Soil Health Principles

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SOIL HEALTH

NDSU | EXTENSION

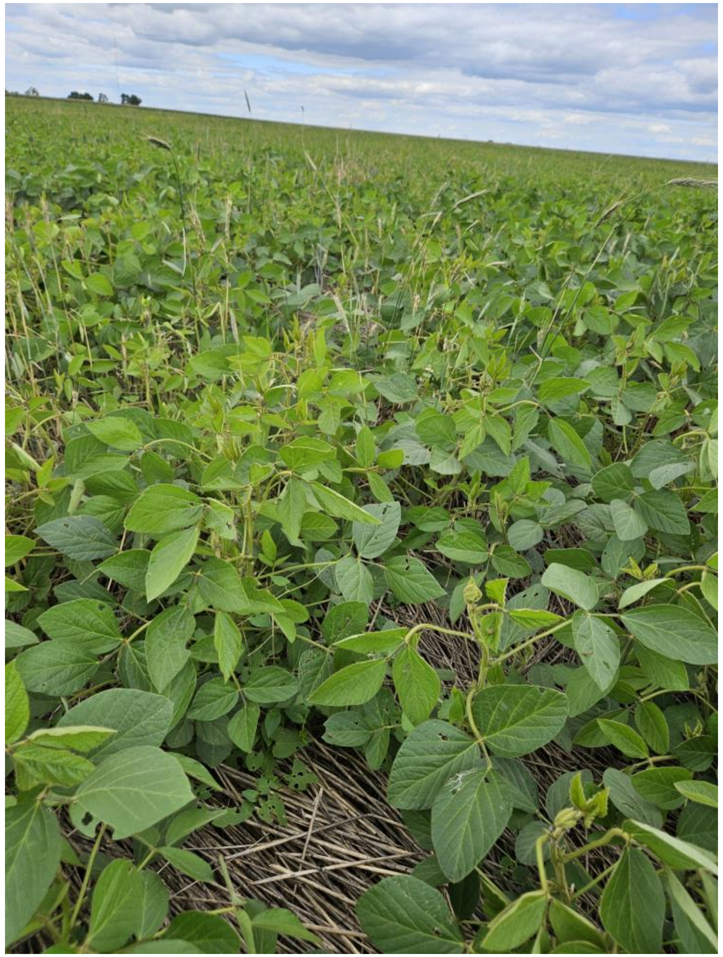
Teams Goals: Extension Soil Health

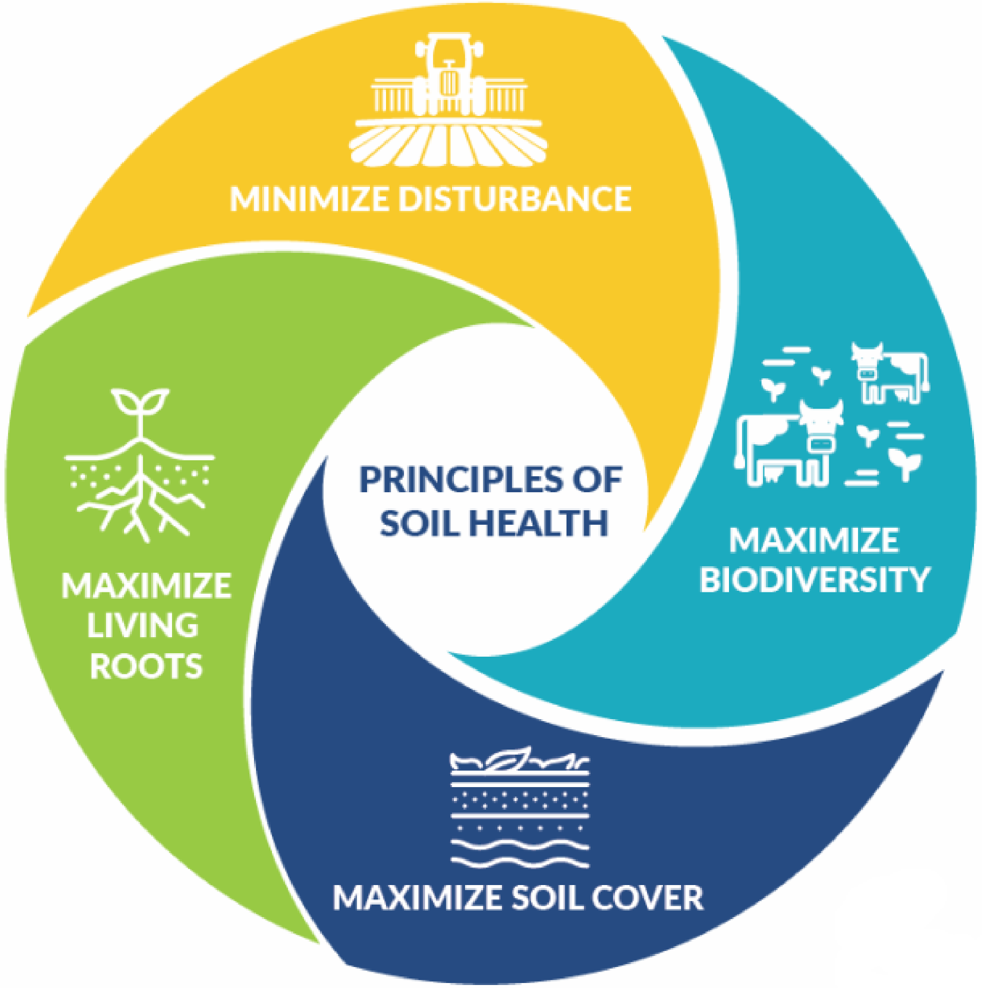
- Team: Chandler Gruener, Naeem Kalwar, and Carlos Pires
- Help assist extension agents, producers, and other stakeholders with key soil health issues
- Increase awareness about the social and economic impacts and costs of the soil health issues currently and in the future
- Provide practical and easy to adopt solutions for these soil health issues

New Demonstration Trailer

- Soil Health Express
- Houses hands-on demonstrations
- Will travel around the state for use at different events

Soil Health Principles

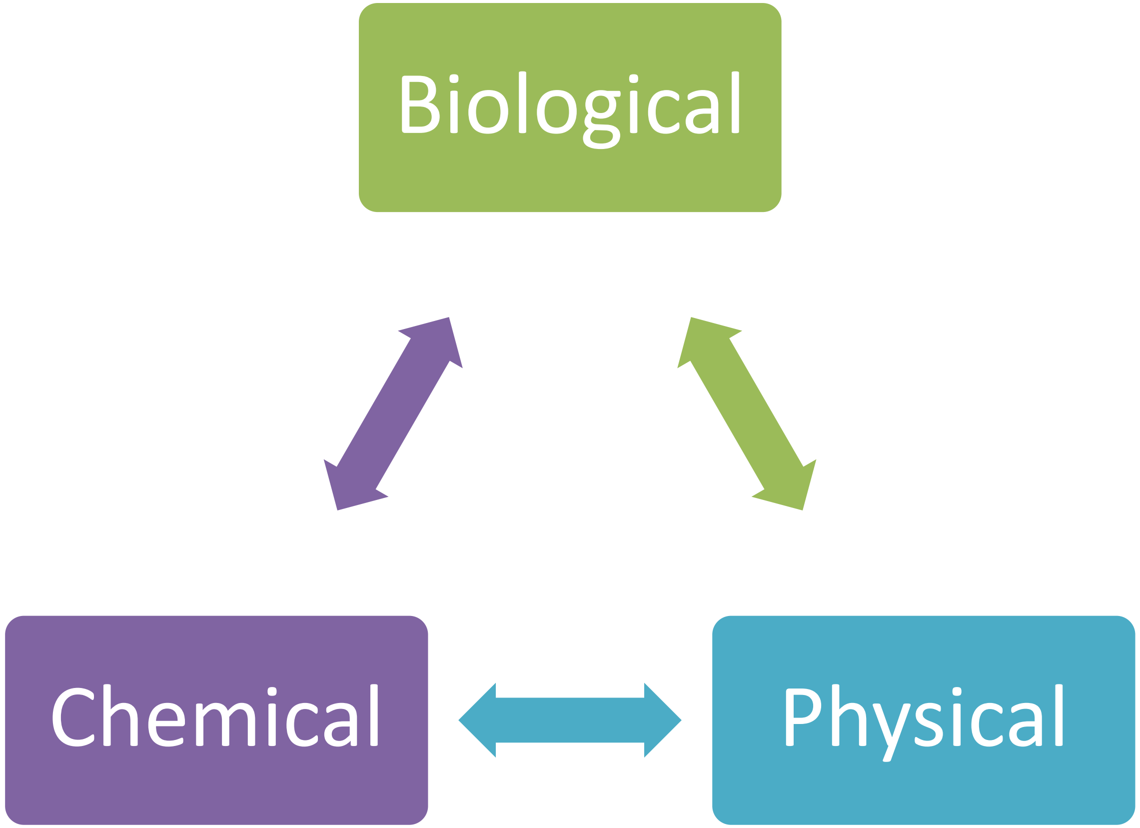




https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soils/soil-health

Soil Health Parameter Indicators

- Items measured to see if changes are happening



Soil Health Indicators: Chemical

- Chemical: N, P, K, and others in nutrient cycling sense
- Reactive carbon (POxC), soil EC, and pH
- Lack of plant growth or ability to keep ground covered from salinity, sodicity, and pH issues

Soil pH Affects Plant Development

- Lowers nutrient availability P, Ca, Mg
- Increases Al, Mn
  - This impacts roots and plant development
- Lower water and nutrient uptake

Photo credit: Carlos Pires

What Can Add to Soil Acidity?

- Nitrogen fertilizers have H
- Breakdown of these fertilizers provides the N desired but frees up H
- 1.8 to 5.4 lbs CaCO3 to lbs of N, depending on the source
- Urea, anhydrous ammonia, and ammonium nitrate 1.8
- Monoammonium and diammonium phosphate 5.4 and 3.6, respectively

Havlin et al., 2005; Chien et al., 2010

What Kinds of Acidity?

- Active: what can be measured by pH meter
- Reserve: could be on OM or held up on soil like clay when soil moisture conditions change will become more available

KEY SOIL HEALTH ISSUES IN NORTH DAKOTA

- Loss of topsoil and steady decline of soil organic matter.
- Contamination of water resources.
- Soil salinity.
- High levels of exchangeable sodium (Na^{+}) versus exchangeable calcium (Ca^{2+}), called sodicity.
- High levels of exchangeable magnesium (Mg^{2+}) versus exchangeable calcium (Ca^{2+}). No specific name yet.
- Lack of plant and microbial diversity.

LOSS OF TOPSOIL
(March 25, 2024 at 1:08 p.m.)

TOPSOIL BLOWING
(April 25, 2024)

Step One Erosion Prevention

- Severely eroded hilltops (May 14, 2021)

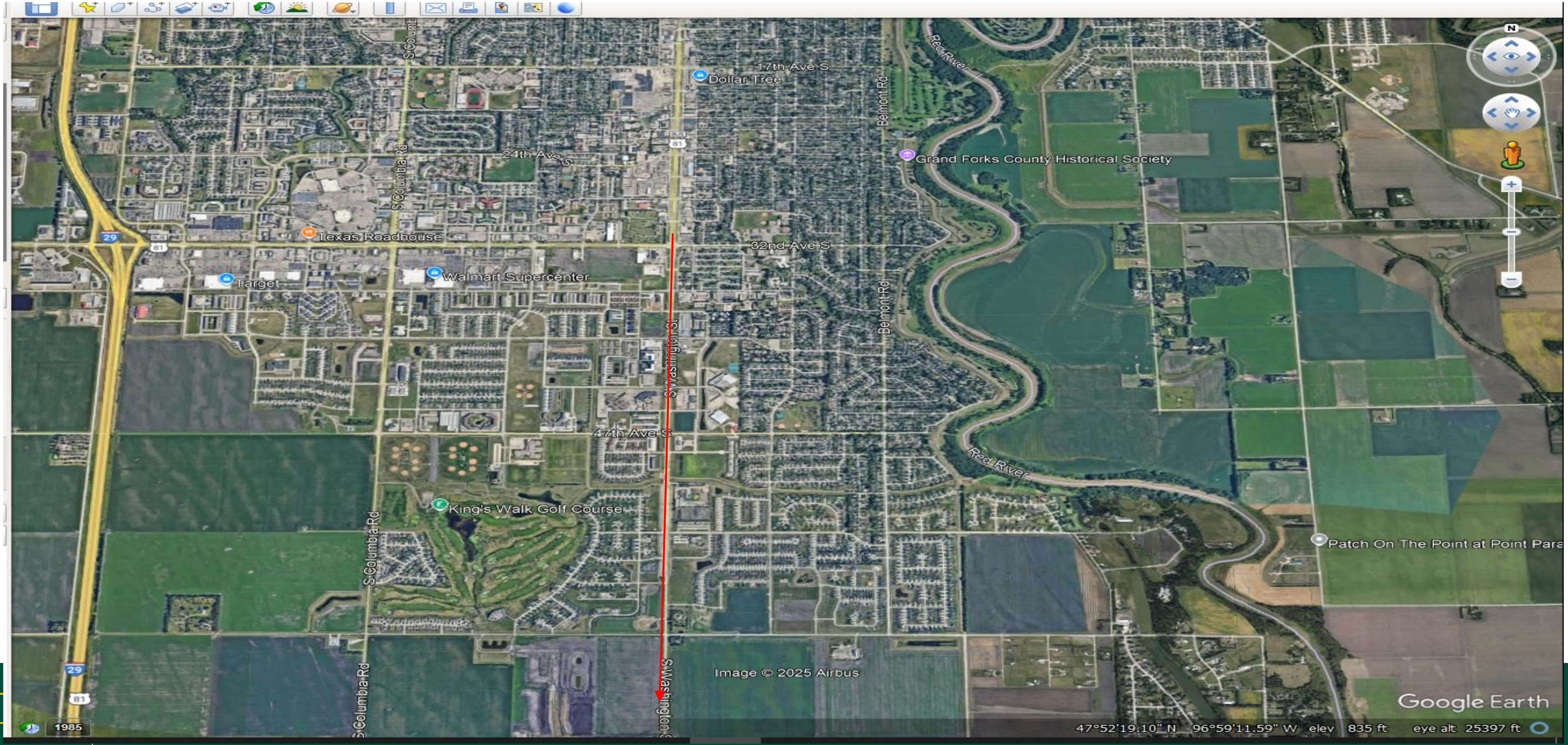
EXAMPLE OF A OCCASIONAL SEVERE WATER EROSION EVENT

May 25, 2023. Near Icelandic State Park.

A BURIED A-HORIZON WITH 5.9% ORGANIC MATTER versus AN AREA AVERAGE of 2.0-2.5%

CONTAMINATION OF WATER RESOURCES (December 19, 2021. Hwy-2 west of Grand Forks)

GRAND FORKS CITY SPRAWL TOWARDS ONE OF ITS BEST SOILS



SOIL SALINITY IS CAUSED BY EXCESS LEVELS OF WATER-SOLUBLE SALTS

Visible White Salt Crust at the Soil Surface along a Headland

Salts Directly affect plants by competing for water

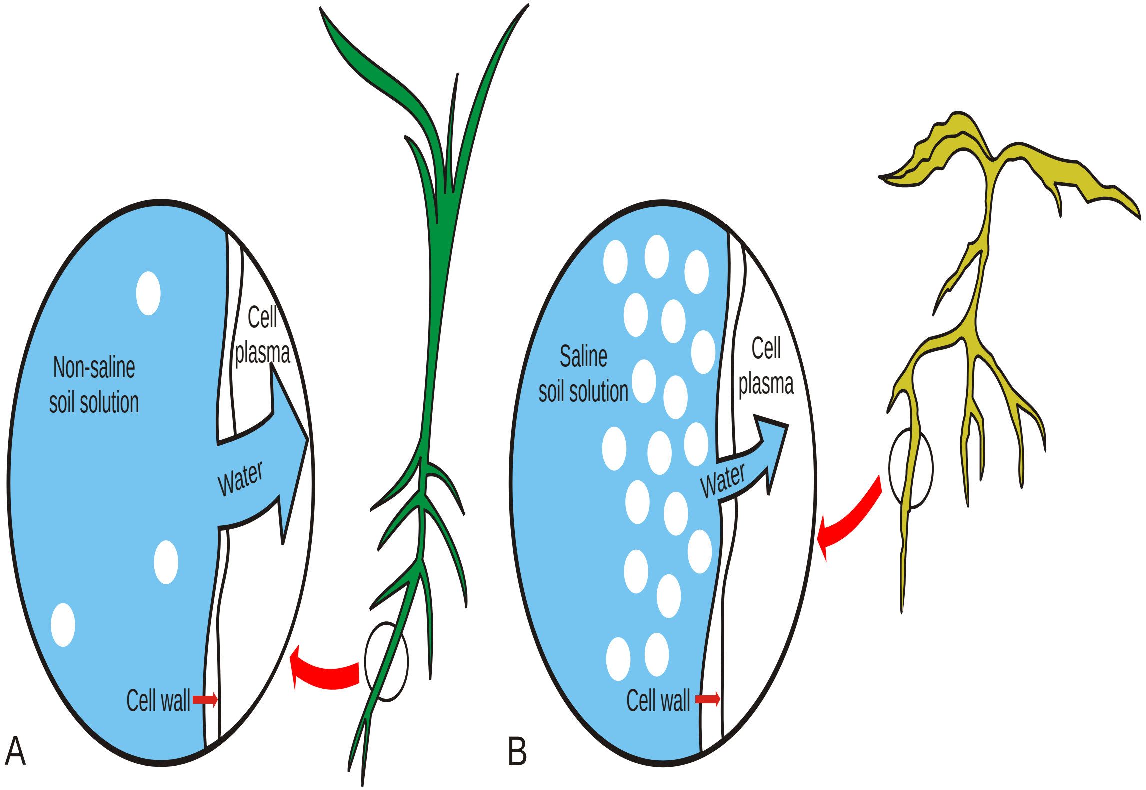
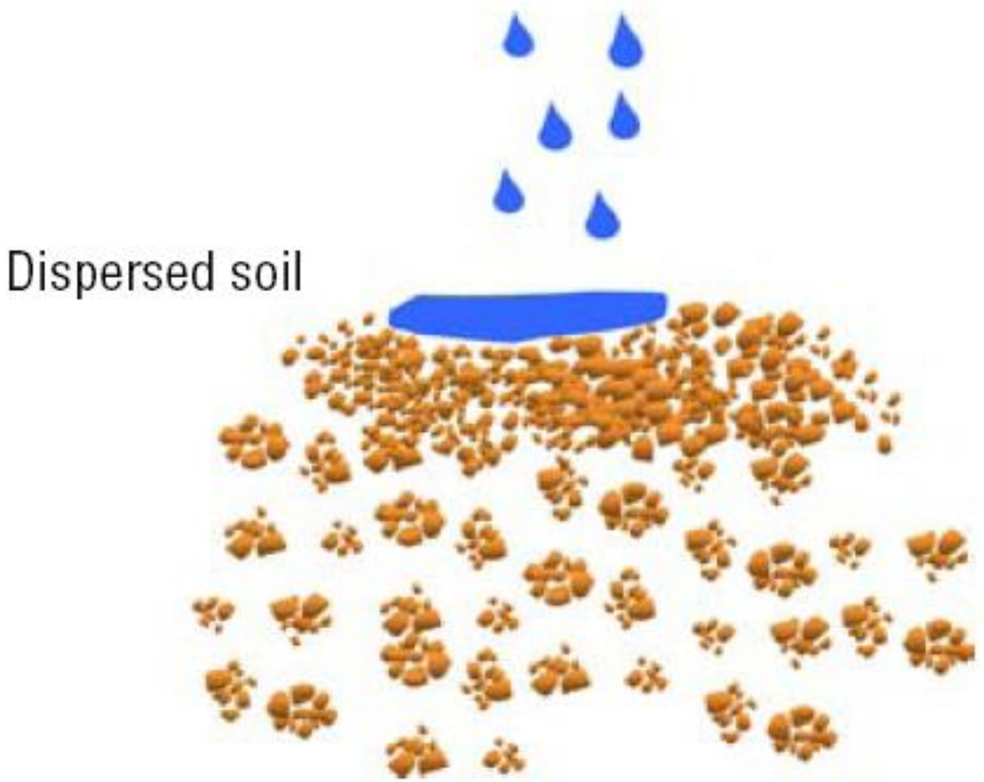


Table Salt = Na^{+} + Cl^{-}

SOIL SODICITY IS CAUSED BY EXCESS EXCHANGEABLE SODIUM ATTRACTED TO CLAY AND HUMUS

A Saline Soil with Visible Salt Crust and Not So Visible Sodicity Symptoms

Soil Sodicity Directly Affects Soils by Breaking Down Aggregates



Soil Sodicity = Na^+ + $Clay^-$ or Na^+ + $Humus^-$

WHY SHOULD WE CARE ABOUT THESE ISSUES?

April 29, 2021. Cavalier County.

AVERAGE DIRECT PLANTING COSTS

(NDSU PROJECTED 2024 CROP BUDGETS for South Valley, North Dakota)

- Includes cost of seed, fertilizer and fuel (1/3 of the total fuel and lubrication cost).
- Spring Wheat: $147.52/acre.
- Sunflower (Oil): $130.46/acre.
- Corn (grain): $270.63/acre.
- Soybeans: $78.38/acre.
- Barley (malting): $120.02/acre.

GOOD SOIL WATER INFILTRATION IS KEY TO A SUCCESSFUL TILE-DRAINAGE SYSTEM

DIFFERENT SOIL WATER INFILTRATION RATES ON A TILED-FIELD

An Area with Low Sodicity Levels

An Area with High Sodicity Levels

September 13, 2019.

NDSU EXTENSION REPORTED SALINITY AND SODICITY BACK IN 1960s

Extension Bulletin No. 2

CAVALIER COUNTY EXTENSION OFFICE
COURTHOUSE
LANGDON, NORTH DAKOTA 58249

Salt Affected Problem Soils In North Dakota

Their Properties and Management

by Gordon A. Johnsgard

COOPERATIVE EXTENSION SERVICE
NORTH DAKOTA STATE UNIVERSITY

RECENT CITATIONS

- Nearly 5.8 million acres are affected by soil salinity in North Dakota (Brennan, J., and M. Ulmer. 2010. Salinity in the northern Great Plains. Natural Resources Conservation Service. Bismarck, N.D.).
  - That will be about 15% of total North Dakota land (39 million acres), which will be about 6 million acres.
  - Most common salts in North Dakota are SO_4 of Ca, Mg and Na (Keller et al., 1984).
  - Soils of northern Red River Valley are high in Cl of Ca, Mg and Na (Seelig, 2000).
  - Usually coarser soils are high in NaCO3 (Seelig, 2000).
- Over 4.7 million acres are affected by sodicity in Northern Great Plains (J. Brennan, personal communication, NRCS North Dakota, 2008).

EFFECTS OF HIGH MAGNESIUM LEVELS VERSUS CALCIUM

- Smectite (2:1) are shrinking and expanding type of clays with one aluminum hydroxide sheet sandwiched between two silicon oxide sheets.
- Illite (2:1) and Koalinite (1:1) are non shrinking and expanding types of clays in which clay sheets are very tightly held with no water between layers called “interlayer space”.
- In smectite clays, layers are further apart allowing water and bigger diameter ions such as magnesium and sodium to move into the interlayer spaces. That can lead to excess swelling of soils, shrinking of pores and slow water infiltration.

CITATIONS FOR HIGH MAGNESIUM LEVELS COMPARED TO CALCIUM

- Alkali Soils. Magnesium Clay “Solonetz” by J. H. Ellis and O. G. Caldwell, 1935. Soils Division, University of Manitoba, Canada.
  - Mentions soils having dispersion without appreciable amounts of sodium and high magnesium levels in the bed of glacial Lake Agassiz.
- Characteristics of Some Morphological Solonetz Soils of Minnesota by C. O. Rost, 1936. Journal of the American Society of Agronomy.
  - Mentions Red River Valley Soils in Minnesota and Manitoba having high magnesium levels combined with dispersion.

A SALINE SOIL WITH VISIBLE SYMPTOMS
IS THERE AN ISSUE OF SODICITY AS WELL?

SOIL ANALYSIS RESULTS OF THE SAME SITE

Soil Depth	EC (dS/m)	SAR	pH	SO4 (ppm)	Cl (ppm)	CCE (ppm)
0-12”	5.85	24.54	8.01	9255.38	363.19	27000
12-24”	3.13	12.94	7.81	4715.69	168.85	125000
24-36”	2.73	9.55	7.83	3599.11	138.22	168000
36-48”	2.87	8.08	7.83	3204.26	116.99	167000

SOIL SAMPLING IS THE BEST WAY TO ASSESS SALINITY, SODICITY AND HIGH MAGNESIUM ISSUES

ASSESSING AND MANAGING SOIL SALINITY, SODICITY AND HIGH MAGNESIUM LEVELS

- Sample and analyze the problematic areas for salinity (Electrical Conductivity or EC), sodicity (Sodium Adsorption Ratio or SAR), pH, Ca, Mg, Na, Cl, SO4, CO3 and HCO3 by using "**Saturated Paste Extract Method**".
  - Create zones based on the severity of the issues, cropping history and landscape.
  - Take separate 3 to 4-deep deep soil samples in 12" increments from each zone.
  - Get each depth analyzed separately.
- Also, analyze the 0-12" depth for Cation Exchange Capacity (CEC) by using "**sodium saturation and ammonium extraction method**".
- Label each sample clearly.
- Clearly communicate to the Soil Testing Lab for tests and methods.

TWO DIFFERENT UNPRODUCTIVE SITES FEW MILES APART

A Saline Site with High Magnesium Levels

CRYSTAL, ND 58222 CRYSTAL, ND 58222

Field ID =	L-1
Co-op/Contr. ID =	
Township =	LODEMA
County =	PEMBINA
Section =	
Sample ID =	0-12
Quarter =	SW
Date Received =	8/ 3/17
Date Reported =	8/ 9/17
AGVISE Lab No =	41,795
AGVISE Ref No =	19,765,145

Cation Exchange Capacity (meq/100 g)	39.9
Cation Exc. Cap. by Na Sat. (meq/100 g)	16.1
% Organic Matter (LOI)	2.7
% Carbonates (Pressure Method)	3.6
pH (Water)	8.4
pH (sat.paste)	8.2
Nitrate Nitrogen (ppm)	27
Olsen Phosphorus (ppm)	26
Soluble Salts--1:1 (mmhos/cm)	2.89
Saturated Paste Data	
SAR	2.89
Calcium Meq/L	25.27
Magnesium Meq/L	74.14
Sodium Meq/L	20.36
Cond. of Sat. Paste Extract (mmhos/cm)	6.84
Sulfate Sulfur (ppm)	60+
Zinc-DTPA (ppm)	1.45
Iron-DTPA (ppm)	7.4
Copper-DTPA (ppm)	0.29
Manganese-DTPA (ppm)	2.1
Chloride (ppm)	86
Boron-Extractable (ppm)	2.30

A Saline and Sodic Site

CRYSTAL, ND 58222 CRYSTAL, ND 58222

Field ID =	T-1
Co-op/Contr. ID =	
Township =	THINGVALLA
County =	PEM
Section =	
Sample ID =	0-12
Quarter =	
Date Received =	8/ 3/17
Date Reported =	8/ 9/17
AGVISE Lab No =	41,791
AGVISE Ref No =	19,765,149

Cation Exchange Capacity (meq/100 g)	53.7
Cation Exc. Cap. by Na Sat. (meq/100 g)	30.6
% Organic Matter (LOI)	3.2
% Carbonates (Pressure Method)	3.6
pH (Water)	8.2
pH (sat.paste)	8.0
Nitrate Nitrogen (ppm)	12.0
Olsen Phosphorus (ppm)	16
Soluble Salts--1:1 (mmhos/cm)	4.00
Saturated Paste Data	
SAR	10.63
Calcium Meq/L	21.83
Magnesium Meq/L	19.81
Sodium Meq/L	48.52
Cond. of Sat. Paste Extract (mmhos/cm)	6.09
Sulfate Sulfur (ppm)	60+
Zinc-DTPA (ppm)	0.92
Iron-DTPA (ppm)	12.5
Copper-DTPA (ppm)	0.70
Manganese-DTPA (ppm)	3.1
Chloride (ppm)	187
Boron-Extractable (ppm)	2.92

EXAMPLE OF A SOIL WITHOUT SALINITY, SODICITY AND HIGH MAGNESIUM ISSUES

SOIL TEST REPORT

SOIL TESTING LAB NDSU DEPT 7680 P.O. BOX 6050 FARGO, ND 58108-6050
Phone: (701) 231-8942

RESEARCH SAMPLES

To: LANGDON RESEARCH EXTENSION CENTER NAEEM KALWAR
9280 107TH AVE NE

LANGDON ND 58249

Copy To:

County: Cavalier

Date Sampled: 4/17/2012

Date Received: 4/18/2012

Date Reported: 6/1/2012

Sample Notes: 2012

SOIL TEST RESULTS

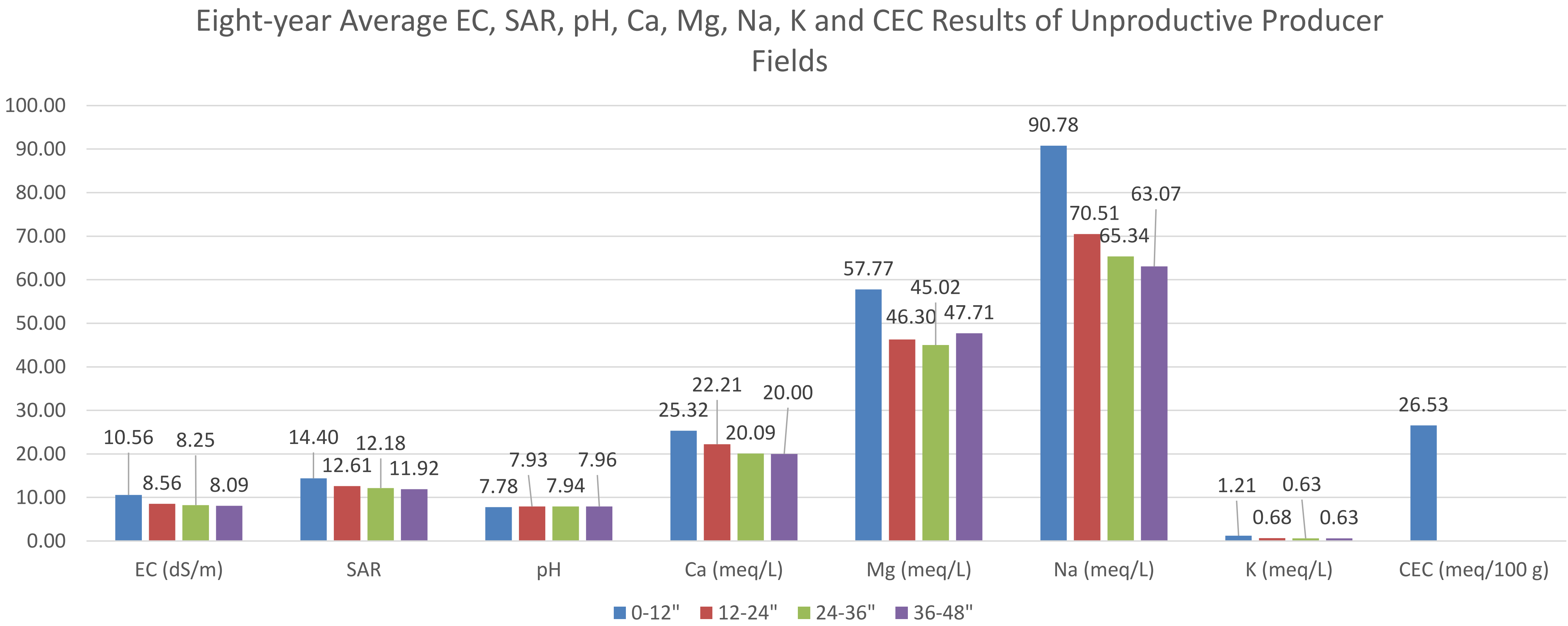
Lab No.	Sample I.D.#	Depth (inches)	NO_3-N lb/A	P ppm	K ppm	pH	EC mmhos /cm	OM %	S lb/A	Zn ppm	Fe ppm	Mn ppm	Cu ppm	Cl lb/A	NH_4-N ppm	SAR	Ca ppm	Mg ppm	Na ppm	CEC Meq /100g	CCE %
13562	NOK 1/2	0 - 6	42	9	340	6.5	0.37	3.9	8	0.80	42.6	31.6	1.00	2.5			1600	560	66	14.0	0.0
13563	NOK 1/2	6 - 24	141	2	190	8.0	0.61	1.8	27	0.30	18.1	6.7	1.00	26.3			2620	940	170	20.3	6.8
13564	NOK 3/4	0 - 6	27	6	305	7.4	0.44	3.9	8	0.50	22.4	16.1	0.50	6.9			2220	740	86	16.9	0.3
13565	NOK 3/4	6 - 24	39	2	175	8.2	0.61	1.8	36	0.30	14.3	4.2	0.70	8.3			3040	1120	208	23.9	8.0

NOK ½: Ca 80 & 131(meq/L), Mg 46.67 & 78.33 (meq/L) and Na 2.87 & 7.39 (meq/L) for 0-6” and 6-24” depths.
NOK ¾: Ca 111 & 152 (meq/L), Mg 61.67 & 93.33 (meq/L) and Na 3.74 & 9.04 (meq/L) for 0-6” and 6-24” depths.

ANNUAL RECORD OF SOIL SAMPLING PRODUCER FIELDS

Year	Sampling Method	No. of Producers	No. of Samples	Counties
2012	Hand-held auger	7	14	4
2013	Hand-held auger	3	19	4
2014	Hand-held auger	3	9	4
2015	Hand-held auger	5	9	5
2016	Hand-held auger	6	13	6
2017	Hand-held auger	14	28	8
2018	Pickup mounted probe	39	131	9
2019	Pickup mounted probe	25	54	7
2020	Pickup mounted probe	20	52	14
2021	Pickup mounted probe	38	88	11
2022	Pickup mounted probe	13	33	8
2023	Pickup mounted probe	14	37	9
Total	Hand-held auger and pickup mounted probe	**187**	**487**	**14**

2016-2023 AVERAGES FOR PRODUCER FIELDS



Averages of 436 soil samples.

NDSU EXTENSION

SUGGESTED SOIL AMENDMENT RATES (per acre-foot)

Soil Depth	SAR (initial)	SAR (final)	ESP	CEC (meq/100 g)	Ex. Na (meq/100 g)	100% Gyp. (t./ac.)	94% Gyp. (t./ac.)	100% E-sul. (t./ac.)	Beetlime (t./ac.)	CaCl Salt (t./ac.)
0-12”	14.40	11.40	13.47	26.53	3.57	6.07	6.46	1.15	12.15	5.22

WALSH COUNTY SALINE AND SODIC SITE NEAR ADAMS

Site	Depth (inches)	pH	EC (dS/m)	SAR
Before Beetlime Application (fall-2014; November 5)				
Vesta-23	0-12”	6.95	10.20	13.90
	12-24”	6.92	10.75	15.87
	24-36”	6.81	11.18	19.45
	36-48”	6.81	10.09	16.24
After Beetlime Application (fall-2015; September 25)				
Vesta-23	0-12”	7.49	1.94	7.73
	12-24”	7.78	4.26	15.60
	24-36”	7.99	6.57	21.45
	36-48”	8.07	6.70	19.89
After Beetlime Application (fall-2016; September end)				
Vesta-23	0-12”	6.00	1.10	1.80
	12-24”	7.80	1.30	3.50
	24-36”	8.80	2.20	8.50
	36-48”	9.00	2.60	14.80
After Beetlime Application (fall-2017; October 13)				
Vesta-23	0-12”	5.70	0.61	1.42
	12-24”	6.70	0.95	2.42
	24-36”	7.50	0.74	4.90
	36-48”	7.90	0.71	7.07
After Beetlime Application (fall-2018; June 8)				
Vesta-23	0-12”	6.60	1.11	0.73
	12-24”	7.90	0.48	1.51
	24-36”	8.20	0.46	5.52
	36-48”	8.30	0.64	10.36

SITE NEAR MOTT

	Site-One			Site-Two		
Soil Depth (in.)	EC (dS/m)	SAR	pH	EC (dS/m)	SAR	pH
	Fall-2012			Fall-2012		
0-12”	4.26	10.00	6.3	4.11	9.83	7.6
12-24”	4.00	4.74	7.9	4.02	10.20	7.9
24-36”	1.94	1.82	6.7	3.82	10.90	8.3
	EC (dS/m)	SAR	pH	EC (dS/m)	SAR	pH
	Fall-2013 (after 98% pure gypsum application)			Fall-2013 (no gypsum application was applied)		
0-12”	4.59	5.53	6.6	4.30	13.20	7.6
12-24”	4.56	4.05	7.8	4.32	13.90	7.9
24-36”	3.70	3.39	7.5	5.07	15.50	8.0

LANGDON REC LONG-TERM GROUNDWATER MANAGEMENT PROJECT

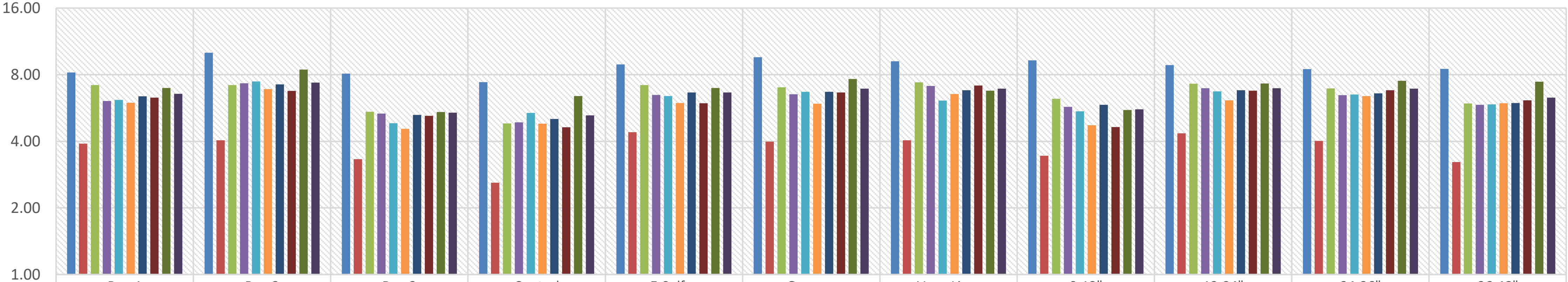
Lift station pumping the tile-drained water out in a ditch on May 15, 2020

Trial background and objectives

- Site was tiled despite existing sodicity to simulate producer fields that were tiled without knowing the negative effects of sodicity on soil water infiltration in order to learn about:
- Does existing soil sodicity negatively affects tile drainage performance?
- Will tiling lower soil salinity under wet and dry weather conditions?
- Does the tile-drained water increase salinity and sodicity levels of the surface water resources?

ANNUAL FLUCTUATIONS IN SOIL EC

Annual Soil EC (dS/m) Means for Replications, Treatments and Soil Depths

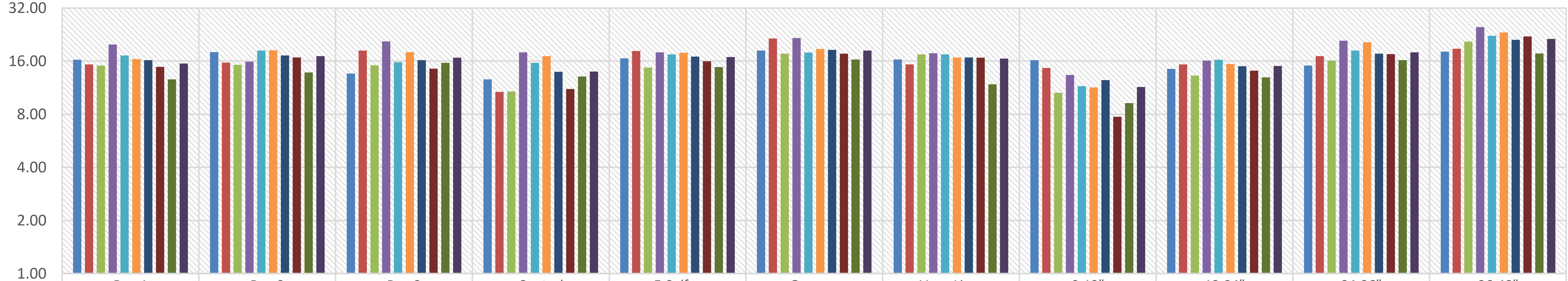


	Rep 1	Rep 2	Rep 3	Control	E-Sulfur	Gypsum	VersaLime	0-12"	12-24"	24-36"	36-48"
2014	8.19	10.05	8.08	7.40	8.91	9.58	9.20	9.29	8.84	8.48	8.49
2016	3.90	4.04	3.32	2.60	4.40	3.99	4.04	3.44	4.35	4.01	3.22
2017	7.18	7.18	5.44	4.82	7.18	7.02	7.38	6.23	7.28	6.93	5.93
2018	6.09	7.31	5.34	4.87	6.48	6.53	7.12	5.73	6.95	6.46	5.84
2019	6.15	7.46	4.83	5.37	6.40	6.69	6.11	5.47	6.72	6.51	5.88
2020	5.97	6.89	4.55	4.80	5.95	5.91	6.54	4.73	6.12	6.41	5.94
2021	6.39	7.23	5.26	5.05	6.64	6.69	6.80	5.85	6.80	6.58	5.95
2022	6.30	6.75	5.22	4.63	5.94	6.64	7.14	4.64	6.78	6.81	6.13
2023	6.97	8.44	5.42	6.41	6.96	7.65	6.77	5.54	7.30	7.50	7.44
2024	6.55	7.37	5.39	5.24	6.65	6.92	6.92	5.58	6.95	6.91	6.30

2014 2016 2017 2018 2019 2020 2021 2022 2023 2024

ANNUAL FLUCTUATIONS IN SOIL SAR

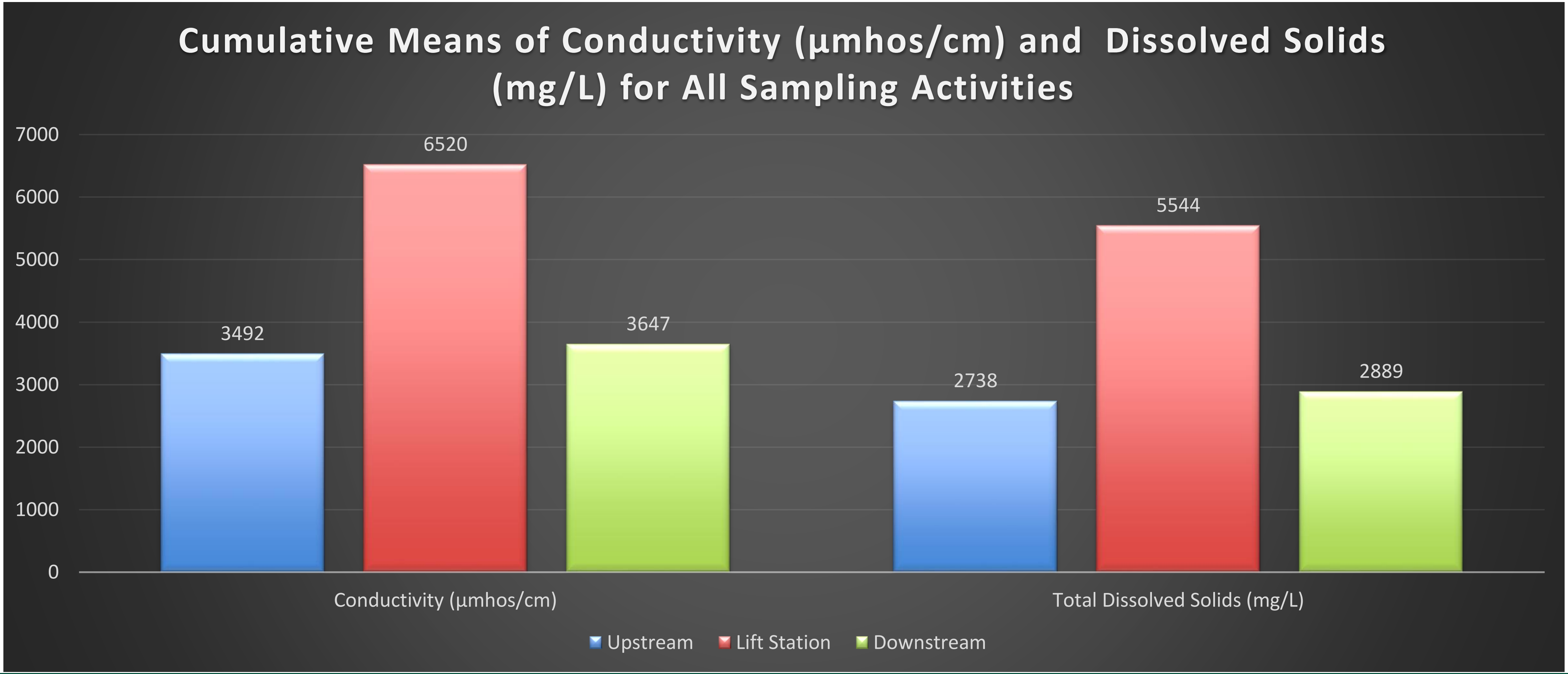
Annual Soil SAR Means for Replications, Treatments and Soil Depths



	Rep 1	Rep 2	Rep 3	Control	E-Sulfur	Gypsum	VersaLime	0-12"	12-24"	24-36"	36-48"
2014	16.30	18.02	13.58	12.59	16.59	18.37	16.34	16.20	14.47	15.10	18.11
2016	15.31	15.68	18.38	10.72	18.27	21.52	15.32	14.63	15.34	17.06	18.79
2017	15.10	15.22	15.15	10.77	14.72	17.65	17.49	10.59	13.25	16.12	20.67
2018	19.86	15.89	20.73	17.95	17.96	21.64	17.75	13.35	16.09	20.88	24.99
2019	17.21	18.39	15.78	15.63	17.50	17.87	17.49	11.56	16.28	18.38	22.28
2020	16.43	18.44	17.99	17.09	17.84	18.76	16.78	11.36	15.41	20.45	23.26
2021	16.21	17.25	16.21	13.94	16.98	18.55	16.77	12.50	14.97	17.63	21.14
2022	14.83	16.79	14.49	11.13	15.98	17.65	16.73	7.74	14.13	17.53	22.10
2023	12.62	13.78	15.64	13.09	14.79	16.36	11.81	9.24	12.94	16.21	17.66
2024	15.52	17.06	16.73	13.96	16.88	18.38	16.53	11.42	15.02	17.92	21.39

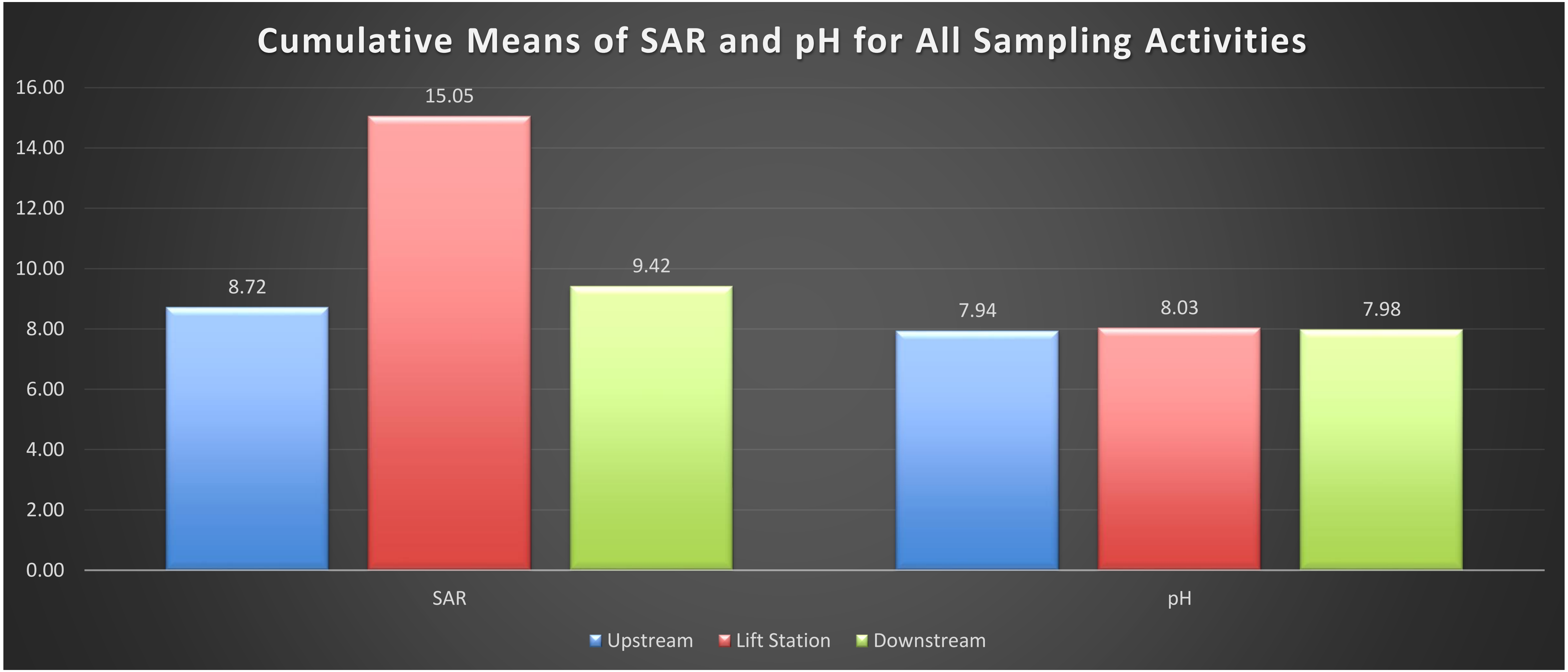
2014 2016 2017 2018 2019 2020 2021 2022 2023 2024

DOES TILE-DRAINED WATER AFFECT CONDUCTIVITY AND DISSOLVED SOLIDS OF SURFACE WATERS?



2015 to 2024.

DOES TILE-DRAINED WATER AFFECT SODICITY AND pH SOLIDS OF SURFACE WATERS?



2015 to 2024.

STEPS TO REMEDIATE SODICITY

- If sodicity is established:
- **Apply** Ca^{2+} **supplements to replace** Na^{+} **(only incase of sodicity) in addition to following the salinity remediation practices.**

STEPS TO REMEDIATE HIGH MAGNESIUM LEVELS

- If high magnesium levels compared to calcium are confirmed:
- **Apply** Ca^{2+} **supplements to replace** Mg^{2+} **in addition to following the salinity remediation practices.**

STEPS TO REMEDIATE SALINITY

- Lower groundwater depths by improving drainage; surface or subsurface.
- Reduce evaporation by establishing a suitable vegetative cover based on site-specific salt (EC) levels.
  - Capillary water moves from wet to dry areas. Increased evaporation will result in soil water wicking up from deeper depths to the surface.
- Will also need timely rains in decent quantities to force the excessive salts into the deeper depths.
  - A smaller gap between evapotranspiration and rain means more leaching and less wicking up.
  - A bigger gap between these two means less leaching and more wicking up.

Barley and Oats Growth in Replication 1 (low to moderate salinity-sodicity) on July 17, 2020

AAC Synergy Barley

ND Heart Oats

Barley and Oats Growth in Replication 2 (moderate to high salinity-sodicity) on July 17, 2020

AAC Synergy Barley

ND Heart Oats

Barley and Oats Growth in Replication 3 (very high salinity-sodicity) on July 17, 2020

AAC Synergy Barley

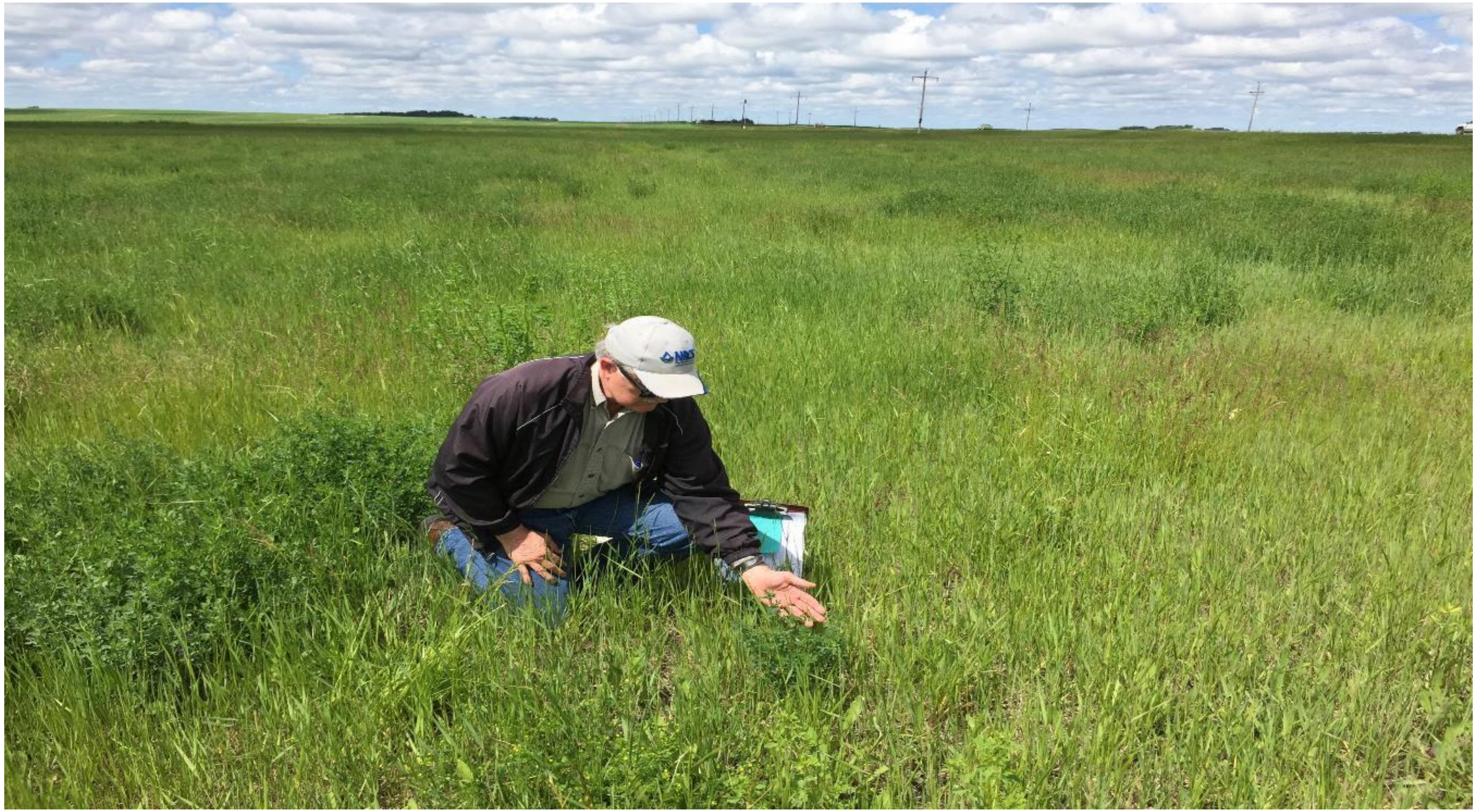
ND Heart Oats

A BARREN AND UNPRODUCTIVE LANGDON REC GWMP SITE

SAME SITE WITH GOOD VEGETATION

A UNPRODUCTIVE PRODUCER SITE IN 2012

SAME SITE PLANTED WITH PERENNIAL SALT-TOLERANT GRASS MIX + ALFALFA IN 2017



KRAHN SITE SOIL RESULTS

		2012		2014		2017	
Soil Property	Soil Depth	No Alfalfa	Good Alfalfa	No Alfalfa	Good Alfalfa	No Alfalfa	Good Alfalfa
EC dS/m	0-6”	6.70	1.80	5.07	1.58	5.5	1.90
	6-24”	5.30	0.97	6.55	4.98	7.3	7.40
SAR	0-6”	5.65	0.84	6.80	1.49	5.50	1.47
	6-24”	3.00	0.61	7.58	5.16	7.99	6.19
pH	0-6”	7.4	7.4	7.41	7.00	7.6	7.6
	6-24”	7.6	7.4	7.75	7.39	7.6	7.4

PRODUCER FIELD HAY YIELDS

- A mix of salt-tolerant perennial grasses and alfalfa was planted in 2012 on three-acres where nothing grew.
- Grasses took 1-2 years to establish.
- Alfalfa established after three years.
- In 2014, three 1200 pound bales were cut.
- 2015 yielded in 4 bales.
- In 2016, 5 bales were cut.
- 2017 and 2018 yielded 5 bales each despite drier weather.

SAME FIELD WITH SPRING-WHEAT ON AUGUST 31, 2020

PERENNIAL SALT-TOLERANT GRASSES + ALFALFA MIX (2015)

GRASS MIX + ALFALFA STRIP IN 2018

GRASS MIX + ALFALFA STRIP IN 2019

GRASS MIX + ALFALFA STRIP IN 2020

LANGDON REC PERENNIAL SALT-TOLERANT GRASS MIX (July 13, 2015)

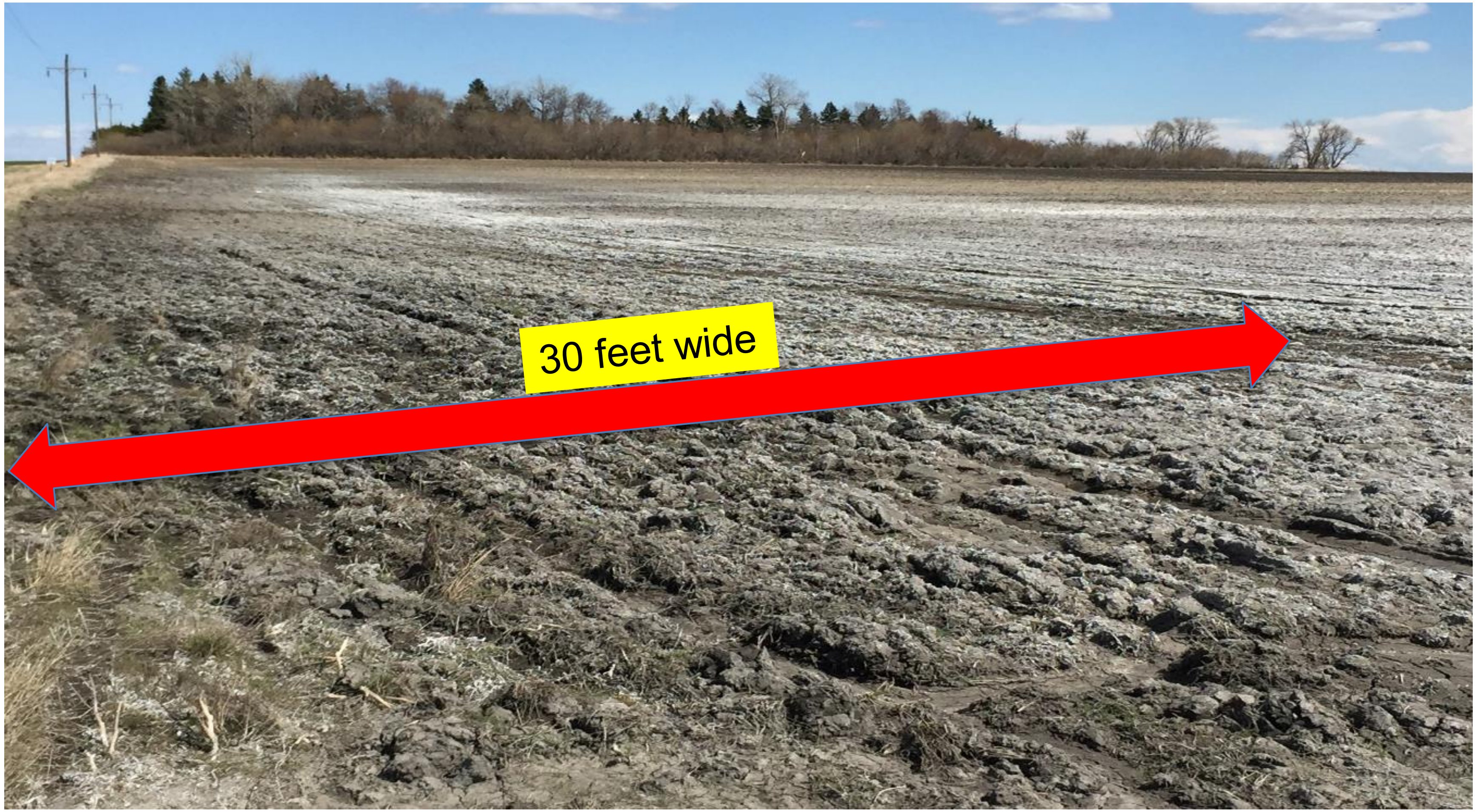
- In 2014, 15 acres were planted with the grass mix at the rate of 8 pounds per acre.
- In 2015, 15 acres yielded 30 hay bales, each weighing about 1500 pounds.
- 2016 was too wet to hay.
- It has been mowed since 2016.

INSTEAD OF LOSING MONEY WE CAN MAKE A PROFIT!

COST OF ESTABLISHING PERENNIAL SALT-TOLERANT GRASSES versus LOSING MONEY ON ANNUAL CROPS

Annual Crops		Perennial Salt-tolerant Grasses	
Crops	Expense	Year	Expense
Spring Wheat	$147.52	One (seed + planting)	$100.00 + $10.00 = $110.00
Sunflower (oil)	$130.46	Second (2-4D Amine at 0.5 – 1.0 pint/acre + Harmony Extra 0.5 ounce/acre mix)	$1.15 - $2.31 + $5.75 + $6.00 (spraying cost) = $12.90 - $14.06
Corn (grain)	$270.63	Third (three – four mowing)	$30.00 - $40.00
Soybean	$78.38	Fourth (three – four mowing)	$30.00 - $40.00
Barley (malting)	$120.02	Fifth (no mowing for reseeding)	$0.00
Total	**$747.01**	Total	**$182.90 - $204.06**

PERRENIAL SALT-TOLERANT BUFFER STRIPS CAN MINIMIZE THE SPREAD OF SALINE AREAS



SALT-TOLERANT PERRENIAL GRASS MIX WHEN ANNUAL OPTIONS DO NOT WORK

- Tall wheatgrass.
- Slender wheatgrass
- Western wheatgrass
- Green wheatgrass (AC Saltlander).
- Russian wildrye.
  - Seed rate for all grasses would be 7-8 lb./acre.
  - Seed cost could be $30-35/acre.
  - These grasses take about one-year to get established and two-years to suppress the weeds.

Soil Health Indicators: Biological

- Indicators of Biological
  - Diverse community of microorganisms in the soil
- Microbial biomass, microbial activity, soil respiration, soil enzymes, carbon (TOC or particulate), and mineralizable C and N, Macro organisms

Common Measurements of Biology

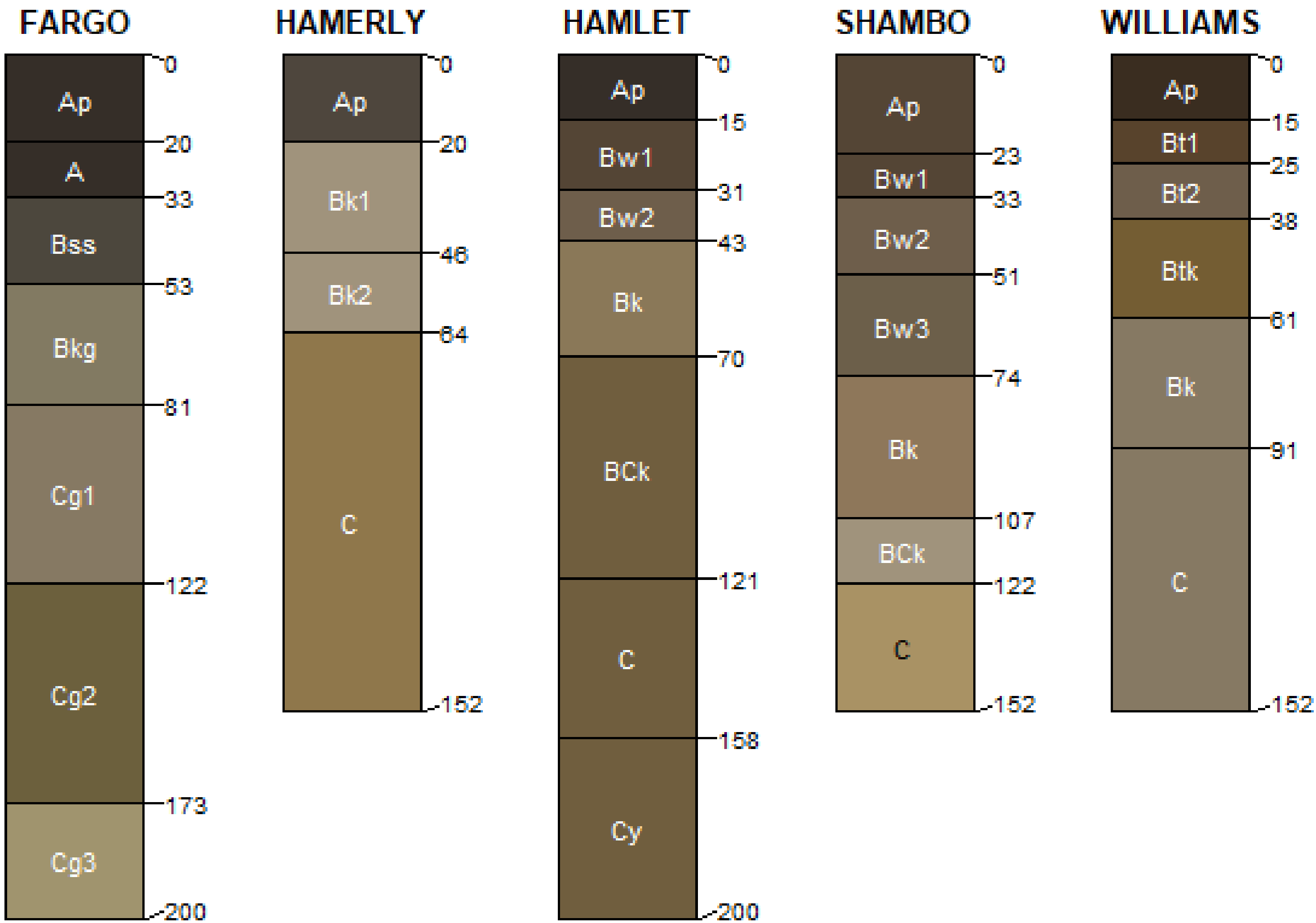
- Test in ND available at a commercial lab
- 24-hour CO_2 respiration (Solvita)
- 4-day CO_2 respiration
- Total organic carbon (dry combustion, pressure calcimeter)
- Bioavailable nitrogen (autoclave citrate extractable protein, ACE protein)

Soil Health Indicators: Physical

- Indicators of Physical
- Bulk density, water infiltration, water holding capacity, wilting point, soil penetration resistance, and aggregate stability

Soil Series

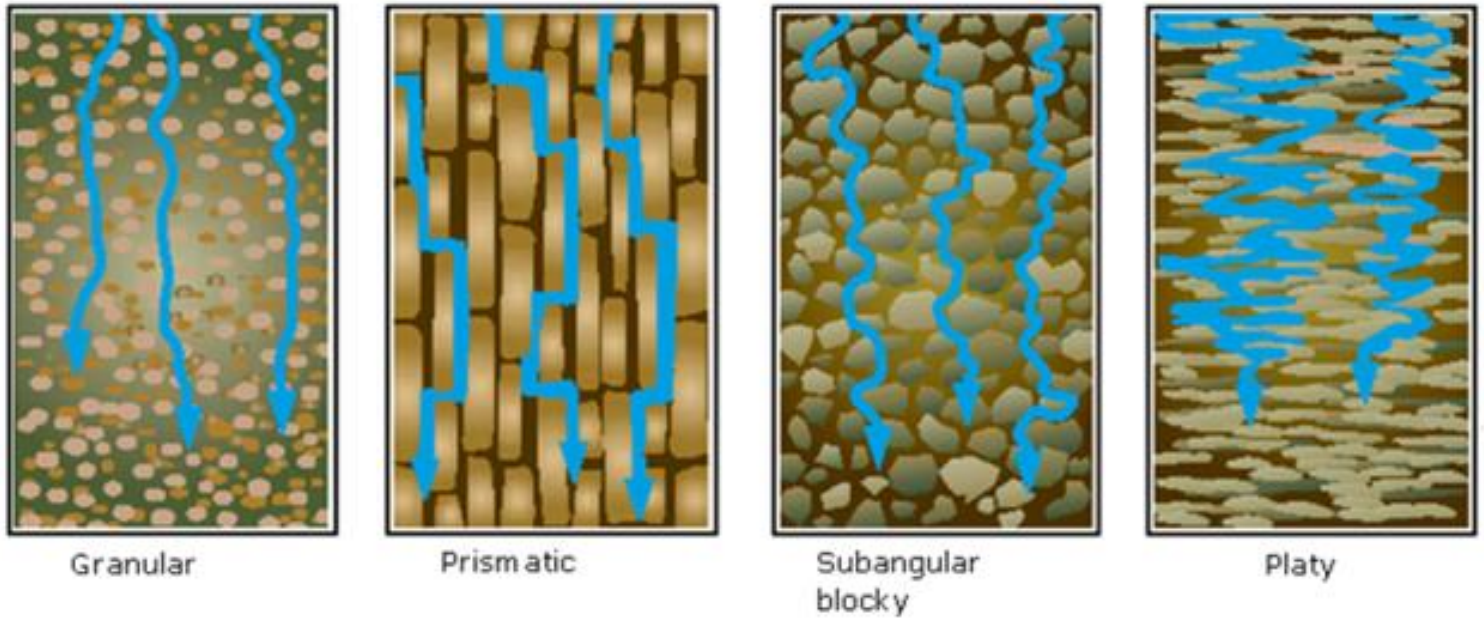
- Important for Context



Physical Connection to Structure

- Physical samples maybe hard to take but direct connection to structure

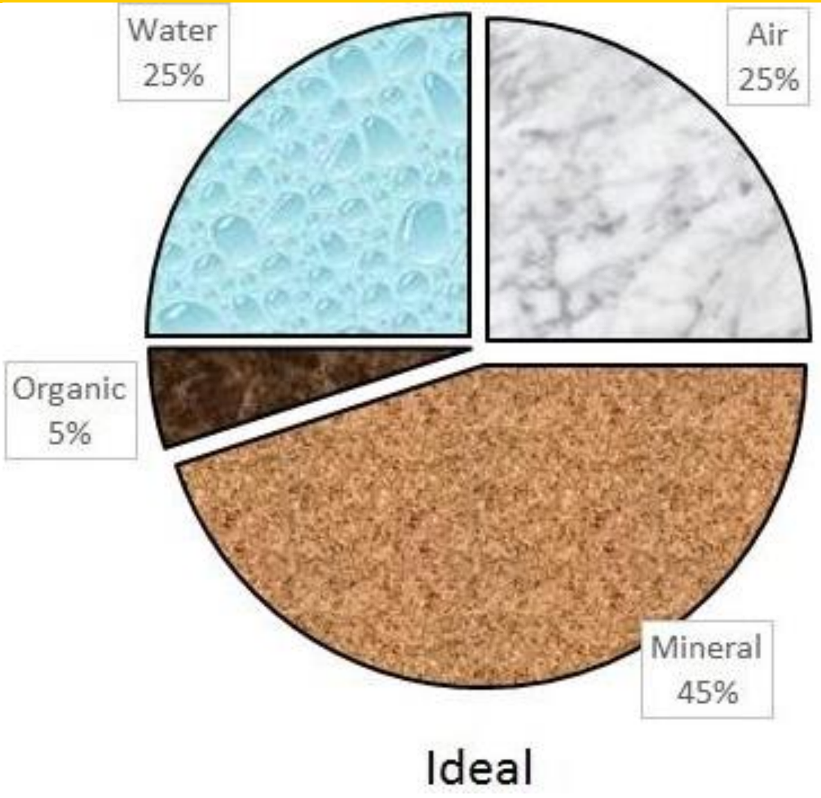
- Water movement into soil impacted by the structure
  - Chemical or physical effect



https://ucanr.edu/blogs/topics/index.cfm?tagname=silt

Soil Series to Soil Texture

- As different soil series has different layers and layers have different textures (mineral)
- Organic binding locations



https://content.ces.ncsu.edu/extension-gardener-handbook/1-soils-and-plant-nutrients

Organic Matter

- While changing soil texture not practical OM is something that can be
- OM can bind nutrients and water molecules
- Increasing OM changes the physical makeup of soil and physical function

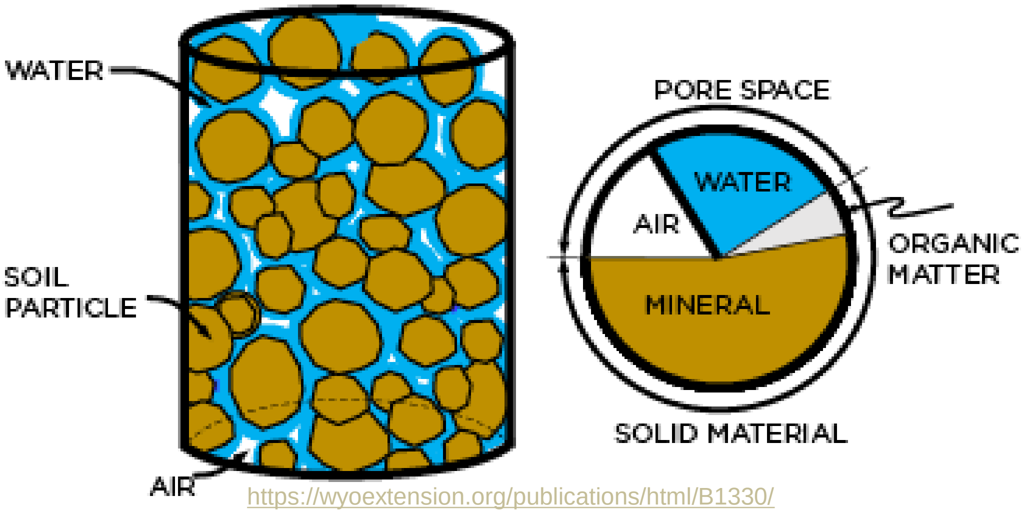
Aggregate Stability

- Water stable aggregates method for testing
- Aggregate is soil particles of sand, silt, and clay held together
- Biology and chemicals are important it doesn't stand alone
- No-till and or cover crop

Aggregate Breakdown and Erosion

Bulk Density

- Different textures has different BD
- Pore space like air and water impact this
- Plow pan



https://wyoextension.org/publications/html/B1330/

Soil Penetrometer

- Can tell you by depth or just 1 depth
- Different Styles
- Pros
  - Easy and lower cost
- Cons
  - Impacted by soil moisture

Soil Structure Impacted by Chemical

- Sodicity impacts structure
- Bulk density goes up
- Pore space goes down
- Salinity can cause crusting
  - Changes structure with a crust
  - Water movement into soil

Water Infiltration

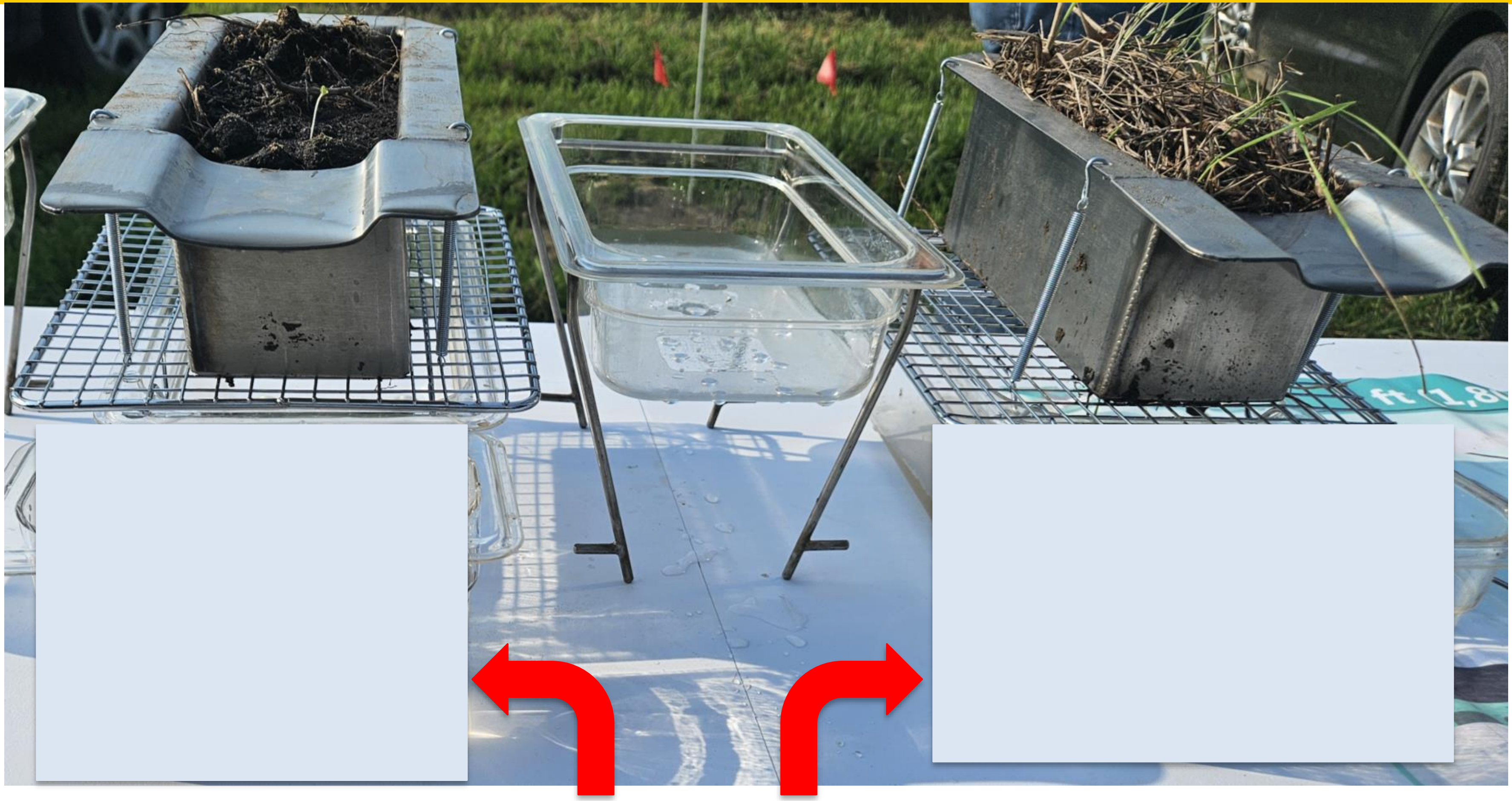
- Cover crops add root channels for water movement same with main crop roots
- Root limiting layers like plow pan can prevent

Water Infiltration Continued

Water Holding Capacity

- Can be increased by increasing pores in the soil
- OM can hold onto water for storage
- Improved structure
- Wilting point and field capacity

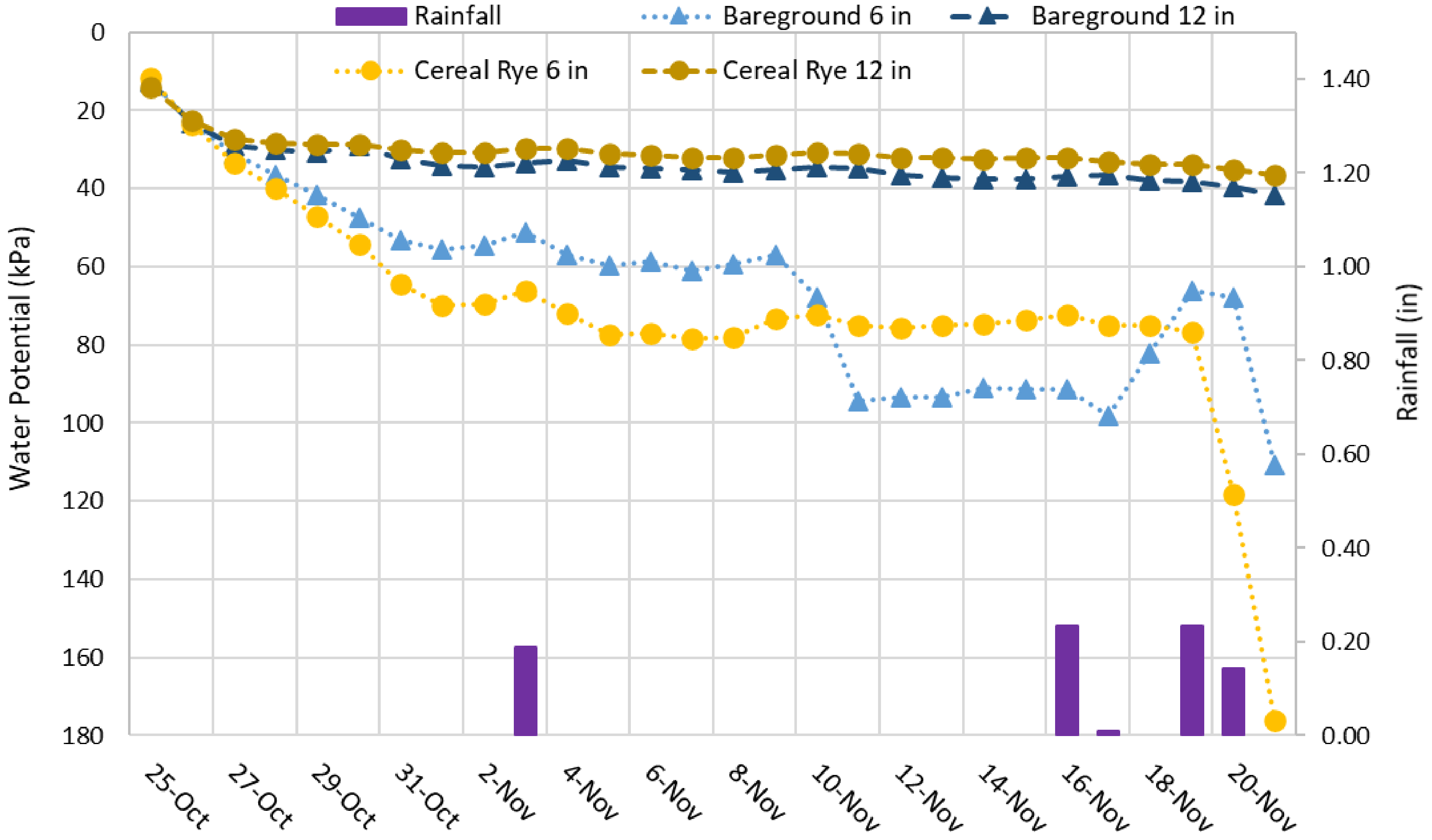
Cover Cropping on Erosion



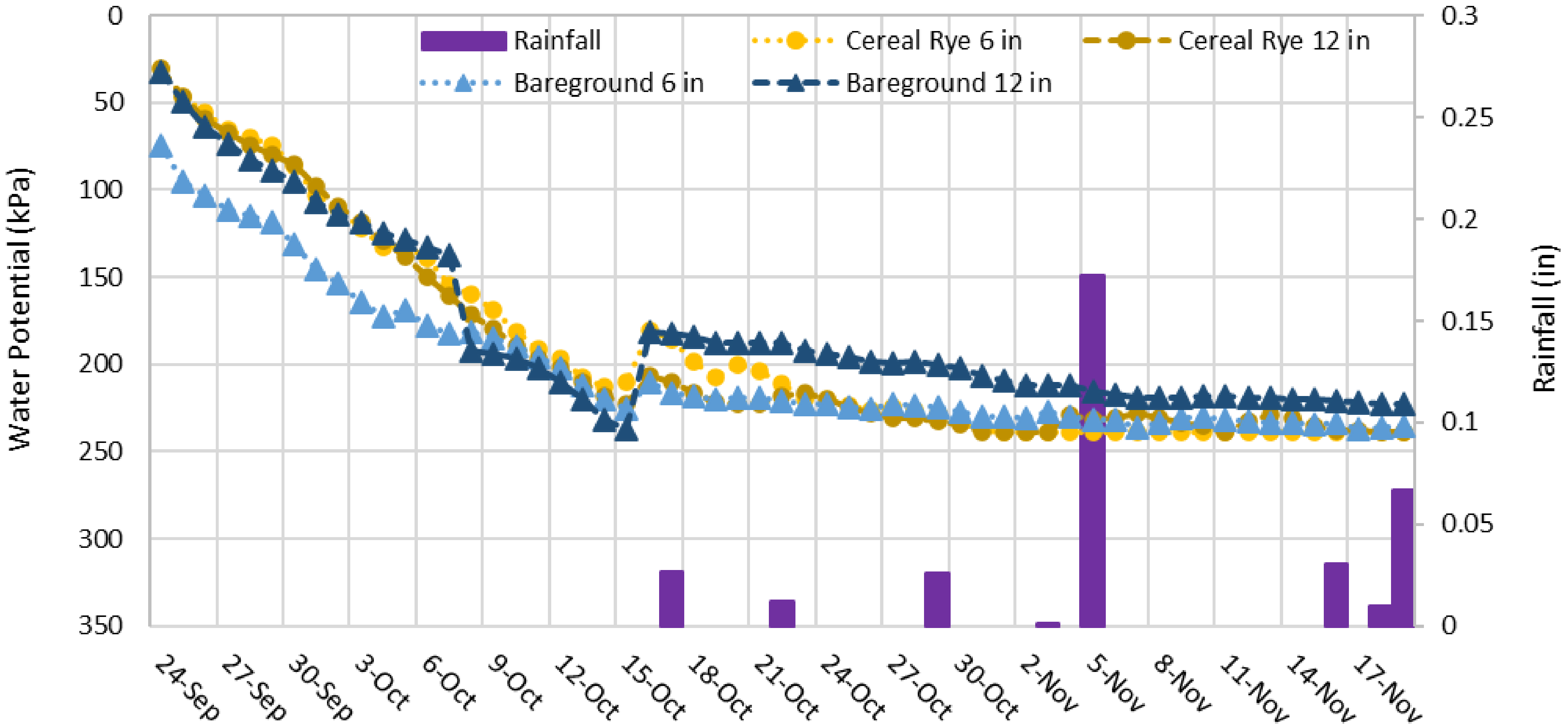
Left: No Cover Crop

Right: Cover Crop

Soil Moisture Minot Fall 2024



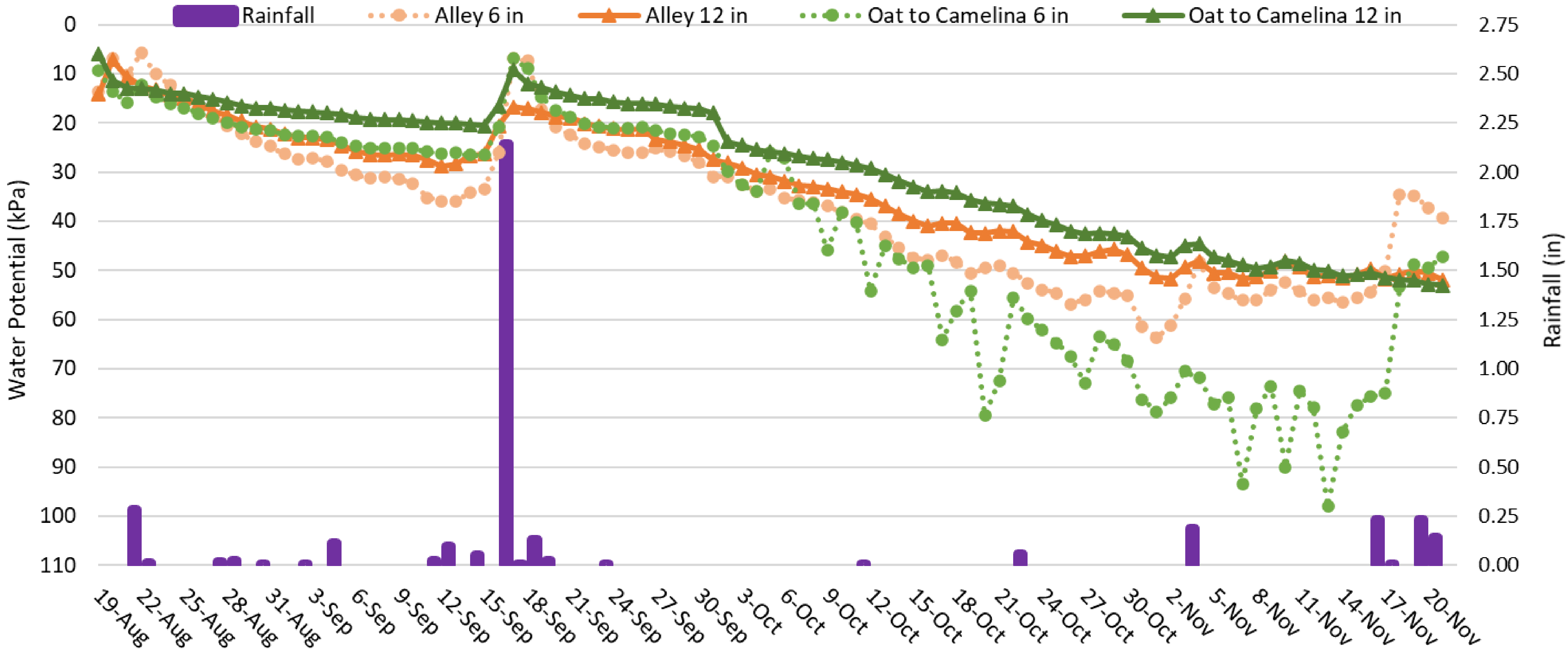
Soil Moisture Dickinson Fall 2024



Low Available Water

- In both sites being dry no cover crop grew above ground
- Also means seeds are sitting there waiting for spring

Minot Forage to Cover Crop Fall 2024



Strategies to Improve Structure

- Tillage with a purpose
  - Reduced tillage, strip tillage
  - Try not to leave uncovered for long
  - Limit when soil moisture high
- Cover crop
  - Helps keep the ground covered
  - Biological associations

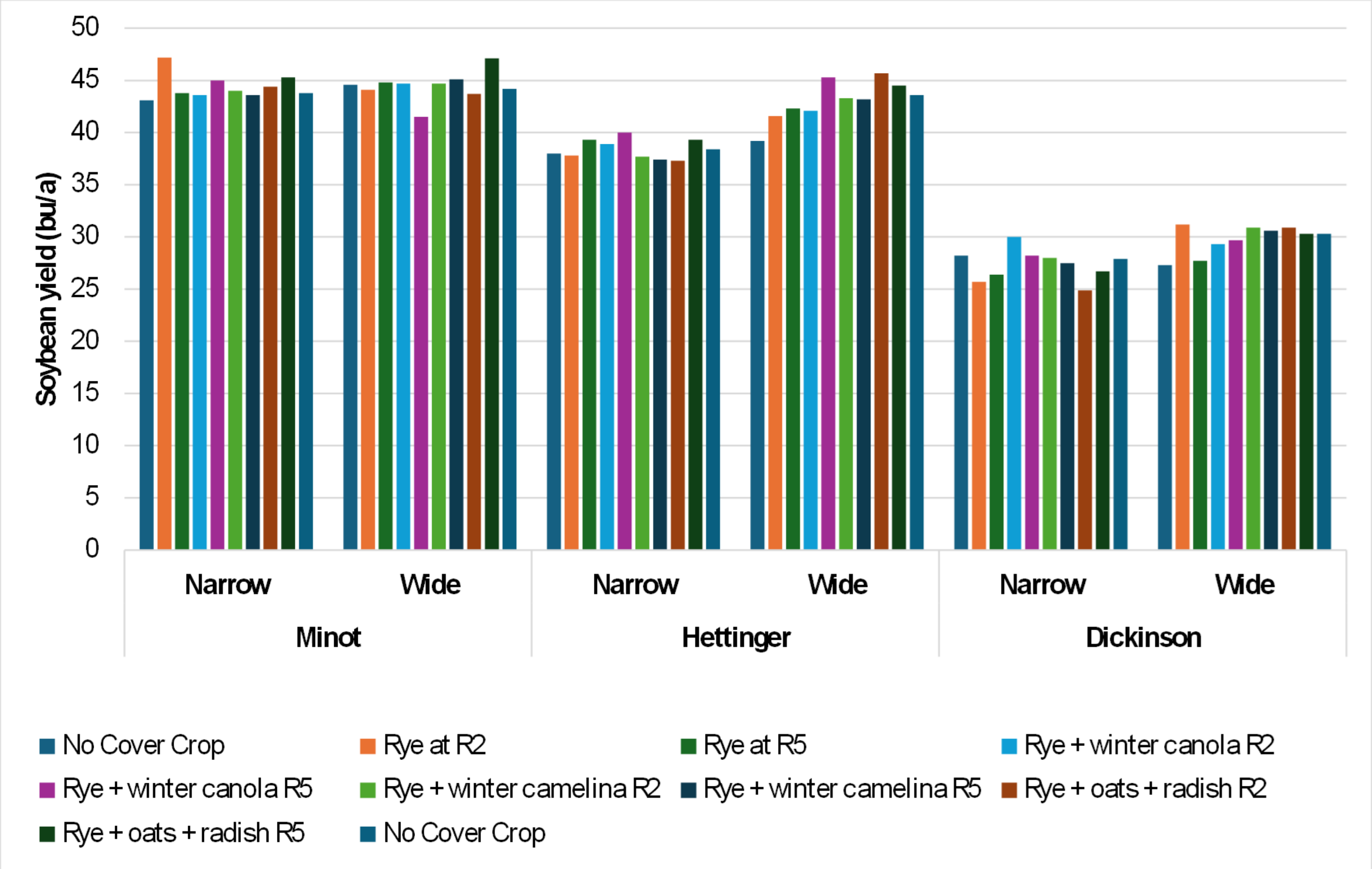
What Kind of Cover Crop Strategy

- Fall cover cropping
- Letting sp wheat grow up till winter kill before cash crop next year
- Intercropping or broadcasting
- Summer or full season cover crop for a forage

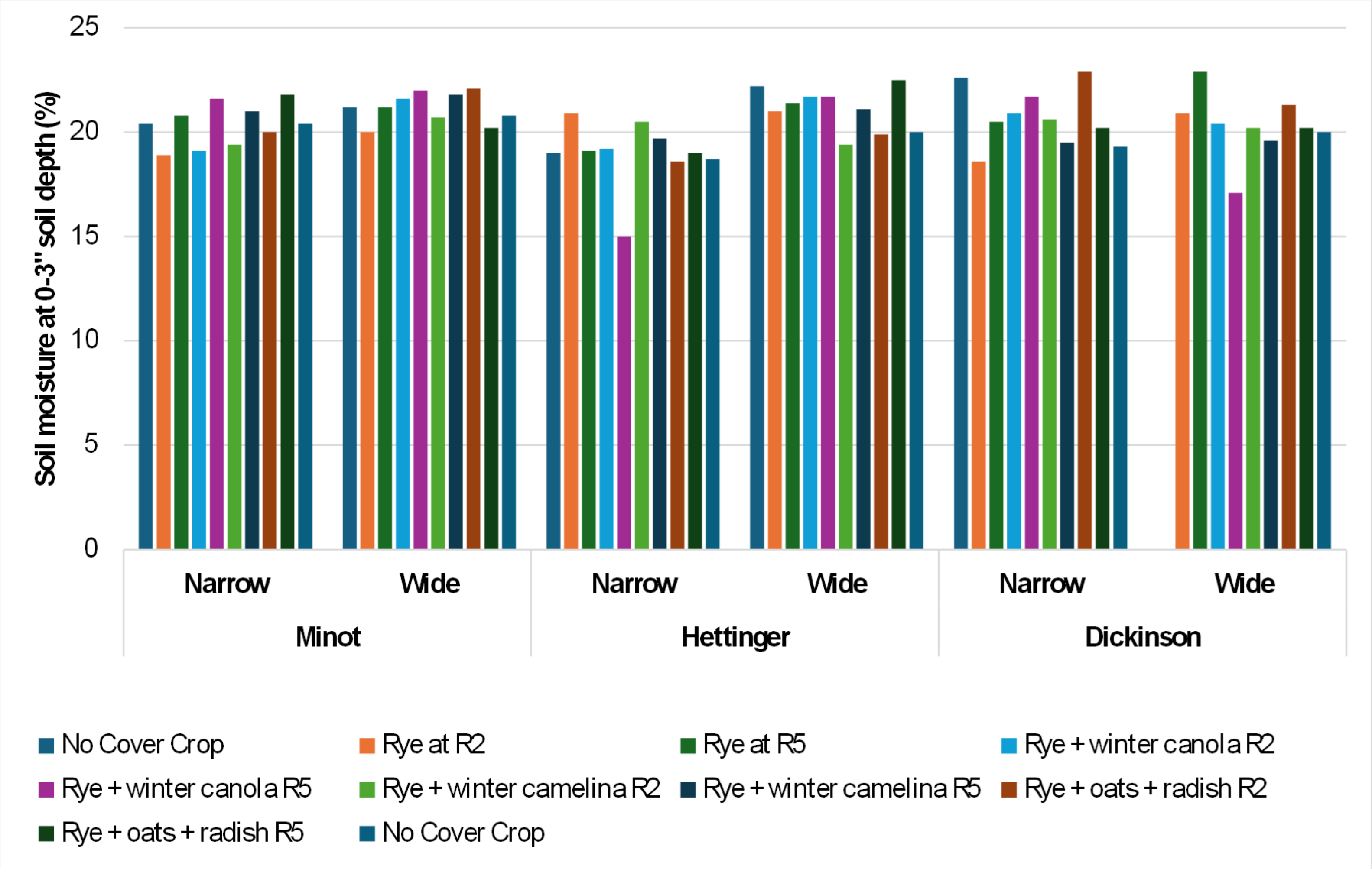
Broad Casting Cover Crops

- This can be done with intent on small broad-cast applicators mounted to a sprayer when doing other applications
- Rye, Oats, Radish
  - All small seeds that can be placed on surface and grow with timely rains

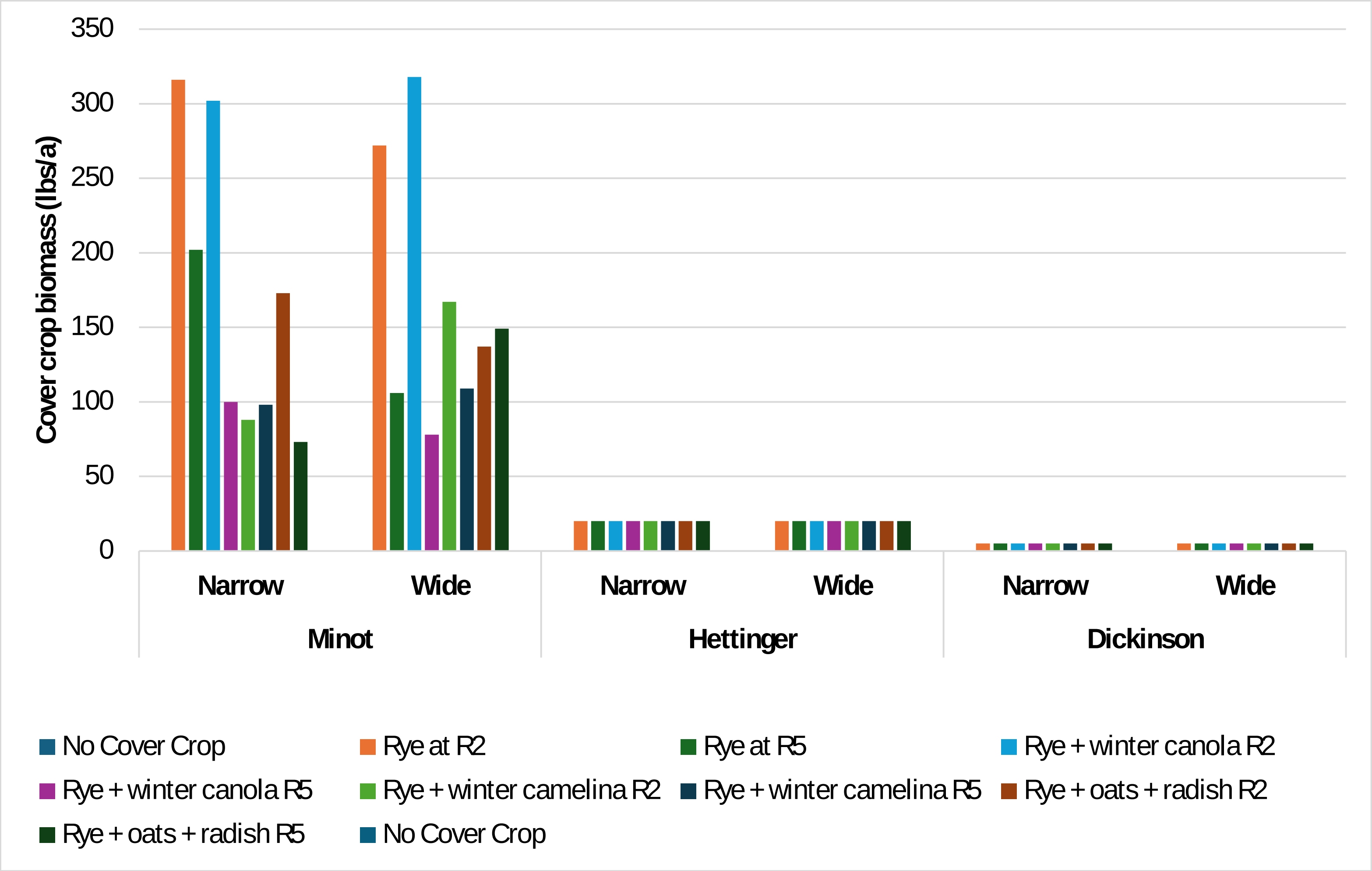
Minot 2023 Soybean Cover Crop Dr. Bortolon



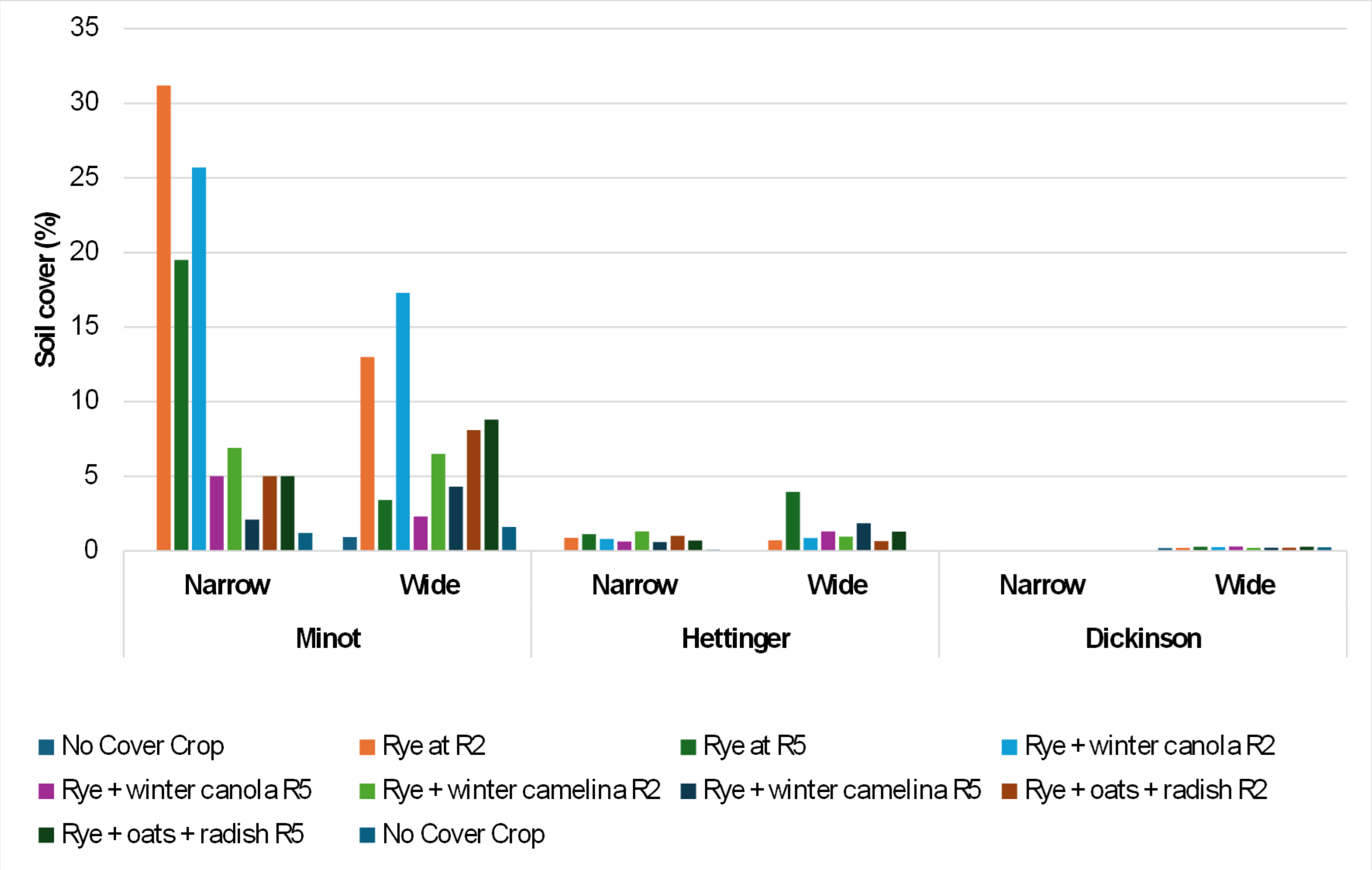
Minot 2023 Soybean Cover Crop Dr. Bortolon



Minot 2023 Soybean Cover Crop Dr. Bortolon



Minot 2023 Soybean Cover Crop Dr. Bortolon



Minot 2023 Soybean Cover Crop Dr. Bortolon

Table 8. Return of investment of cover crop use implemented into standing soybeans in three locations planted in narrow and wide rows. Return of investment is showing considering no cost sharing and with cost sharing.

Location/system	No Cover crop	Rye	Rye + Winter Canola	Rye + Winter Camelina	Rye + oats + radish
			ROI ($/a) with no cost sharing		
Minot Narrow	444	419	407	422	444
Minot Wide	443	418	406	421	443
Hettinger Narrow	384	359	347	362	384
Hettinger Wide	431	406	394	409	431
Dickinson Narrow	272	247	235	250	272
Dickinson Wide	298	273	261	276	298
			ROI ($/a) with cost sharing		
Minot Narrow	444	449	437	452	444
Minot Wide	443	448	436	451	443
Hettinger Narrow	384	389	377	392	384
Hettinger Wide	431	436	424	439	431
Dickinson Narrow	272	277	265	280	272
Dickinson Wide	298	303	291	306	298

East ND 2017-18 Kandel et al. (2021)

- Soybeans interseeded with cover crops planted in furrows in Fargo and Casselton
- 1 or 2 ft row space had no difference in soybean yield with cover crop
- Interseeded cover crop to non-cover crop had no yield difference
- Seeded at R6 stage in the study Winter Rye or Winter Camelina

Roots

- 31 inch limit
- 95 days to grow
- Bulk density 1 g/cm^3

Summary

- Try something on small area that:
  - Keeps the ground covered
  - Lower disturbance on the soil
  - Keeping a living root for more of the year
  - Increasing biodiversity

Test Method Packages Available

- Soil health test packages available in ND
  - What was their design?
  - Are they worth the cost?
  - What do they mean?
- Haney Test: Nutrients (food) available to soil microbes

Soil Health Principles

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SOIL HEALTH