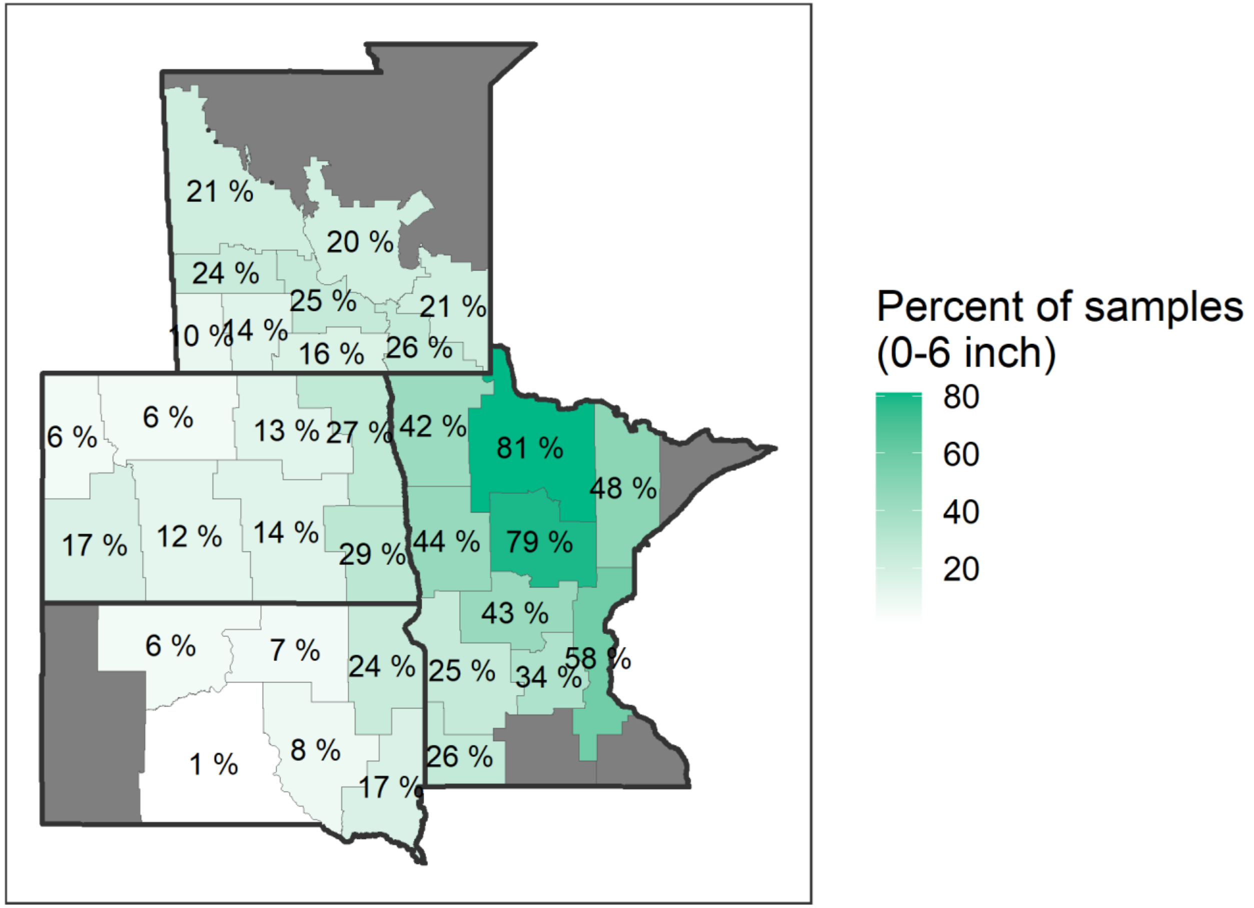
- Corn likely has highest P removal in the rotation
- In-furrow P is shown to increase corn yields even at high soil test levels compared to broadcast
- Applying broadcast P in corn is still recommended with banded P

Table 11. Corn yield with in-furrow application of 10-34-0, Hendrickson, 2007.

Rate of 10-34-0, gallons per acre	Corn yield, bushels per acre
0	101
2	121
4	125
6	150
8	156
10	153

Source: NDSU-Extension Publication SF712

Soil samples with soil test potassium below 150 ppm in 2024



Data not shown where n< 100
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Source: https://www.agvise.com/resources/soil-test-summaries/

K Considerations

- Drought conditions will exacerbate K deficiency
- Focus K applications on corn, forage, and canola first, then wheat
- K recommendations are dependent of clay type

S Considerations

- Sulfate test is not a good predictor of S response
- Aggravating factors of S deficiency:
  - above average rainfall,
  - sandy soil,
  - low organic matter (<3%)
- 10 lb/ac *sulfate-S* is good insurance for most crops
- S application in canola is not optional, 20-30 lb/ac *sulfate-S* is recommended

Sources of Sulfur

Table 9-12. Sulfur fertilizers.

Material	Chemical formula	Fertilizer analysis $N–P_2O_5–K_2O$	Sulfur content
		— % —	— % —
Very soluble			
Ammonium sulfate	$(NH_4)_2SO_4$	21-0-0	24
Potassium sulfate	K_2SO_4	0-0-50	18
Potassium-magnesium sulfate	$K_2SO_4{\bullet}2MgSO_4$	0-0-22	23
Ammonium thiosulfate[a]	$(NH_4)_2S_2O_3 + H_2O$	12-0-0	26
Magnesium sulfate (Epsom salts)	$MgSO_4{\bullet}7H_2O$	0-0-0	14
Ordinary superphosphate	$Ca(H_2PO_4)_2 + CaSO_4$	0-20-0	14
Slightly soluble			
Calcium sulfate (gypsum)	$CaSO_4{\bullet}2H_2O$	0-0-0	17
Insoluble			
Elemental sulfur	S	0-0-0	88–98

[a]*Ammonium thiosulfate is a 60% aqueous solution.* Source: Management of Wisconsin Soils, 2009

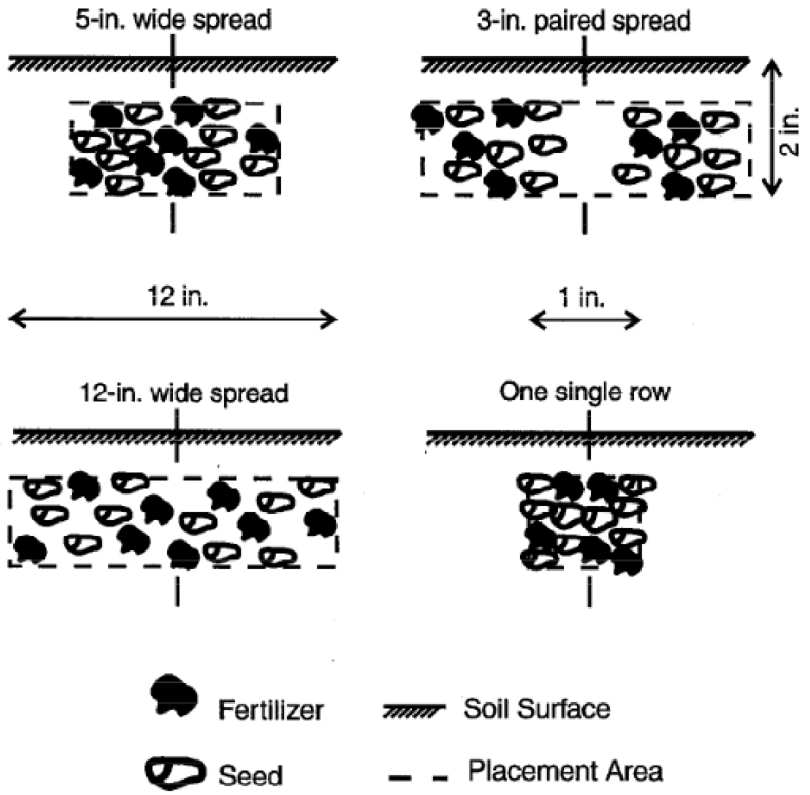
Similar effectiveness whether surface applied or incorporated

Elemental Sulfur

- Very insoluble
- Requires oxidation before it is plant available
- Oxidation rate depends on:
  - Particle size
  - Soil mixing/incorporation
  - Soil moisture and temperature
  - Microbial activity
- Sulfur deficient fields should include SO_4-S application for immediate availability

Remember!

- Safe amount of banded/seed applied fertilizer depends on:
  - Amount of N and K
  - Soil texture
  - Proximity of fertilizer to seed
- Consult *Fertilizer Application With Small-grain Seed at Planting (SF1751)*



Source: NDSU-Extension Publication SF1751

What about…?

- Micronutrients
  - Zn in corn is not a bad idea (10 lb Zn/ac broadcast or 3-4 lb Zn/ac banded with seed)
  - Perhaps Cl in small grain, if levels are low (<40lb/ac)
  - Don’t worry about the other ones this year unless there is a history of deficiency

What awaits us in 2025?

Photo Sources: x.com/DesignUXUI/status/758101772409765888/photo/1, www.yahoo.com/news/mystery-solved-inside-magic-8-ball-202010631.html

Fertilizer Outlook

- Prices are mixed and the outlook is cloudy
- Urea, UAN steadily trending up
- MAP and DAP are expected to increase with market volatility
- Potash is currently down from last year with currently good supply, however, Canada is threatening retaliatory tariffs

Take-Home Points

- Soil test focusing on zone sampling
- Focus on economic recommendations
- Band fertilizer if you can
  - Yield response is likely and rates can be decreased
- Focus on products with proven response

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Source:https://ndsuspectrum.com/sunflower-remains-important-crop-in-north-dakota/

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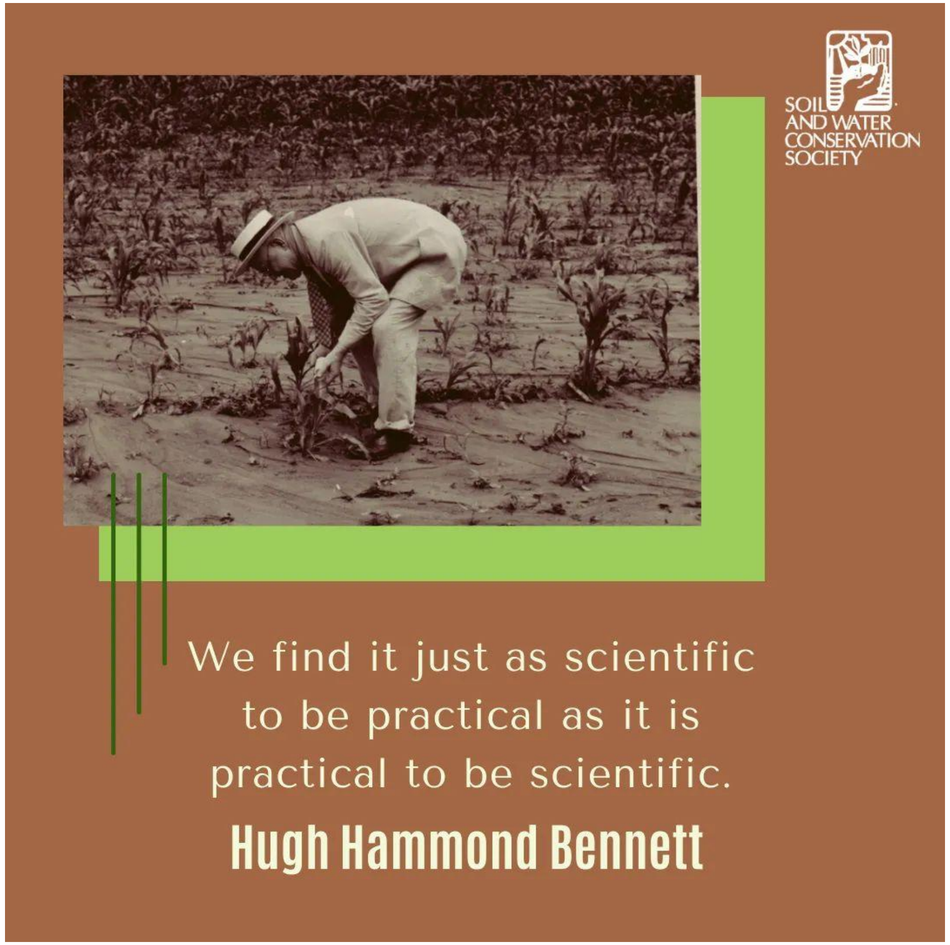
CERTIFIED
CROP ADVISER



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