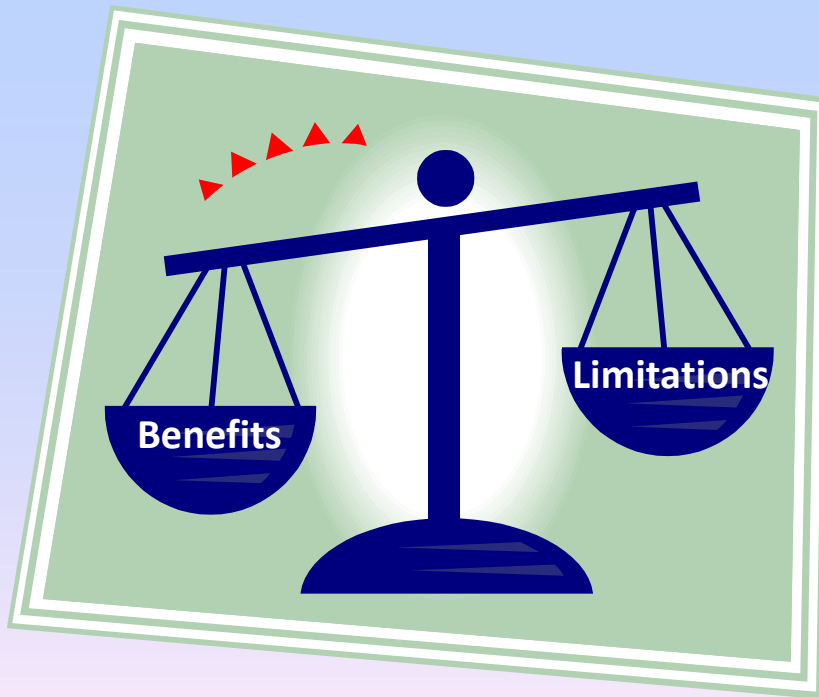


Soil Testing with (Real) Intelligence: Maximizing Benefits, Minimizing Limitations

Don Flaten, U of M Professor Emeritus, C.R.O.S.S.*



* Cranky Retired Old Soil Scientist

Outline

Exploring questions ... and sharing ideas about:

With crop producers' cost-price squeeze, 4R Nutrient Stewardship and soil testing are especially important now.

But how many farmers are routinely soil testing?

Why are some farmers not routinely soil testing?

How can we use sound science and “real” intelligence to improve soil testing’s reliability, value, and farmer-confidence ... to maximize soil testing’s benefits and minimize its limitations?



Fertilizer costs are high ... but crop prices are not ...

Manitoba Agriculture - Crop Production Costs 2026 Guidelines (\$/Acre)

	HRS			
	Wheat	Canola	Soybeans	Peas
Estimated Operating Costs				
Seed & Treatment	\$ 32.00	\$ 82.50	\$ 90.00	\$ 49.50
Fertilizer	\$ 132.90	\$ 150.30	\$ 50.35	\$ 34.02
Crop Protection	\$ 50.25	\$ 68.75	\$ 23.25	\$ 42.50
Other Operating Costs	✓\$ 149.74	✓\$ 148.86	✓\$ 150.21	✓\$ 158.08
Total Operating Costs	\$ 364.89	\$ 450.42	\$ 313.81	\$ 284.10
Land & Machinery Costs	\$ 191.58	\$ 191.58	\$ 191.58	\$ 191.58
Owners - Labour & Living	\$ 28.00	\$ 28.00	\$ 28.00	\$ 28.00
Total Costs	\$ 584.46	\$ 669.99	\$ 533.39	\$ 503.67
Estimated Revenue				
Target Price \$ per bushel	\$ 7.75	\$ 14.25	\$ 12.75	\$ 6.00
Target Yield (bu/acre)	66	45	42	55
Gross Revenue / acre	\$ 511.50	\$ 641.25	\$ 535.50	\$ 330.00
Marginal Returns				
Over Operating Costs	\$ 146.61	\$ 190.83	\$ 221.69	\$ 45.90
Over Operating & Fixed	-\$ 44.96	-\$ 0.74	\$ 30.11	-\$ 145.67
Over Total Costs (Net Profit)	-\$ 72.96	-\$ 28.74	\$ 2.11	-\$ 173.67

Farmers are at the high stakes poker table ... again

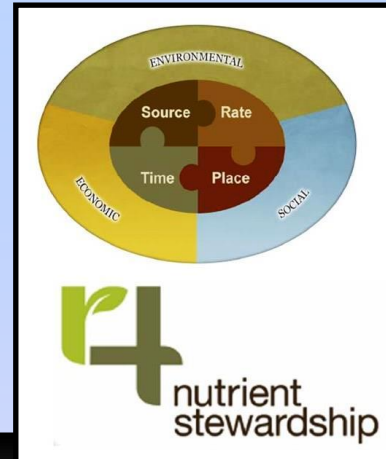
**High fertilizer costs
and modest crop
prices for crops have
increased the
financial risks from
inefficient use of
fertilizer**



4R Nutrient Stewardship More Important Than Ever

4R Nutrient Stewardship

- ✓ Right rates
- ✓ Right sources
- ✓ Right placement
- ✓ Right timing



4R Soil Testing ... every field, every year

- ✓ Right sampling
- ✓ Right analyses
- ✓ Right recommendations
- ✓ Right data management & use

A sound 4R Nutrient Stewardship strategy relies on soil testing every field/mgmt zone ... every year ... to:



Photo: Amy Mangin

1. Predict fertilizer and/or manure requirements for the next crop, based on existing reserves in soil and current goals for the fertility program in each field or management zone
2. Diagnose “unusualities” ... e.g., areas of unusually good or poor crop growth
3. Evaluate/audit the current nutrient management plan for the most recent crop(s) ... e.g., excess N fertilization or more N mineralization than immobilization
4. Monitor for long-term upward or downward trends in soil fertility and soil health ... e.g., decreasing soil test P, increasing salinity or acidity

But how many farmers are routinely soil testing?



According to Statistics Canada surveys, soil testing is a very popular practice in the Prairies, e.g. in 2021 the percentage of farmers who “tested soil for nutrient content” was:

- 92% in Manitoba
- 88% in Saskatchewan
- 84% in Alberta

But the percentages of farmers who “tested soil for nutrient content every year” was only:

- 62% in Manitoba
- 40% in Saskatchewan
- 36% in Alberta

Fertilizer Canada's Detailed Survey of Fertilizer Use Conducted by Stratus Ag Research (Nov-Dec 2024)

<https://fertilizercanada.ca/our-focus/stewardship/fertilizer-use-survey/>

OUR FOCUS > STEWARDSHIP

Fertilizer Use in Canada

4R Nutrient Stewardship Grower Adoption

It's Simple to Implement 4R Nutrient Stewardship

Sustainable farming is the future

Watch on  YouTube

Reports

Fertilizer Use: Western Canada

Fertilizer Use: Manitoba

Fertilizer Use: Ontario

Fertilizer Use: Quebec

Fertilizer Use: PEI

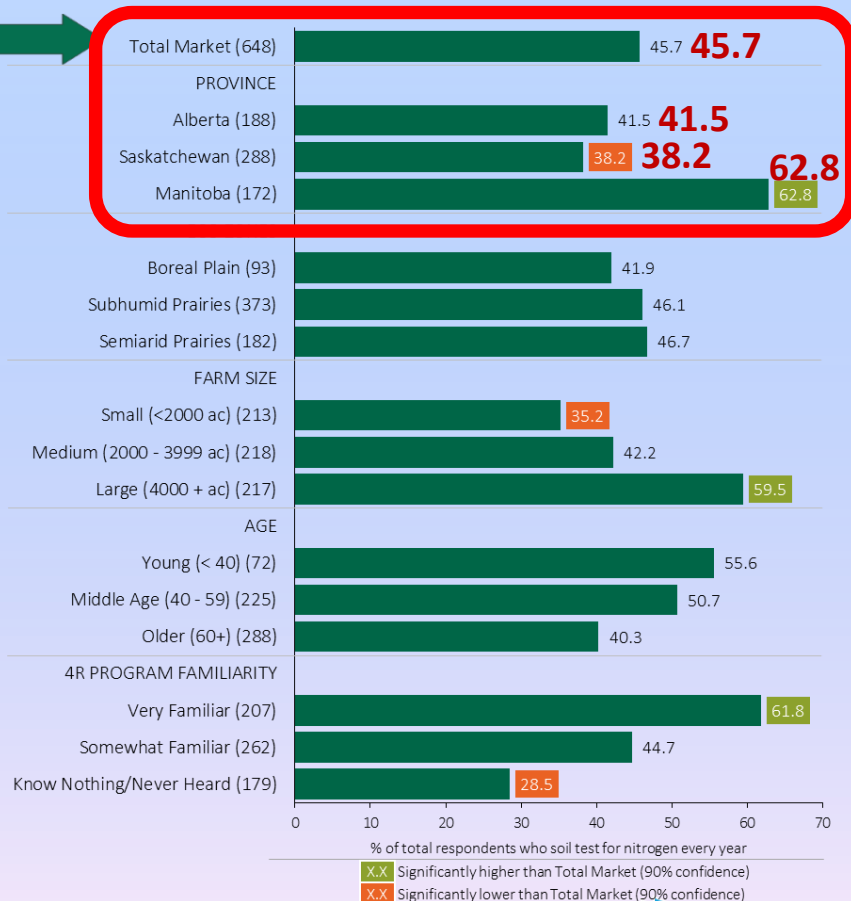
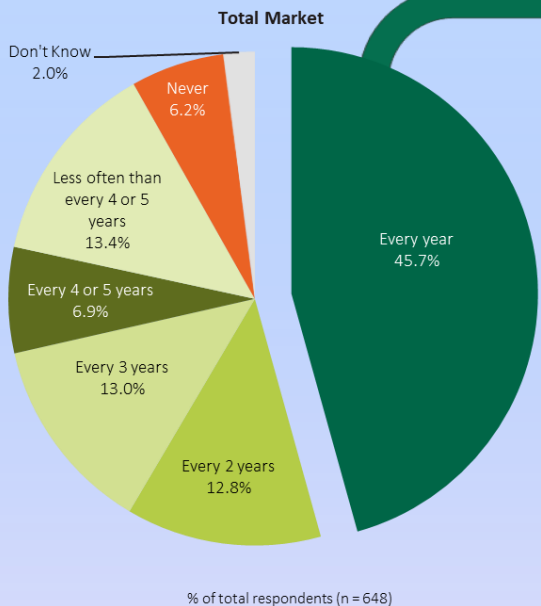
Fertilizer Canada's Detailed Survey of Fertilizer Use Conducted by Stratus Ag Research (Nov-Dec 2024)

e.g., 4R Nutrient Stewardship in Prairie Canola Production

“Rate determination is the primary barrier to 4R compliance”

- Most canola acres meet the “Advanced 4R” criteria for N source, timing and placement [... but not rate?]
- 42% of canola acres meet the “Basic 4R” criteria for P
- 26% of canola acres meet all “Basic 4R” criteria for both N & P
- 63% of canola growers say they use the same fertilizer rate on all their canola fields

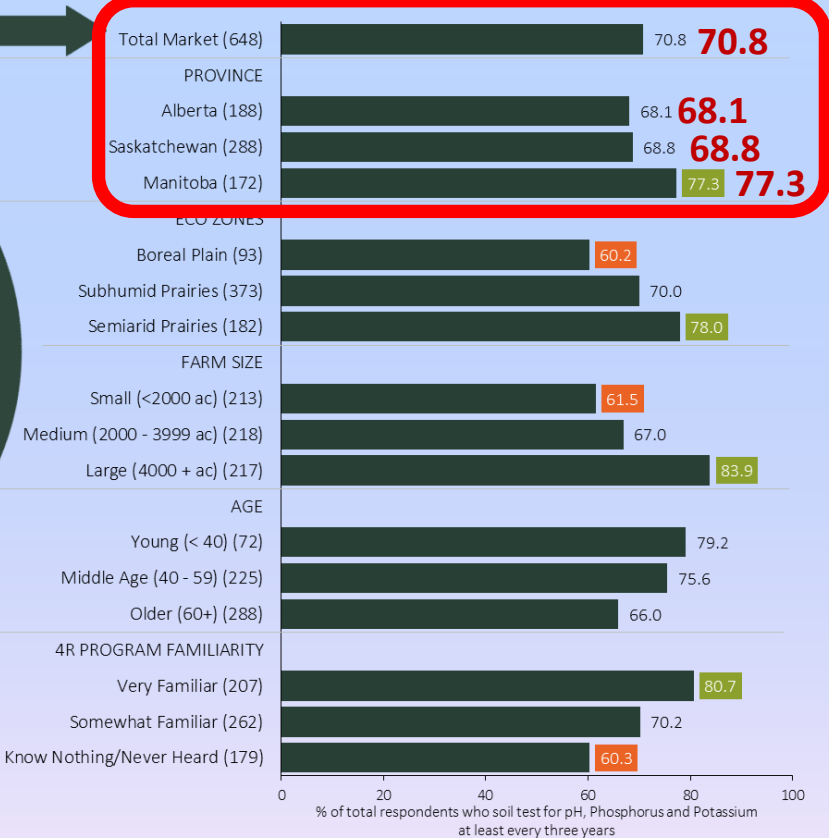
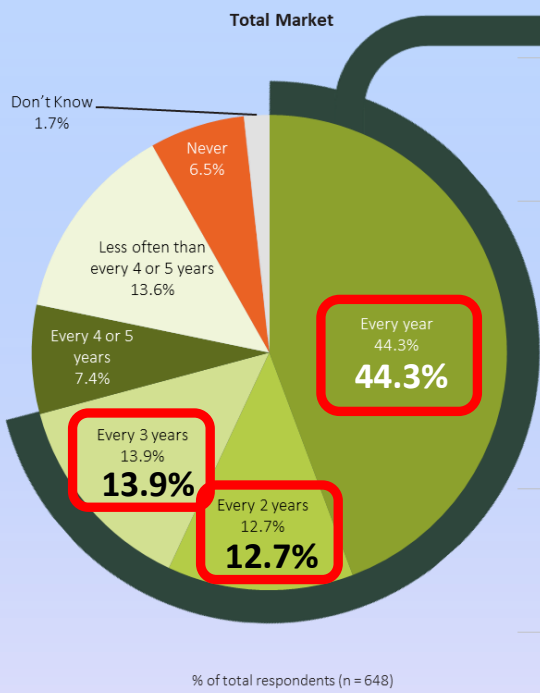
% of Prairie Farmers Who Test Each Field for N Each Year



Source: Fertilizer Canada (2024) Survey of Fertilizer Use conducted by Stratus Ag Research

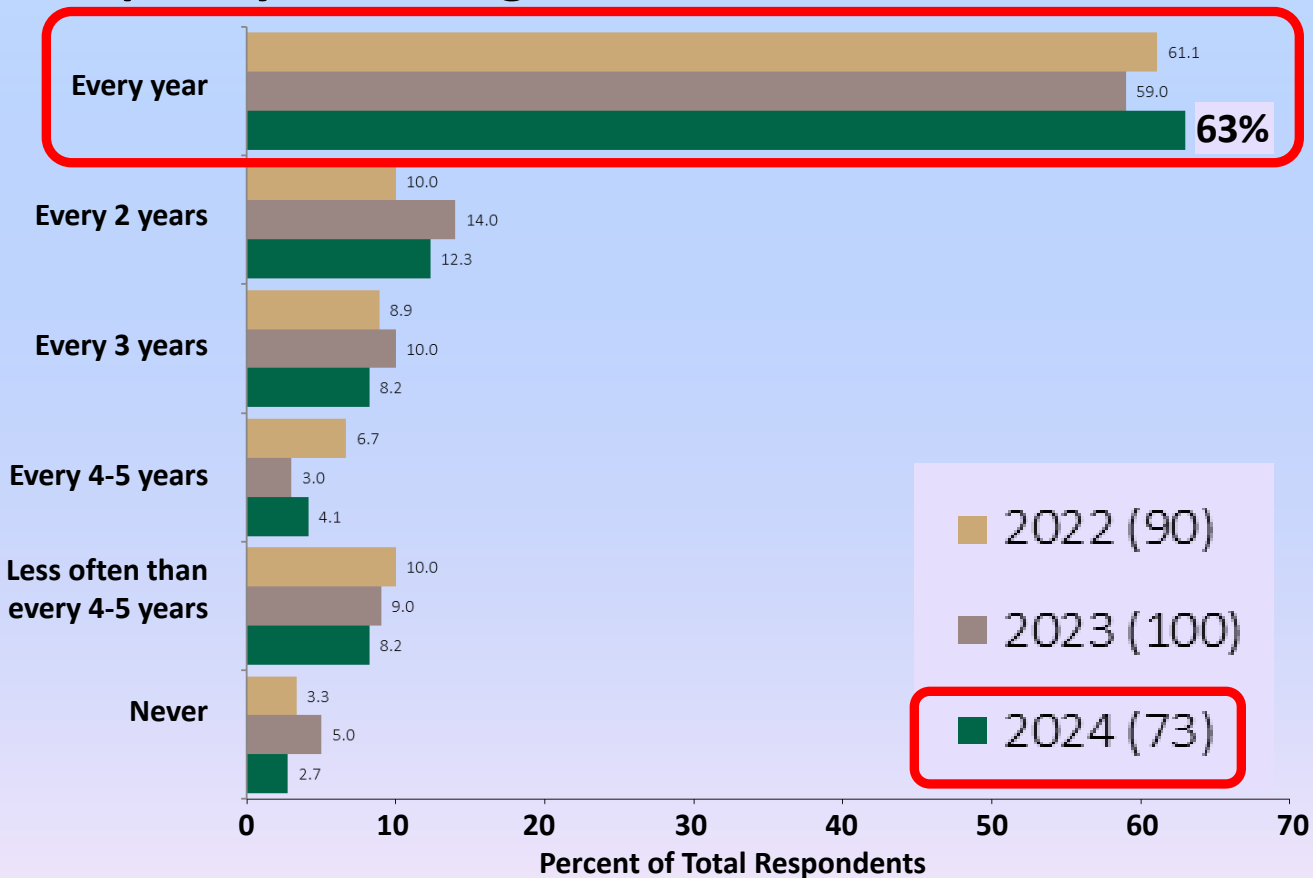


% of Prairie Farmers Who Test Each Field for P, K, pH (1-3 yrs)

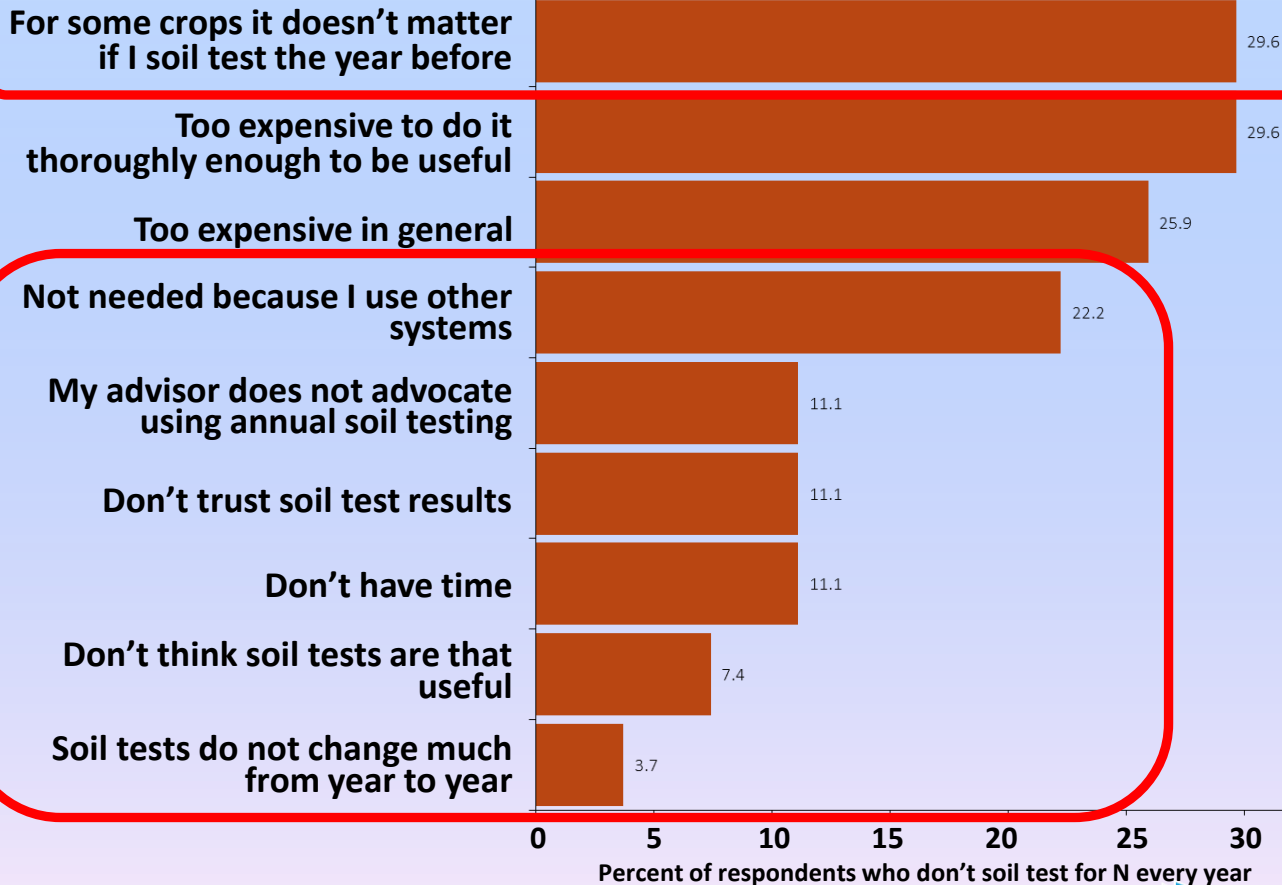


XX Significantly higher than Total Market (90% confidence)
XX Significantly lower than Total Market (90% confidence)

Frequency of Testing Each Field for N in Manitoba



Reasons for Not Soil Testing for N Every Year in Manitoba



Source: Fertilizer Canada (2024) Survey of Fertilizer Use conducted by Stratus Ag Research

4R Nutrient Stewardship and 4R Soil Testing More Important Than Ever



What can we do to improve soil testing's reliability, value, and farmer-confidence?

4R Soil Testing ... every field, every year

- ✓ Right sampling
- ✓ Right analyses
- ✓ Right recommendations
- ✓ Right data management & use

Improving Reliability, Value, and Confidence in Soil Testing

Step 1: Right Sampling

Frequency of Sampling



- Annual sampling is strongly recommended for nutrients such as N and S that are required and removed in large quantities, move with water, may be taken up from modest reserves. As a result, N and S might vary substantially from one year to another, depending on crop uptake and environmental conditions
- In theory, sampling every 2-3 years might be OK for nutrients such as P and K that are required in modest quantities, are not very mobile with water, and taken up from relatively large, stable reserves ... but yearly sampling improves ability to track trends

Improving Reliability, Value, and Confidence in Soil Testing

Step 1: Right Sampling

Sampling Depth

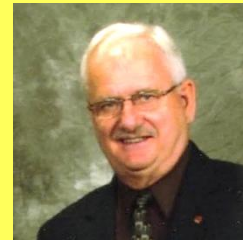


- **Sample to 6 inches for P, K, Cu, Zn, Fe & Mn ... nutrients that are enriched and retained in topsoil due to plant uptake & decomposition followed by retention in topsoil ... and move short distances to roots by diffusion, which requires a high density of roots**
- **Sample to 24 inches for water soluble nitrate-N, sulphate-S, or chloride ... nutrients that are not retained strongly by soil, enabling them to move in the soil with water, i.e., up with evaporation & down with infiltration ... and move to roots by mass flow, which does not require high density of roots**

N Soil Test for a Topdressing Winter Wheat Trial Near Claresholm, AB (Spring & Summer 1979)

We established two replicated field trials for topdressing N on winter wheat in early spring 1979:

- One trial was planted on a summerfallow field and one trial was planted on a stubble field
- We collected soil samples from 0-6 inch depth only ... and soil tests showed that both sites tested similarly low in residual N
- Several rates of N applied to both trials, varying from 0-100 lb N/acre
- Yield response to 100 lb N/acre was 25 bu/acre on the stubble field, but only 2 bu/acre on the fallow field
- Why didn't the soil test work well?
- Dr. Jim Bole (AAFC) tried his best to get me back on track ... explaining how crops could use nitrate-N in the 6-24 inch depth of soil, too



Improving Reliability, Value, and Confidence in Soil Testing

Step 1: Right Sampling

Effect of Soil Sample Depth on Accuracy of Nitrate Soil Test (Soper, Racz & Fehr 1971)

Sample Depth	r^2 *	Grade
0-6"	0.32	32%=F
0-12"	0.64	64%=C
0-24"	0.84	84%=A
0-48"	0.78	78%=B+

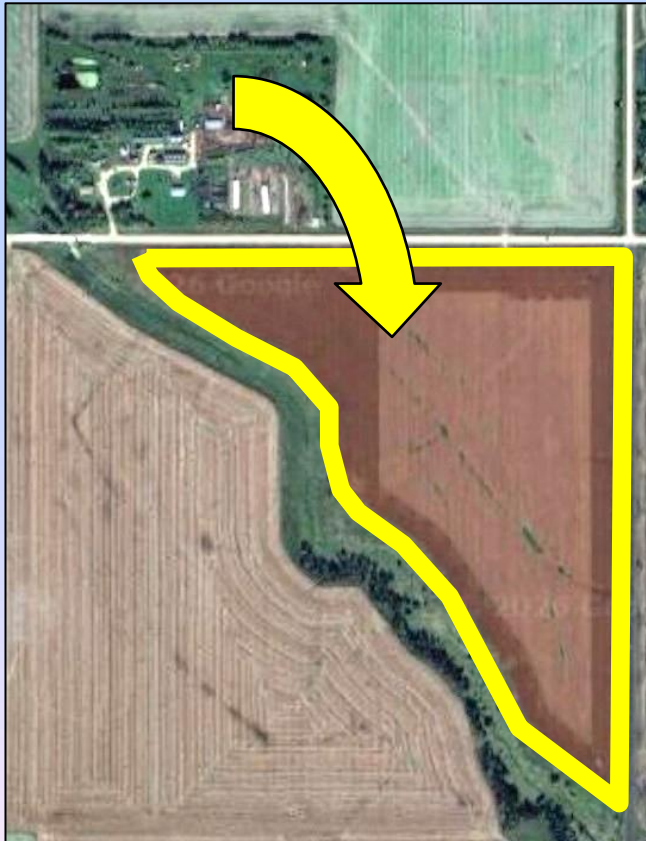
* Correlation between uptake of N by barley and nitrate-N in soil for 22 experiments, 1962-1968

Effect of shallow vs. deep sampling on soil tests for residual N in Manitoba fields ... Aggie students' projects

AGVISE 0-6" vs 0-24" soil nitrate-N analyses & fertilizer N recommendations for SOIL 4520 Soil Fertility class projects 2017-2019

	Soil Sample Depth					
	0-24"	0-6"	0-24"	0-6"	0-24"	0-6"
Fall 2017 - LaSalle	Canola		Soybeans		Spring Wheat	
Soil Analysis (lb N/ac)	72	33(66)*	52	25(50)	175	91(182)
Fertilizer Rec. (lb N/ac)	103	112	-	-	10	55
Fall 2018 - Brunkild	Spring Wheat		Soybeans		Canola	
Soil Analysis (lb N/ac)	42	15(30)	58	22(40)	60	27(54)
Fertilizer Rec. (lb N/ac)	201	213	-	-	135	141
Fall 2019 - Domain	Per. Ryegrass		Spring Wheat		Canola	
Soil Analysis (lb N/ac)	37	13(26)	43	7(14)	61	16(32)
Fertilizer Rec. (lb N/ac)	63	74	131	154	149	178
Avg Rec for 0-6" samples	132 lb N/ac		lower soil analysis than other depth			
Avg Rec for 0-24" samples	113 lb N/ac		higher fertilizer recommendation			
*number in parentheses is estimated total for 0-24" depth based on 0-6" sample						

An example of why it's important to sample every field ... every year



... including the field across the road from the farm yard, which had 175 lbs of residual N after growing a 50 bu/acre canola crop ... and was the field where grandpa used to haul the manure from the cattle overwintering pens

Improving Reliability, Value, and Confidence in Soil Testing

Step 1: Right Sampling

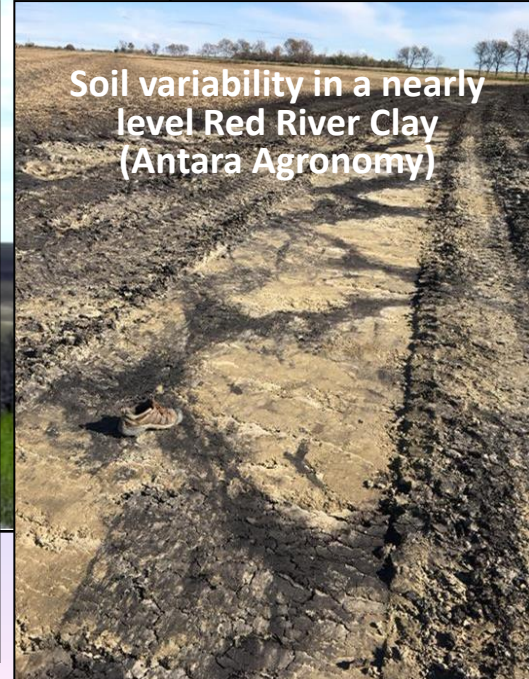
Soils are variable at large & small scales ... take lots of subsamples

Soil variability in a rolling landscape in Western MB

Soil variability in a Red River Clay (UM Glenlea RS)



Soil variability in a nearly level Red River Clay (Antara Agronomy)



Improving Reliability, Value, and Confidence in Soil Testing

Step 1: Right Sampling

Soils are variable at large & small scales ... take lots of subsamples

- For a 160 acre field, 2.5 billion lbs of root zone soil are represented by < 1 lb soil sample ... and nutrient conc'n varies greatly within a field, especially if field has a history of fertilizer banding or manure app'n ... so take at least 15-20 subsamples per field or zone

Nitrogen variability between individual soil sample cores collected near Fort Qu'Appelle, SK

SOIL TYPE	SOIL TEST EXTRACTABLE NITRATE-N (LB N/ACRE)		
	LOWEST	HIGHEST	AVERAGE
OXBOW LOAM	6	161	44
INDIAN HEAD CLAY	5	26	11

* Simmons 1985 (Sask. Ag. and Food)

Improving Reliability, Value, and Confidence in Soil Testing

Step 1: Right Sampling

If the variability in **soil fertility and yield potential** are systematic ... farmer may benefit from variable rate fertilization ...

Crop: Canola
 Last Crop: Barley-Malt
 Yield Goal (bu/ac) 43.6

Zone	Acres	(bu/ac)
1	10.5	30
2	18.2	35
3	25.6	40
4	27.8	45
5	28.3	50
6	24.9	50
7	15.6	50
8	7	40
9	2.5	30
10	1.2	15
Average: 43.6		

Notes: Low P in zone

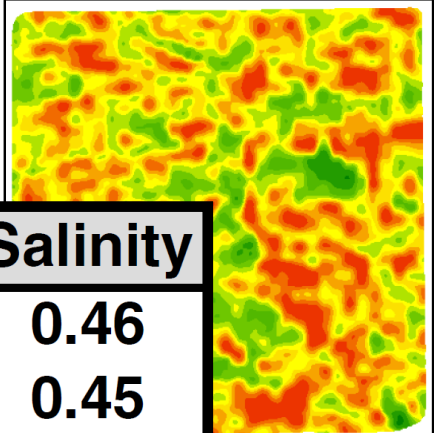
Field Area	% Field
zone 1,2	18
zone 3,4	33
zone 5,6	33
zone 7,8	14
zone 9,10	2

Zone	Acres	(bu/ac)	YieldGoal
1	10.5	30	High areas
2	18.2	35	
3	25.6	40	
4	27.8	45	
5	28.3	50	
6	24.9	50	
7	15.6	50	
8	7	40	
9	2.5	30	Low areas
10	1.2	15	
Average: 43.6			

Machine Controller: X30
 Prescription File: D1MervinCanola2022
 CropPro SWAT map provided by Dwight Odelein, Quill Lake, SK

Actual Fertility Rates

- 0 - 0	+ 3Mg
- 0 - 0	+ 3Mg
- 0 - 0	+ 3Mg
- 0 - 0	+ 3Mg
- 0 - 0	+ 3Mg
- 0 - 0	+ 3Mg
- 0 - 0	+ 2Mg
- 0 - 0	+ 2Mg
- 0 - 0	+ 1Mg
- 0 - 0	+ 1Mg
- 0 - 0	



Salinity
0.46
0.45
0.70
1.36
4.85

Salinity	CMPT Date
0.46	May 05, 2021
0.45	May 05, 2021
0.70	May 05, 2021
1.36	May 05, 2021
4.85	May 05, 2021

in zones 1-2. Light sal

gh in zones 9-10.

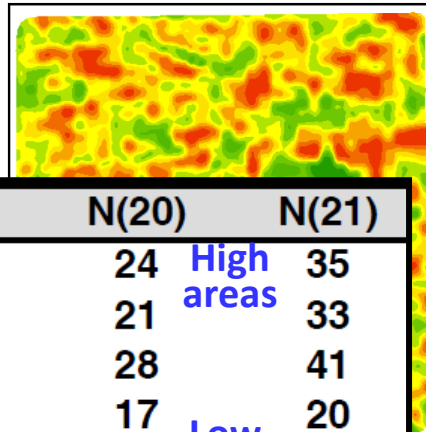
K	S	Cl	Z
249	27	11	0.
253	45	8	0.
335	59	19	1.
400	160	24	1.
304	160	60	0.

N fertility is often variable within fields eg. due to landscape

Crop: Canola
Last Crop: Barley-Malt
Yield Goal (bu/ac) 43.6

Machine Controller: X30
Prescription File: D1MervinCanola2022
CropPro SWAT map provided by Dwight Odelein, Quill Lake, SK

Zone	Acres	YieldGoal (bu/ac)	YieldGoal Canola MAP Urea Crystal Green					Actual Fertility Rates	
			Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
1	10.5	30	5.3	30	160	60	82 - 39 - 0 - 0	+ 3Mg	
2	18.2	35	5.1	30	170	60	86 - 39 - 0 - 0	+ 3Mg	
3	25.6	40	4.9	35	180	50	91 - 38 - 0 - 0	+ 3Mg	
4	27.8	45							
5	28.3	50							
6	24.9	50							
7	15.6	50							
8	7	40							
9	2.5	30							
10	1.2	15							
Average:		43.6							

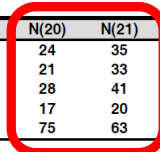


Field Area	% Field	N(20)	N(21)
zone 1,2	18	24	35
zone 3,4	33	21	33
zone 5,6	33	28	41
zone 7,8	14	17	20
zone 9,10	2	75	63

High areas (red/yellow) and Low areas (blue) are indicated on the map.

Notes: Low P in zone

Field Area	% Field	N(20)	N(21)	DM %	pH	P	K	S	Cl	Zn	Cu	B	Texture	Salinity	CMPT Date
zone 1,2	18	24	35	4.0	7.9	8 (Olsen)	249	27	11	0.4	0.7	1.1		0.46	May 05, 2021
zone 3,4	33	21	33	4.3	7.8	11 (Olsen)	253	45	8	0.5	0.5	1.2		0.45	May 05, 2021
zone 5,6	33	28	41	5.5	7.7	12 (Olsen)	335	59	19	1.1	0.6	1.5		0.70	May 05, 2021
zone 7,8	14	17	20	6.2	7.8	27 (Olsen)	400	160	24	1.2	1.1	2.2		1.36	May 05, 2021
zone 9,10	2	75	63	5.4	8.0	45 (Olsen)	304	160	60	0.8	0.9	2.8		4.85	May 05, 2021



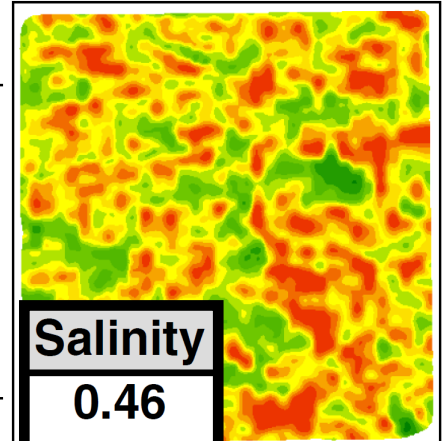
CropPro SWAT map provided by Dwight Odelein, Quill Lake, SK

S fertility is also often variable within fields eg. due to landscape

Crop: Canola
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Yield Goal (bu/ac) 43.6

Machine Controller: X30
Prescription File: D1MervinCanola2022
CropPro SWAT map provided by Dwight Odelein, Quill Lake, SK

Zone	Acres	YieldGoal (bu/ac)	Canola	MAP	Urea	Crystal Green	Actual Fertility Rates		
			Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		
1	10.5	30	5.3	30	160	60		82 - 39 - 0 - 0	+ 3Mg
2	18.2	35	5.1	30	170	60		86 - 39 - 0 - 0	+ 3Mg
3	25.6	40	4.9	35	180	50		91 - 38 - 0 - 0	+ 3Mg
4	27.8	45	4.8	35	180	50		91 - 38 - 0 - 0	+ 3Mg
5	28.3	50	4.8	35	180	50		91 - 38 - 0 - 0	+ 3Mg
6	24.9	50	4.8	35	190	50		95 - 38 - 0 - 0	+ 3Mg
7	15.6	50	4.8	30	190	40		93 - 32 - 0 - 0	+ 2Mg
8	7							0	+ 2Mg
9	2.5							0	+ 1Mg
10	1.2							0	+ 1Mg



Field Area	S
zone 1,2	27
zone 3,4	45
zone 5,6	59
zone 7,8	160
zone 9,10	160

Salinity
0.46
0.45
0.70
1.36
4.85

Notes: Low P

Field Area
zone 1,2
zone 3,4
zone 5,6
zone 7,8
zone 9,10

...nes 1-2. Light salinity

S	Cl	Zn
27	11	0.4
45	8	0.5
59	19	1.1
160	24	1.2
160	60	0.8

...gh in zones 9-10.

Salinity	CMPT Date
0.46	May 05, 2021
0.45	May 05, 2021
0.70	May 05, 2021
1.36	May 05, 2021
4.85	May 05, 2021

Saline areas might have 30,000 lbs S/acre

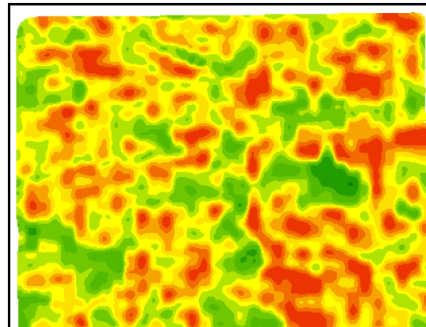
CropPro S

Soil test P also varies spatially within fields ... e.g., STP is often high in low areas of the landscape

Crop: Canola
Last Crop: Barley-Malt
Yield Goal (bu/ac) 43.6

Machine Controller: X30
Prescription File: D1MervinCanola2022
CropPro SWAT map provided by Dwight Odelein, Quill Lake, SK

Zone	Acres	YieldGoal (bu/ac)	Canola MAP					Actual Fertility Rates		
			Layer 1	Layer 2	Layer 3	Layer 4	Layer 5			
1	10.5	30	5.3	30	160	60	82	- 39	- 0 - 0	+ 3Mg
2	18.2	35	5.1	30	170	60	86	- 39	- 0 - 0	+ 3Mg
3	25.6	40	4.9	35	180	50	91	- 38	- 0 - 0	+ 3Mg
4	27.8	45	4.8	35	180	50	91	- 38	- 0 - 0	+ 3Mg
5	28.3	50	4.8	35	180	50	91	- 38	- 0 - 0	+ 3Mg
6	24.9	50	4.8	35	190	50	95	- 38	- 0 - 0	+ 3Mg
7	15.6	50	4.8	30	190	40	93	- 32	- 0 - 0	+ 2Mg
8	7	40	5.1	20	170	30	82	- 22	- 0 - 0	+ 2Mg
9	2.5	30	5.3	15	100	15	49	- 14		
10	1.2	15	4	15	50	15	26	- 14		
Average:		43.6	4.9	32.5	177.4	49.1	89 - 36			



Notes: Low P in zones 1-6. Low chloride in zones 1-4. Low zinc in zones 1-4.

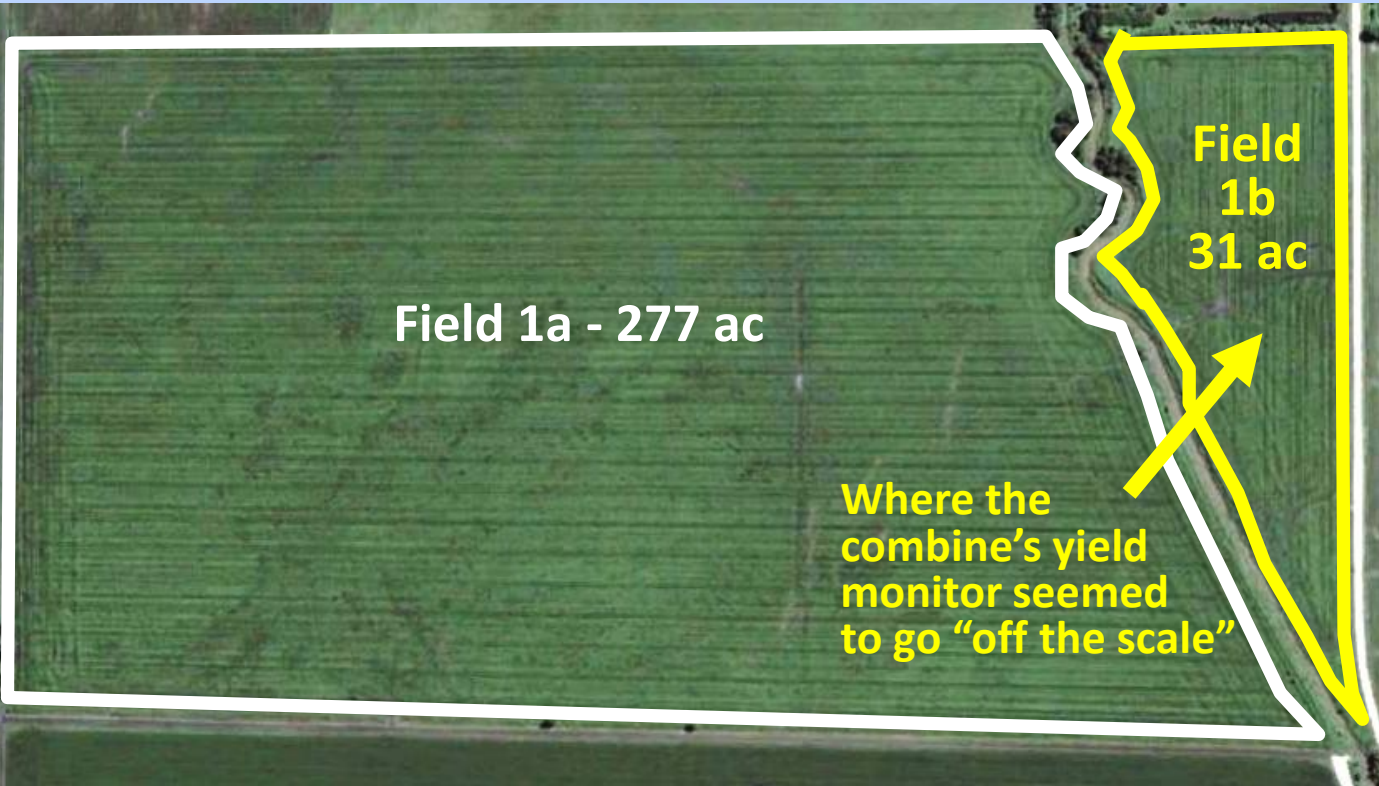
Field Area	% Field	N(20)	N(21)	OM %	pH	P
zone 1,2	18	24	35	4.0	7.9	8 (Olsen)
zone 3,4	33	21	33	4.3	7.8	11 (Olsen)
zone 5,6	33	28	41	5.5	7.7	12 (Olsen)
zone 7,8	14	17	20	6.2	7.8	27 (Olsen)
zone 9,10	2	75	63	5.4	8.0	45 (Olsen)

Field Area	% Field	P
zone 1,2 High areas	18	8 (Olsen)
zone 3,4	33	11 (Olsen)
zone 5,6	33	12 (Olsen)
zone 7,8 Low areas	14	27 (Olsen)
zone 9,10	2	45 (Olsen)

CropPro SWAT map provided by Dwight Odelein, Quill Lake, SK

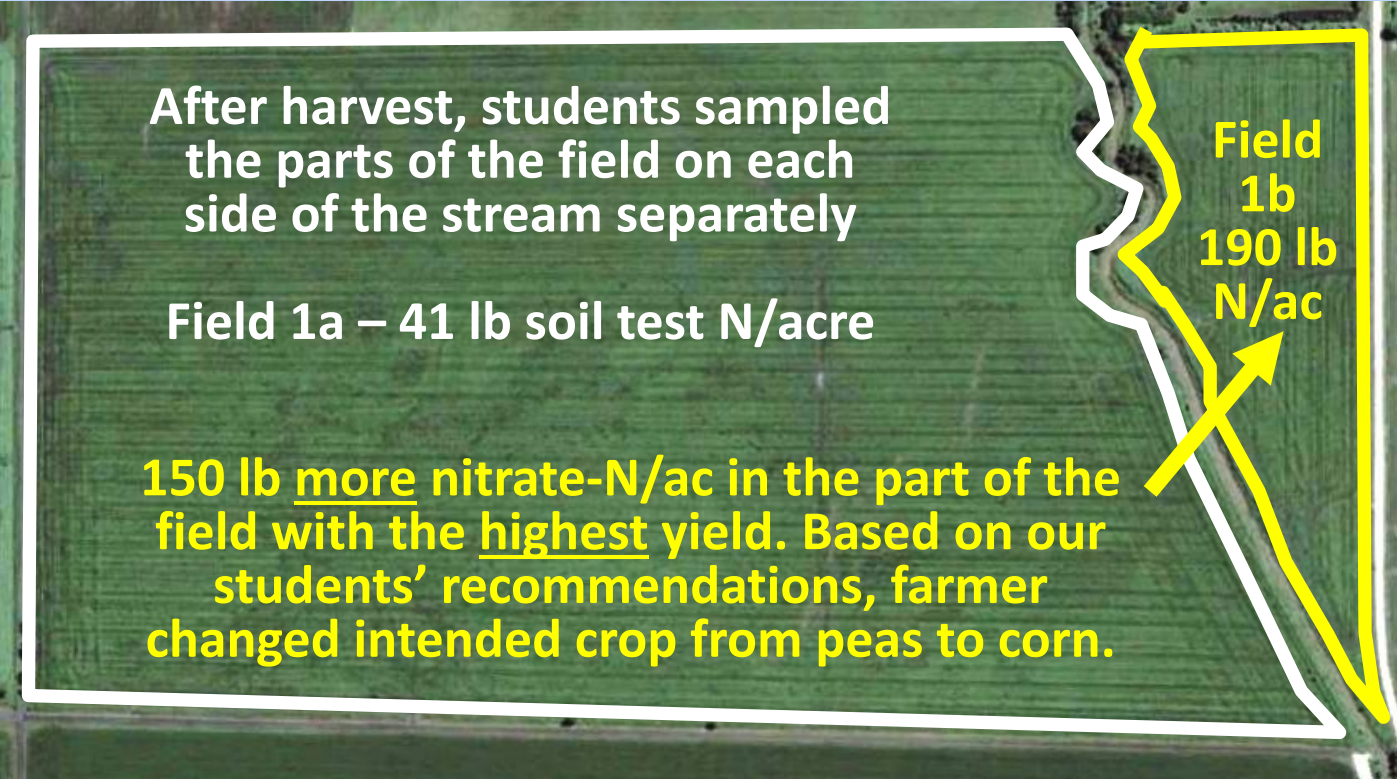
**Soil fertility might also vary due to
historical management ...**

e.g., within a nearly level field of clay soil near Winnipeg



Soil fertility might also vary due to historical management ...

e.g., within a nearly level field of clay soil near Winnipeg



After harvest, students sampled the parts of the field on each side of the stream separately

Field 1a – 41 lb soil test N/acre

150 lb more nitrate-N/ac in the part of the field with the highest yield. Based on our students' recommendations, farmer changed intended crop from peas to corn.

Field
1b
190 lb
N/ac

Improving Reliability, Value, and Confidence in Soil Testing

Step 1: Right Sampling

Time of Sampling:


- Fall sampling for residual nitrate-N is usually OK for the Prairies, but is not reliable in wetter regions of the world where leaching and denitrification losses are large (e.g., Southern Ontario or the U.S. Midwest)
- However, if fall weather in Prairies is unusually wet, sample and/or re-sample soil in spring

Handle Samples Carefully:

- Mix thoroughly and select a representative subsample
- Avoid contamination during sampling and handling
- Minimize unnatural mineralization gains, denitrification losses
- Handle sample as recommended by lab; consider effect of artificial drying and/or freezing

Improving Reliability, Value, and Confidence in Soil Testing

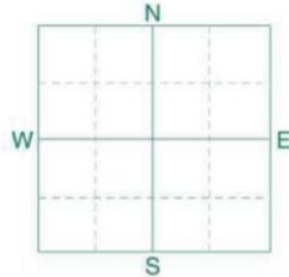
Step 2: Right Analysis



Soil Analysis by Agvise Laboratories
<http://www.agvise.com>
 Northwood: (701) 587-6010
 Benson: (320) 843-4109

SOIL TEST REPORT

FIELD ID
 SAMPLE ID **Clay's field**
 FIELD NAME **Osborne Clay**
 COUNTY **Heavy Clay**
 TWP **(>70% clay)**
 SECTION
 PREV. CROP **Peas-Field**



SUBMITTED FOR:

SUBMITTED BY: **UN2158**

REF # **19339137** BOX # **2704**
 LAB # **NW167944**

Soil Analyses

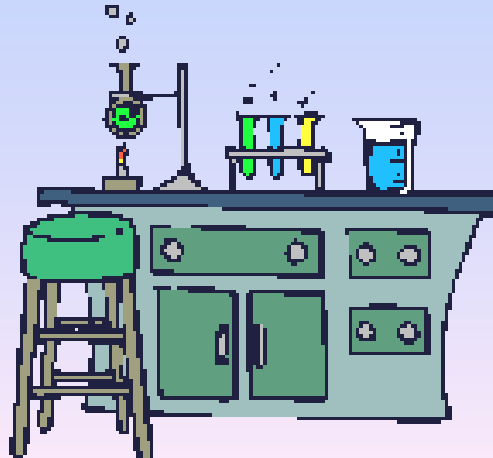
Nutrient In The Soil		Interpretation				
		V.Low	Low	Med	High	
Nitrate	0-6" 6-24"	18 lb/acre				
	0-24"	18 lb/acre				
		36 lb/acre	*****			
Olsen	16 ppm	*****				

1st Crop Choice		2nd Crop Choice		3rd Crop Choice	
Canola-bu		Wheat-Spring			
YIELD GOAL		YIELD GOAL		YIELD GOAL	
50 BU		80 BU			
SUGGESTED GUIDELINES		SUGGESTED GUIDELINES		SUGGESTED GUIDELINES	
Band/Maint.		Band/Maint.			
LB/ACRE	APPLICATION	LB/ACRE	APPLICATION	LB/ACRE	APPLICATION
N	124	N	165	N	

Analysis of Soil Nutrient Content, cont'd.

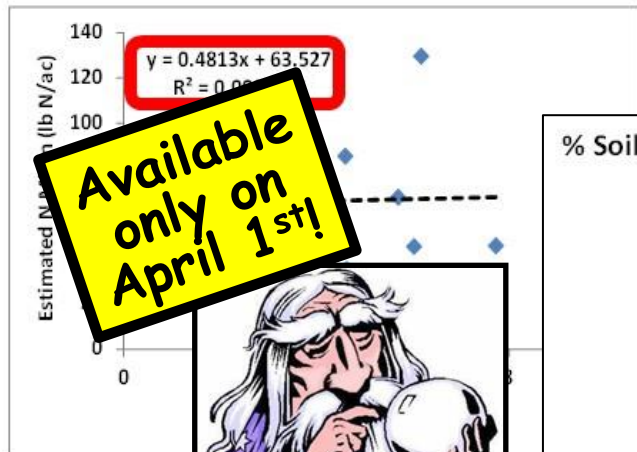
Most appropriate type of analysis varies with nutrient, regional climate & soil characteristics. Pools of nutrients typically measured by chemical extraction for Western Canadian soils are as follows:

- Water – for extracting plant available forms that are readily soluble (ie. not precipitated), not adsorbed, and move easily to plant roots by mass flow & not lost between sampling & crop demand, eg. nitrate-N, sulphate-S, chloride and perhaps boron ...
but does not measure N and S mineralized from organic matter



Predicting N mineralization from % Soil Organic Matter doesn't work either ... due to variable & unpredictable differences in organic matter composition, seasonal weather conditions, and agronomic practices

% Soil Organic Matter for Estimating N Mineralization for High Yielding Spring Wheat in the Field for 8 Site-Years



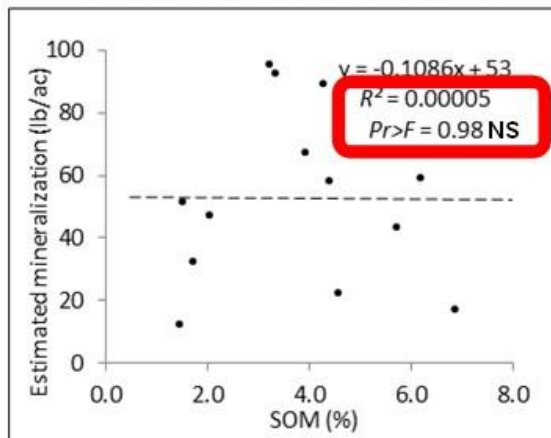
Mangin et al. 2018



AGVISE
LABORATORIES

Crystal Ball Services

% Soil Organic Matter for Estimating N Mineralization for Corn in the Field for 13 Site-Years



Gardiner and Flaten 2020

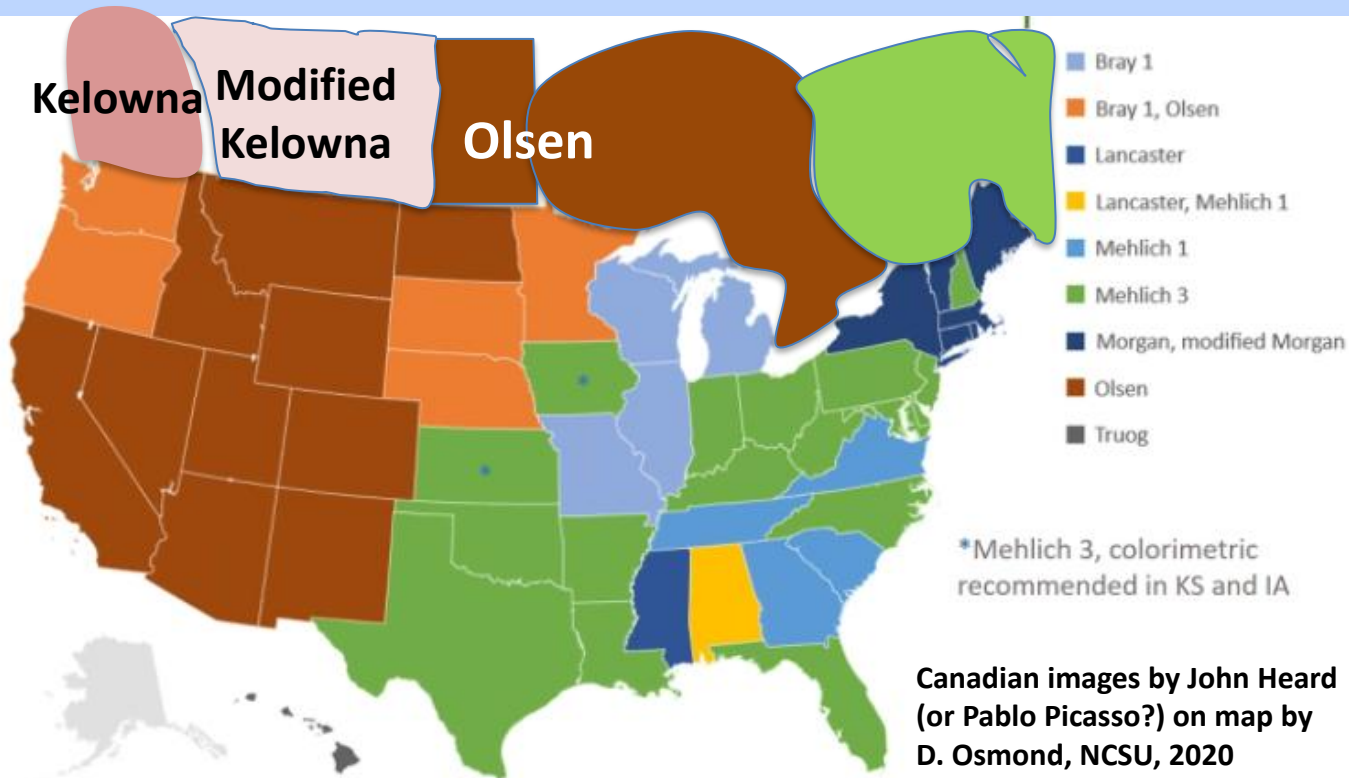
Analysis of Soil Nutrient Content, cont'd.

Most appropriate type of analysis varies with nutrient, regional climate & soil characteristics. Pools of nutrients typically measured by chemical extraction for Western Canadian soils are as follows:

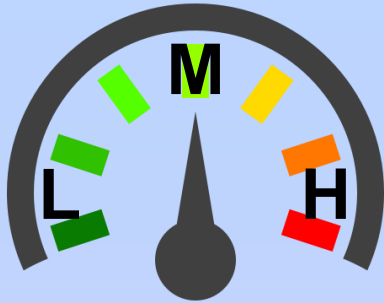
- Water – for extracting plant available forms that are readily soluble (ie. not precipitated), not adsorbed and move easily by mass flow & not lost between sampling & crop demand, eg. nitrate-N, sulphate-S, chloride and perhaps boron ... but does not measure N and S mineralized from organic matter
- Sodium bicarbonate (Olsen test) is generally recommended for extracting “labile” P in Prairie/Northern Great Plains soils, but acetic fluoride (modified Kelowna test, with a high concentration of weak acid) is also acceptable in SK & AB



Standard Recommended Soil Tests for P in Canada and U.S.



Analysis of Soil Nutrient Content



www.iconfinder.com

- P & K soil tests provide a relative index or gauge (eg. H,M,L) of plant available nutrients, based on probability of fertilizer response
- “ppm” values should not be converted to lb of P or K available to crop per acre (e.g., soil test P & K ppm values vary with extractant)

Approximate soil test P sufficiency ranges for crops in the Northern Great Plains*

Table 3. Approximate soil test phosphorus sufficiency ranges^a for crop production in Northern Great Plains soils using various soil testing methods.

Soil Test Method	Very Low to Medium	Medium to High	High to Excessive
	----- parts per million (ppm) or mg/kg ^b -----		
Olsen (Sodium Bicarbonate)	<10	10 to 20	>20
*Mehlich-3	<20	20 to 40	>40
*Bray-1 (Weak Bray)	<15	15 to 25	>25
*Bray-2 (Strong Bray)	<27	27 to 40	>40
*Miller-Axley	<13	13 to 22	>22
Modified Kelowna (Enviro-Test) ^c	<15	15 to 25	>25
Modified Kelowna (Norwest) ^d	<15	15 to 27	>27
Kelowna	<15	15 to 30	>30
Water	<3	3 to 5	>5

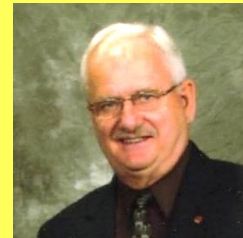
***Assuming that the soil tests are suitable for the soil ... e.g., that these acidic extracts are not used on high pH, calcareous soils, where they are neutralized**

<https://fertilizercanada.ca/wp-content/uploads/2019/07/4R-P-fertilizer-mgmt-Chapter-5-P-Rates-final.pdf>

P Soil Test for a Perennial Forage Trial near Nanton, AB (1978-1979)

This field trial was designed to evaluate conversion of an annual crop field to sainfoin, a non-bloating perennial legume forage suitable for cattle grazing

- Although the field was regarded as having a history of regular fertilization, the soil tests that I collected & submitted in Spring 1979 showed extremely low Bray soil test P levels
- Soil pH was very high ... above pH 8
- Was the P soil test correct?
- Again, Dr. Jim Bole (AAFC) tried to get me back on track ... explaining how this soil's lime neutralized the low conc'n of HCl acid in the Bray extract and he recommended remedial training at U of M



Analysis of Soil Nutrient Content, cont'd.

Most appropriate type of analysis varies with nutrient, regional climate & soil characteristics. Pools of nutrients typically measured by chemical extraction for Western Canadian soils are as follows:

- Water – for extracting plant available forms that are readily soluble (ie. not precipitated), not adsorbed and move easily by mass flow & not lost between sampling & crop demand, eg. nitrate-N, sulphate-S, chloride and perhaps boron ... but does not measure N and S mineralized from organic matter
- Sodium bicarbonate (Olsen test) or acetic fluoride (modified Kelowna test, with a high concentration of weak acid) is recommended for extracting “labile” P
- Dissolved salts (e.g., ammonium acetate) that displace “exchangeable” potassium, calcium, and magnesium (K^+ , Ca^{2+} , Mg^{2+}) ... cations that are held loosely on the soil surfaces
- Chelate-extractable metallic micros (eg. DTPA-Cu, Zn, Mn, Fe)


Other soil measurements ... OM, pH, CEC, CCE, EC, etc

Org.Matter	5.7 %										
Carbonate(CCE)	7.5 %			Soil pH	Buffer pH	Cation Exchange Capacity	% Base Saturation (Typical Range)				
							% Ca	% Mg	% K	% Na	% H
0-6"	0.57 mmho/cm			0-6"	8.0						
6-24"	0.64 mmho/cm			6-24"	8.5	50.1 meq	(65-75)	(15-20)	(1-7)	(0-5)	(0-5)
Sol. Salts							61.9	35.4	2.3	0.4	0.0

- Org. Matter is an indicator of soil quality or health, but SOM varies substantially with sample location and depth and very slowly with time
- Carbonates (e.g., calcium carbonate equivalent or CCE) are a useful measure of the soil's lime content, e.g., for tying up P & micronutrients and increasing the risk of iron deficiency chlorosis (IDC) in soybeans and flax
- Soluble Salts (EC) indicate the presence of salinity & also risk of iron deficiency chlorosis in (IDC)
- Soil pH indicates presence of acidity (pH<7) or alkalinity (pH>7)
- Cation Exchange Capacity (CEC) indicates the soil's capacity to hold positively charged nutrients (e.g., NH_4^+ , K^+ , Ca^{2+} , Mg^{2+}) ... but regular soil fertility tests only estimate CEC and high CCE or EC inflates estimated CEC, especially in Prairie soils
- Base Saturation is not important unless your soil is acidic ... also, the B.S. values are inflated by high CCE or EC

Improving Reliability, Value, and Confidence in Soil Testing

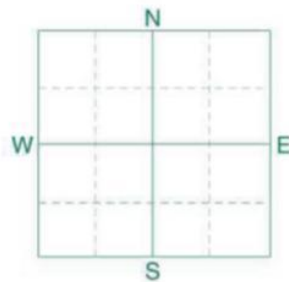
Step 3: Right Recommendations



Soil Analysis by Agvise Laboratories
(<http://www.agvise.com>)
Northwood: (701) 587-6010
Benson: (320) 843-4109

SOIL TEST REPORT

FIELD ID
SAMPLE ID **Clay's field**
FIELD NAME **Osborne Clay**
COUNTY **Heavy Clay**
TWP **(>70% clay)**
SECTION
PREV. CROP **Peas-Field**



SUBMITTED FOR:

SUBMITTED BY: **UN2158**

REF # **19339137** BOX # **2704**
 LAB # **NW167944**

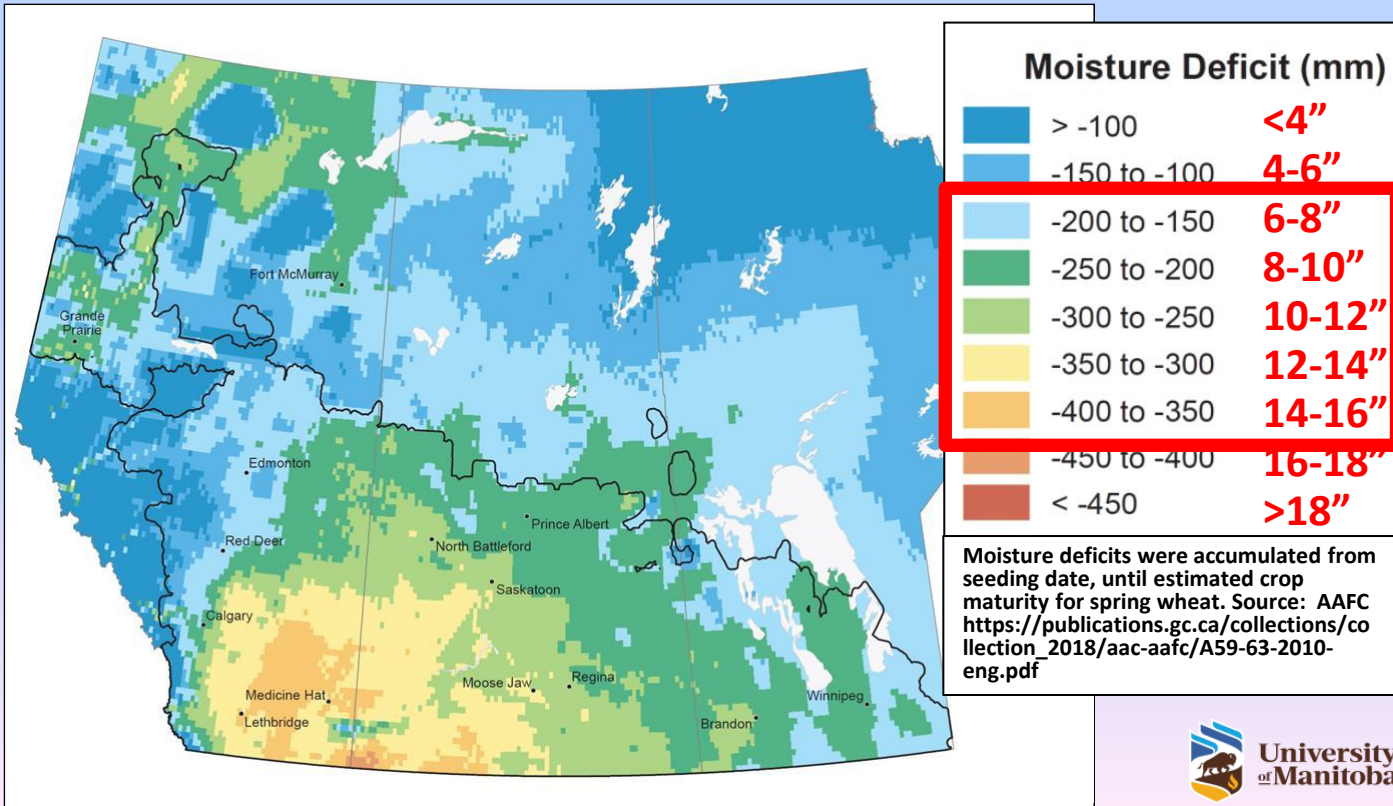
Nutrient Recommendations

1st Crop Choice		2nd Crop Choice		3rd Crop Choice	
Canola-bu		Wheat-Spring			
YIELD GOAL		YIELD GOAL		YIELD GOAL	
50 BU		80 BU			
SUGGESTED GUIDELINES		SUGGESTED GUIDELINES		SUGGESTED GUIDELINES	
Band/Maint.		Band/Maint.			
LB/ACRE	APPLICATION	LB/ACRE	APPLICATION	LB/ACRE	APPLICATION
N 124		N 165		N	

Nutrient In The Soil		Interpretation			
		Low	Med	High	
Nitrate	0-6" 6-24"	18 lb/acre	18 lb/acre		
	0-24"	36 lb/acre			
	Olsen	16 ppm			
Phosphorus					

Nutrient Recommendations

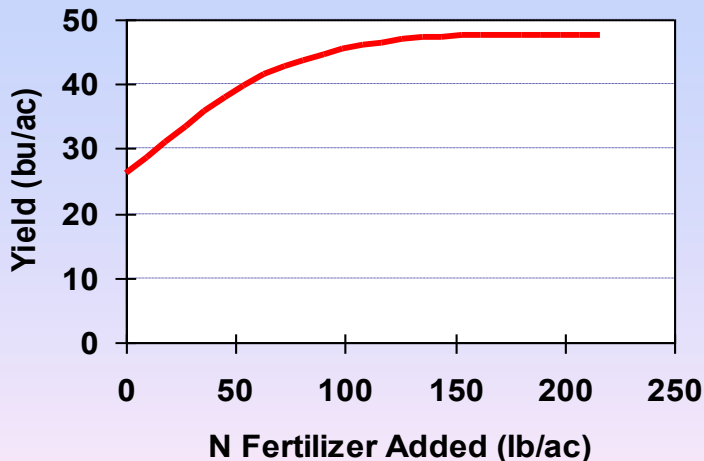
- Recommendations for fertilizer must be locally relevant ... e.g., correlated with crop yield responses to fertilizer in the region where the crop is grown, e.g., accounting for moisture supply



Nutrient Recommendations, cont'd.

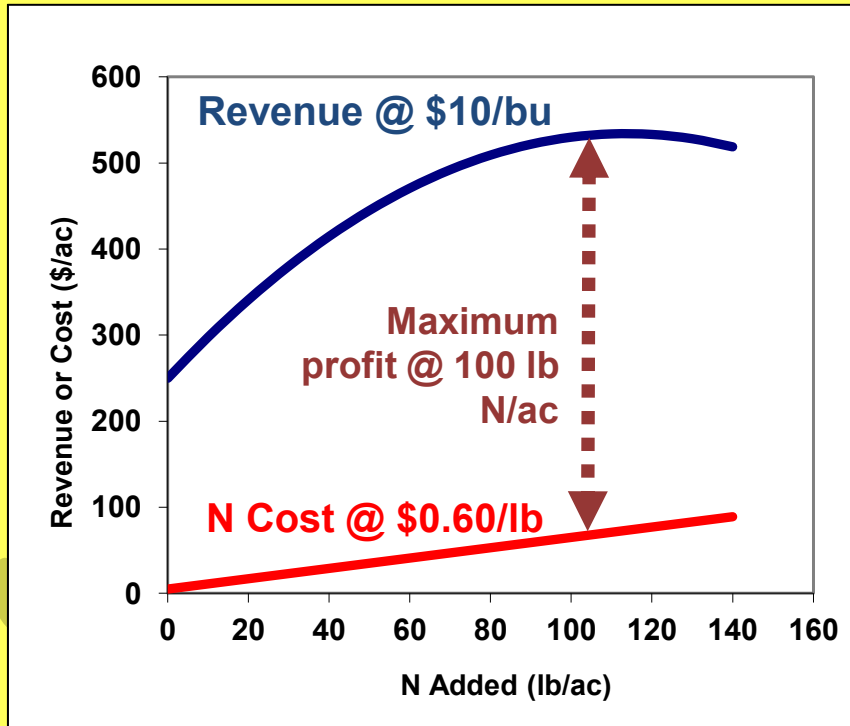
Recommendations also vary with goals of fertilization program:

- Short term maximum economic yield or agronomic sufficiency
 - Yield responses to nutrients are often illustrated as precise curves ... but fertilizer responses vary substantially with growing season moisture & temperature, crop variety/hybrid, etc. ... so portraying a single response curve can be misleading ... and the choice of a response “curve” can make a big difference to the recommendation ... so we should not oversell accuracy of recommendations



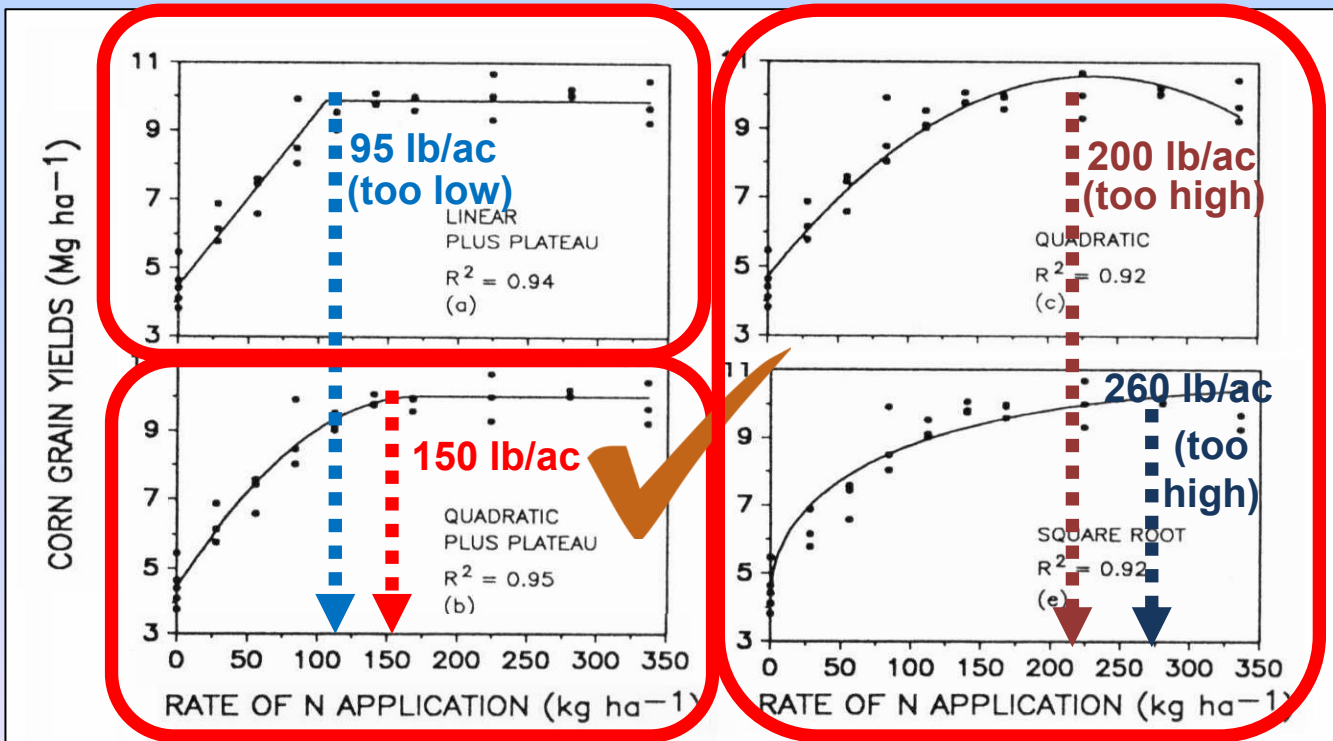
Calculating the Economic Optimum Rate of N Fertilizer

It “should” be easy to describe the crop’s response to N using a quadratic equation ... plus a linear equation for describing fertilizer cost ... then use differential calculus to determine the N rate where profits are maximized (e.g., for canola)



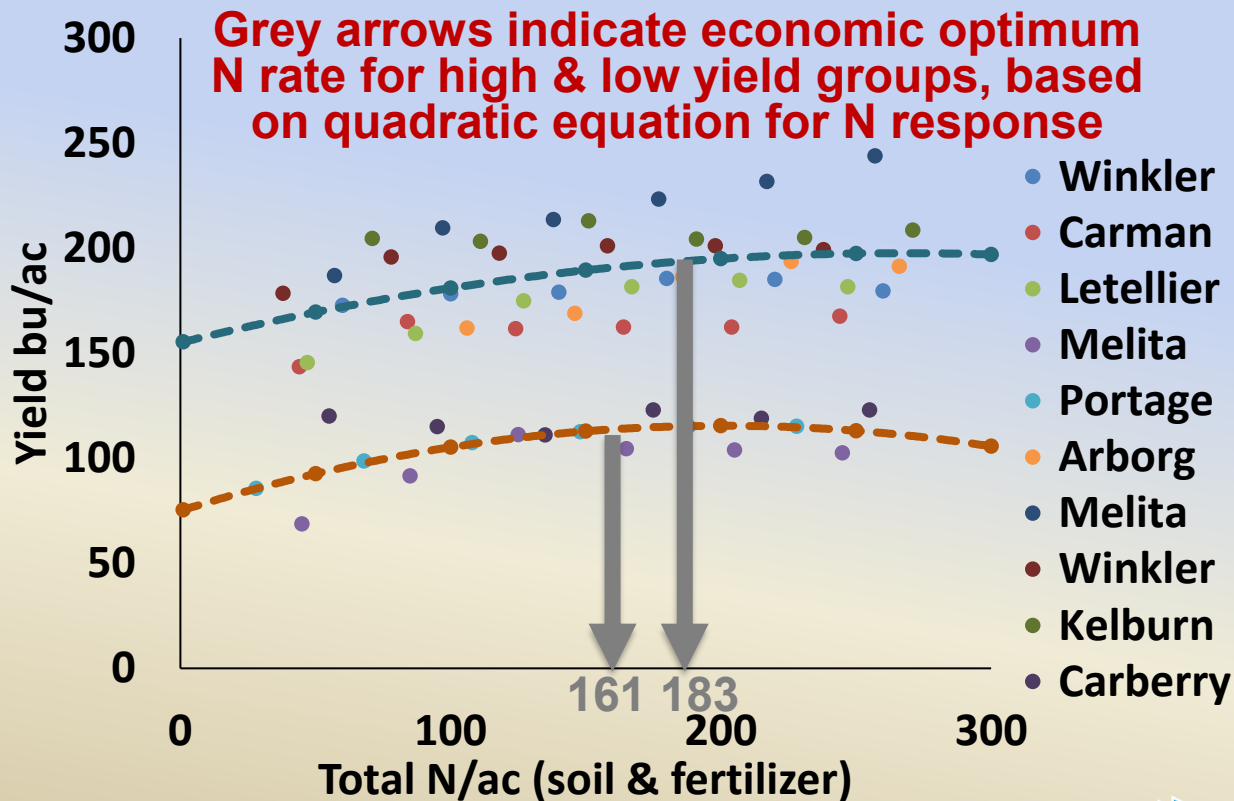
But in the early 1990s, Dr. Manuel Cerrato, who had just finished his Ph.D. in Iowa State University, showed us that calculating the optimum rate of N was not that easy ...

Maximum Economic Yield calculated with different response curves/models varied from 95-260 lb N/ac for the same corn response trial in Iowa ... "best" was QPP (Cerrato & Blackmer 1990)



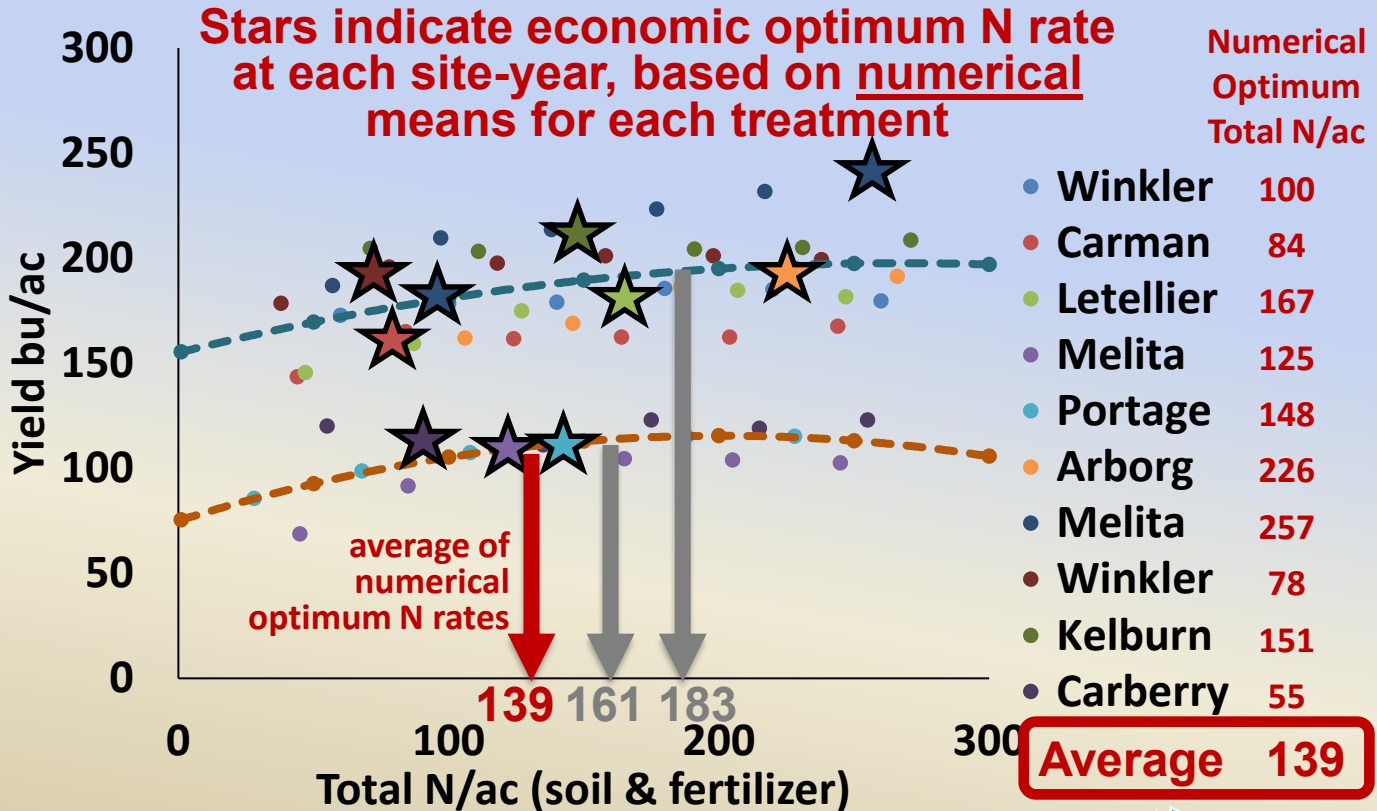
Cerrato and Blackmer Agron. J. 82:138-143 (1990)

Most economic rate of N @ \$4/bu corn and \$0.40/lb N



(John Heard, MB Agriculture)

Most economic rate of N @ \$4/bu corn and \$0.40/lb N



(John Heard, MB Agriculture)

Most Accurate N Response Curves for High-Yielding Spring Wheat in Manitoba (Mangin et al. 2018)*

Site-Year	Wheat Variety	Statistical Model for N Response Curve				
		Linear - Plateau	Linear - Linear	Quadratic - Plateau	Quadratic	Linear
Brunkild 2016	Brandon	Best		?		
	Prosper		Best			
Carman 2016	Brandon					Best
	Prosper					Best
Brunkild 2017	Brandon					Best
	Prosper		Best			
Carman 2017	Brandon					Best
	Prosper		Best			
Melita 2016	Brandon					Best
	Prosper	Best				
Carberry 2016	Brandon					Best
	Prosper					Best
Melita 2017	Brandon					Best
	Prosper					Best
Grosse Isle 2017	Brandon	Best				
	Prosper					Best

*Accuracy determined using Akaike Information Criterion (AIC) values for each model and site-year

Nutrient Recommendations, cont'd.

- For some nutrients (e.g., P) the short term yield response to fertilizer is so variable that it's best to view the response as a probability, not a response "curve"

e.g. 45 years of P response trials on Sceptre clay site in Saskatchewan

Annual variations in phosphorus responses can be expected. The yield increases in wheat, due to 20 kg/ha (18 lb/ac) application of P_2O_5 on Sceptre Clay, which always requires additional phosphorus, are given in Fig. 8. Similar variations are encountered in other soils. These variations are unpredictable and are related to the phosphorus-release mechanisms in the soil.

- Guide to Farm Practice in Saskatchewan 1987

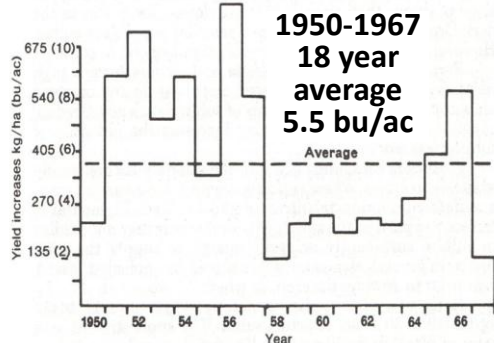
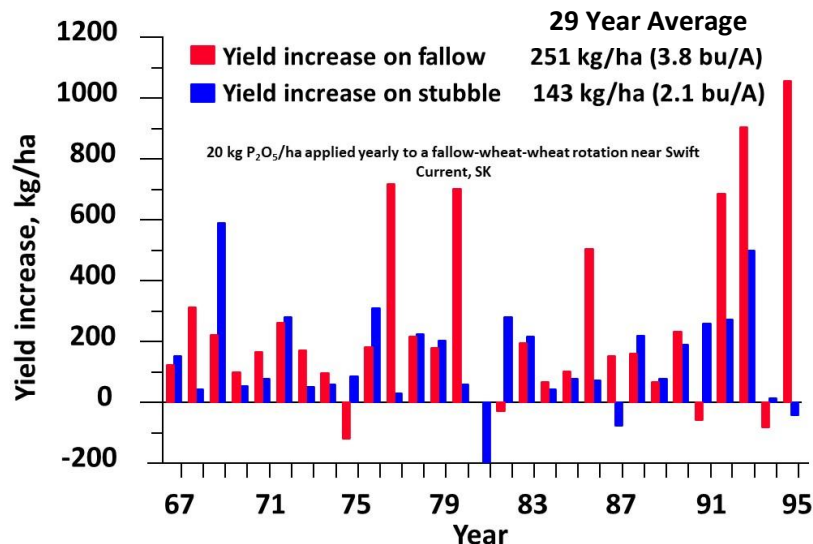


Fig. 8 — Average annual increase in wheat yield from 20 kg/ha (18 lb/ac) P_2O_5 on Sceptre clay



Adapted from Campbell, C. A., Zentner, R. P., Selles, F., Jefferson, P. G., McConkey, B. G., Lemke R. and Blomert, B. J. 2005. Long-term effect of cropping system and nitrogen and phosphorus fertilizer on production and nitrogen economy of grain crops in a Brown Chernozem. Can. J. Plant Sci. 85: 81-93.

Nutrient Recommendations, cont'd.

- For some nutrients (e.g., P) the short term yield response to fertilizer is so variable that it's best to view the response as a probability, not a response "curve"

Manitoba P Response Probabilities for Cereals and Hay Crops

Available P (ppm Olsen)	Number of Experiments	% Responding to Fertilizer P
0-5 V. Low	15	100
5-12 Low-Med	50	62
12-18 Med-High	16	56
>18 High-VH	14	29
Overall	95	63

Hedlin, U of M,

e.g., in Prairie soils, probability of cereal crop response to fertilizer P drops below 50% at Olsen soil test P levels greater than ~ 15 ppm

Saskatchewan P Response Probabilities

Soil Test P 0-6 inch (ppm)	Recommended Fertilizer Rate (lb P ₂ O ₅ /A)	Probability of Yield Response (%)
0-5	0-10	>75
5-10	11-20	50-75
10-15	21-30	50
15-30	31-60	25-50
>30	>60	0-15
		less than 25

Nutrient Recommendations, cont'd.

Recommendations also vary with goals of fertilization program:

- Short term maximum economic yield or agronomic sufficiency
- Specific target yield or yield goal (e.g., 2.0-2.25 lb soil + fertilizer N per bu for HRS wheat)
- Crop quality (e.g., more N for high protein HRS wheat, less N for low protein malt barley)
- Environmental protection (e.g., reduce nitrate leaching, N_2O emissions, excessive P in runoff)
- Building, maintaining, or depleting soil fertility over the long term (e.g., for P)

Nutrient Recommendations, cont'd.

Recommendations aimed at short-term maximum economic yield or agronomic sufficiency often result in long term depletion of soil fertility (e.g., for P) ... especially for today's high crop yields

P balance for 4 yr rotation following MB Soil Fertility Guide rec. for seed-placed P fertilizer for 10 ppm Olsen P				
Crop	Average* Yield (bu/ac)	P Applied -----	P Removed** (lb P ₂ O ₅ /ac)	Annual Balance -----
Spring Wheat	65	30	34	-4
Canola	50	20	39	-19
Oats	120	30	32	-2
Soybeans	40	10	35	-25
4 Year Total		90	141	-51

*P removal should be calculated for average yield ... not target yield
** Using 0.53, 0.78, 0.27, 0.87 lb P₂O₅/bu respectively for grain only

Prairie Nutrient Removal Calculator ... an online tool to help manage soil fertility

SELECT YOUR CROP

Crop Type

Cereals

Oilseeds

Pulse Crops

Canola

Flax

Mustard

Soybean

PRAIRIE NUTRIENT REMOVAL CALCULATOR (in harvested seed/grain)

This nutrient removal calculator estimates the nutrients removed in the harvested seed or grain. The removal coefficients are based on survey data collected from commercial fields from 2020-2022 in Saskatchewan, Alberta and Manitoba. The coefficients are estimates only and are based on the 75th percentile of the survey data for each nutrient. Research has shown that nutrient concentrations in the harvested seed or grain varies from year to year and with crop variety, soil fertility and climatic conditions. Consequently, these estimates are not prescriptive and should be used in conjunction with regular soil testing.

Selected Crop: **Canola**

50

Adjust the yield to your nutrient removal rate

NUTRIENT	REMOVAL (lb/acre)
----------	-------------------

N	94
---	----

P ₂ O ₅	39
-------------------------------	----

K ₂ O	19
------------------	----

S	11
---	----

B	0.029
---	-------

Cu	0.012
----	-------

Zn	0.092
----	-------

Funding and resources for "Revising the Crop Nutrient Uptake and Removal Guidelines for Western Canada" (College of Agriculture and Bioresources, University of Saskatchewan) provided by:

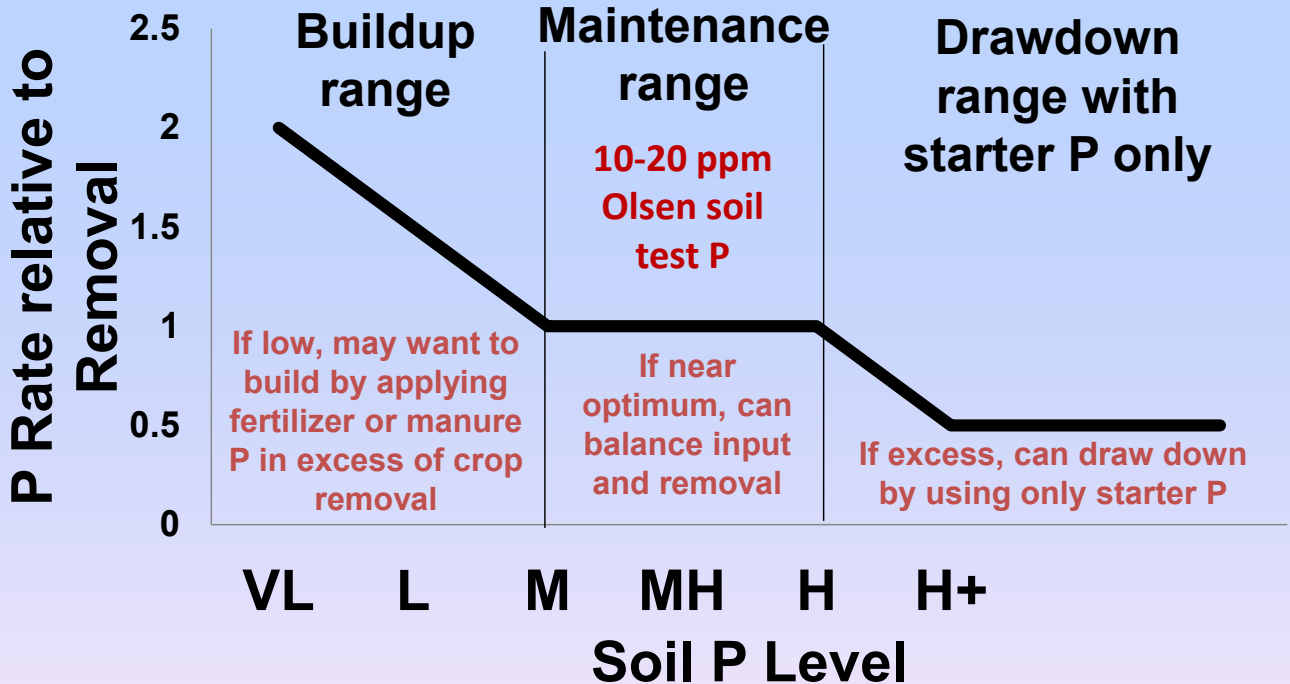


<https://prairienutrientcalculator.info/>



Nutrient Recommendations, cont'd.

Therefore, some farmers may select the goal of building, maintaining, or depleting soil fertility over the long term (e.g., for P)

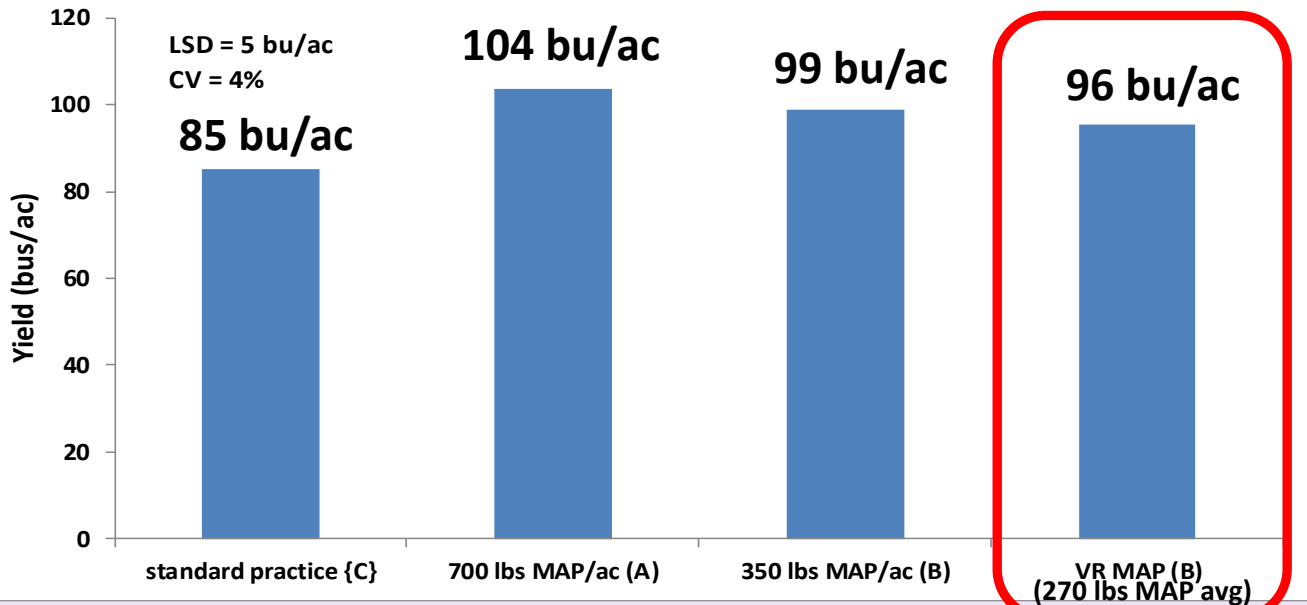


Adapted from OMAFRA Soil Fertility Handbook

Crops respond to P fertilizer and soil P fertility: Adam Gurr's field trial with supplemental P ... First year benefits after initial application in 2018

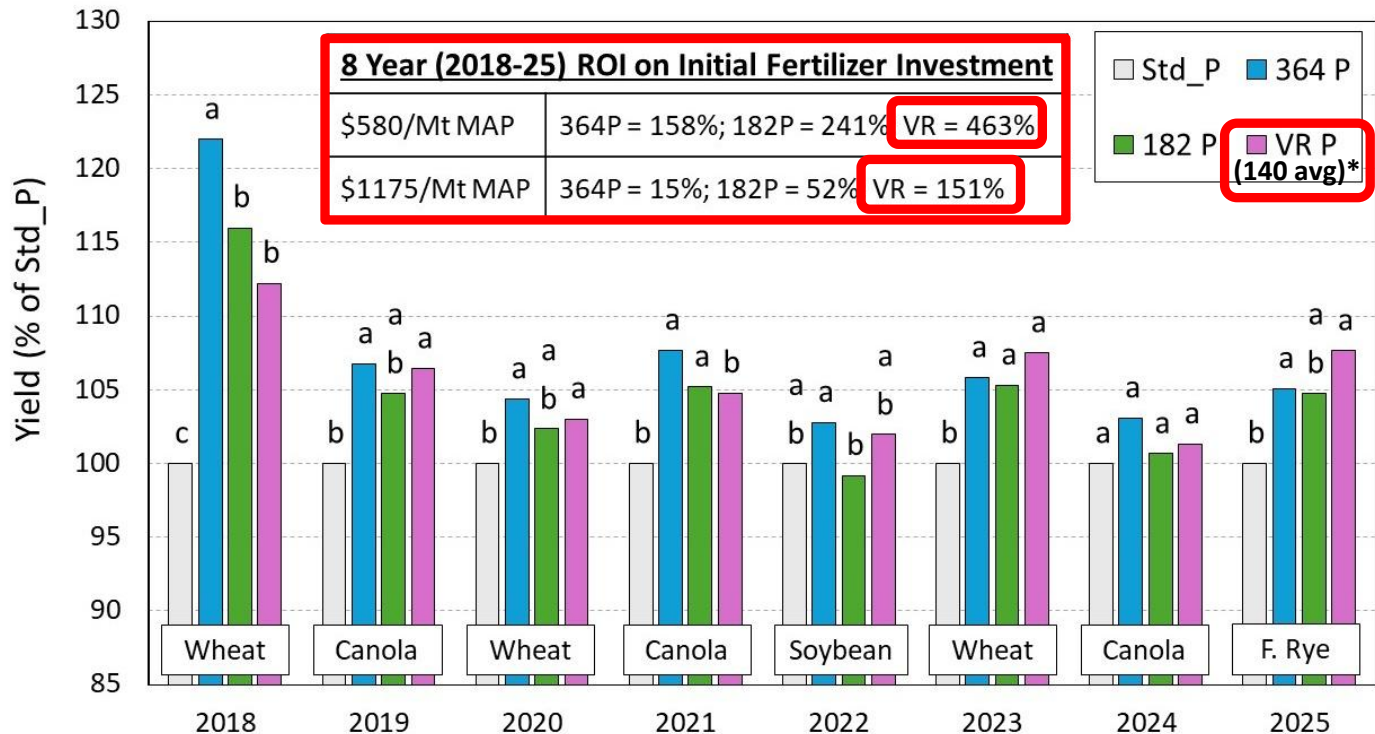
Faller Spring Wheat Yield Response to High Rates of Supplemental P Fertilizer *

(Adam Gurr, Agritruth Research, Rapid City, MB)



* P rates are in addition to 36 lbs P_2O_5 /ac sidebanded at planting;
yields are for the 1st year of study (2018)

Crops respond to P fertilizer and soil P fertility: Adam Gurr's field trial with supplemental P ... 8-year benefits after 1 "batch application" in 2018



* P rates are in addition to 36 lbs P₂O₅/ac sidebanded at planting; yields are for the 1st year of study (2018)

Nutrient Recommendations, cont'd.

But the goals for nutrient management recommendations can and should be varied to address changes in fertilizer and crop prices, land ownership, and stage of farming career ... additional factors that should be considered for every field, every year ...



AGVISE Fertilizer Guideline Options in Tight Economic Times

In the current economic climate of high production costs for land, seed, fertilizer, chemical, fuel, and

you also need to make sure that you are applying enough P fertilizer to achieve high yields.

equipment, it can decrease yield in the short term. The importance of fertilizer has

While building soil test P may not be the best idea for next year, you also need to make sure that you are applying enough P fertilizer to achieve high yields.

fertility specialists and ag economists alike. Both over- and under-fertilization reduce grower profits. While

choose which fertilizer guideline is best suited to your equipment and management.

building soil test P may not be the best idea for next year,

The late harvest may force some people to take soil samples in the winter or next spring. AGVISE sells in-cab hydraulic

Improving Reliability, Value, and Confidence in Soil Testing

Step 4: Right Data Management & Use

To fully capitalize on the benefits of soil testing, data from soil testing must be transformed into useful information

A sound 4R Nutrient Stewardship strategy relies on soil testing every field/mgmt zone ... every year ... to:



Photo: Amy Mangin

1. Predict fertilizer and/or manure requirements for the next crop, based on existing reserves in soil and current goals for the fertility program in each field or management zone
2. Diagnose “unusualities” ... e.g., areas of unusually good or poor crop growth
3. Evaluate/audit the current nutrient management plan for the most recent crop(s) ... e.g., excess N fertilization or more N mineralization than immobilization
4. Monitor for long-term upward or downward trends in soil fertility and soil health ... e.g., decreasing soil test P, increasing salinity, decreasing pH

“Drowning in data and starving for information,” is a quote from Weyburn farmer Norm Flaten that I have used often.

- Les Henry, Grainews August 2013

Improving Reliability, Value, and Confidence in Soil Testing

Step 4: Right Data Management & Use



- Ask the right questions at every stage in the soil & crop management cycle ... from “advance” planning ... to sampling, in-season monitoring, and post-harvest evaluation/audit
- Equipped with that information, collect, track, distill, and share data in a user-friendly and strategic manner ... to fit each individual farmer and their farms, fields, and management zones ... and to fit closely with their entire 4R Nutrient Stewardship “system”

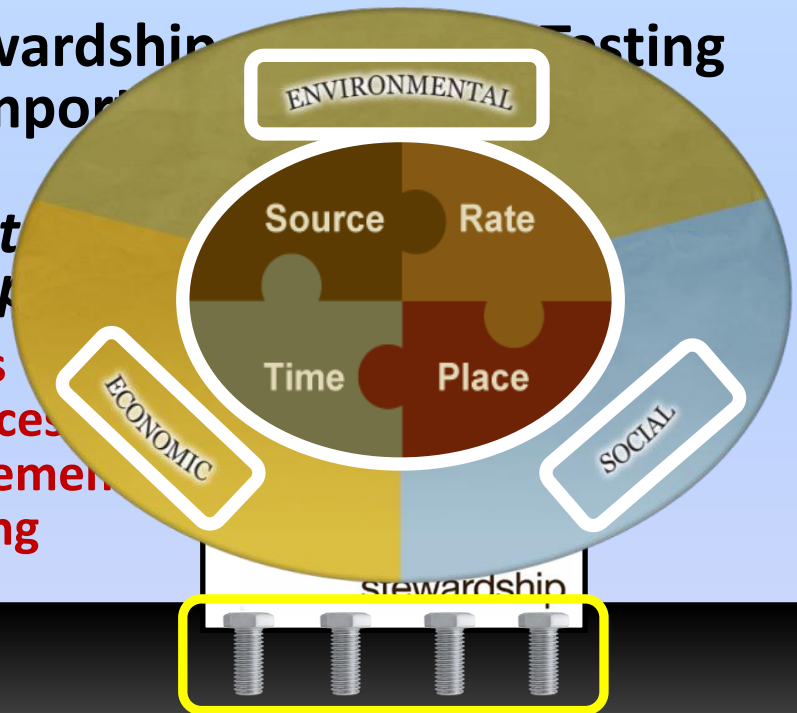
4R Nutrient Stewardship

More Important

Soil Testing

4R Nutrient Stewardship

- ✓ Right rates
- ✓ Right sources
- ✓ Right placement
- ✓ Right timing



4R Soil Testing ... every field, every year

- ✓ Right sampling
- ✓ Right analyses
- ✓ Right recommendations
- ✓ Right data management and use

My idea for a new, more efficient consulting group ...



INCITE

Soil & Crop Management Consultants

**We don't mince words or waste time
with lots of questions ...
we just tell you what's wrong with
your farm and how you should fix it**

**For reasons that I don't understand,
our business is struggling to find clients ...**

Summary: 4R Nutrient Stewardship & 4R Soil Testing More Important Than Ever

- methods for soil sampling, analyses, and recommendations should be matched with the soil, climate, and landscape characteristics for each region, field or management zone ... as well as the farmer's agronomic & economic goals and current/expected weather & market conditions



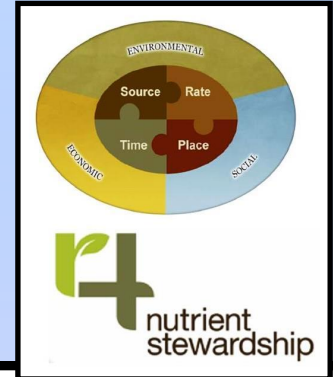
4R Soil Testing ... every field, every year

- ✓ Right sampling
- ✓ Right analyses
- ✓ Right recommendations
- ✓ Right data management & use

- use sound science & “real” intelligence to develop & implement a locally-relevant soil testing system that fits the local field, farm, and farmer for the upcoming growing season ... to maximize benefits & minimize limitations

Summary: 4R Nutrient Stewardship & 4R Soil Testing More Important Than Ever

Thank you for your
attention ...
any questions?



4R Soil Testing ... every field, every year

- ✓ Right sampling
- ✓ Right analyses
- ✓ Right recommendations
- ✓ Right data management & use