Troubleshooting Problem Areas: Plant Tissue and Soil Analysis

Demonstration Project Update

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Troubleshooting nutrient deficiencies with plant and soil sampling

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Plant tissue analysis as a tool

- Snapshot in plant lifecycle
  - Measure of nutrient uptake so far
  - Reflection of plant history

- Sufficiency ranges and DRIS index provide context for “normal” or “critical” nutrient concentrations in plant tissue

- Valuable tool for agronomists
  - Insight into things seen and unseen

Plant tissue analysis as a tool

1. Confirm visible nutrient deficiency symptoms (e.g., nitrogen vs. sulfur)
2. Diagnose problem areas
   - Slow or uneven growth
   - Unusual symptoms
3. Compare fertilizer efficacy (rate, placement, timing)

Limitations of plant tissue analysis

- Sufficiency ranges are not universal or permanent
  - Research on specific plant parts for specific growth stages
  - Interpolation for growth stages with limited or no research basis
  - Survey ranges, not evaluated for plant response

- Snapshot in plant life cycle
  - Reflection of history
  - No crystal ball for the future

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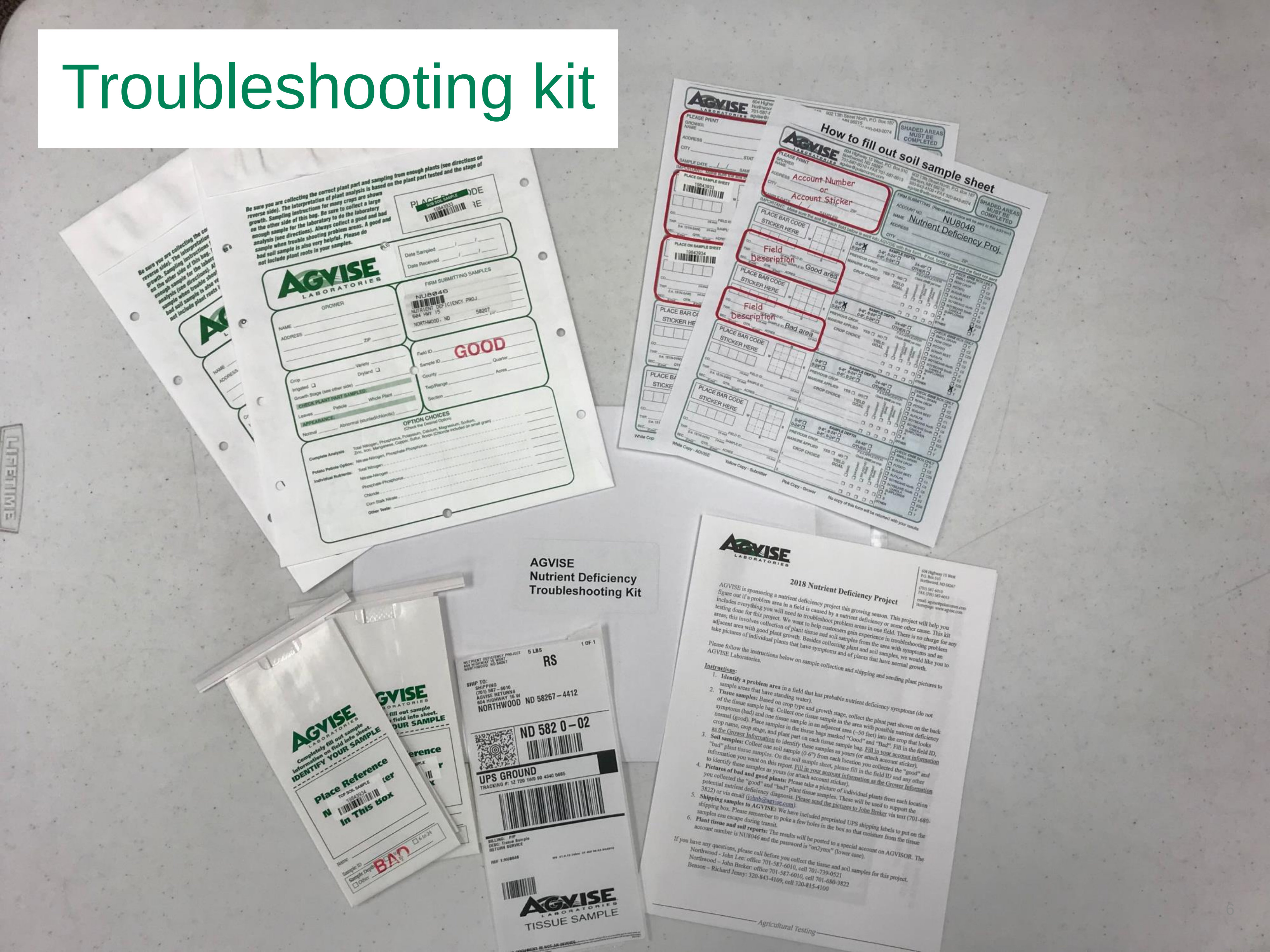
Troubleshooting kit



Troubleshooting with plant tissue analysis

- Information from good and bad areas (paired samples required)
  - Plant tissue sample (speedometer)
  - Soil sample (gas tank)
- Observations and field information
  - Plant symptoms, photographs
  - Fertilizer applied (rate, placement, timing, source)
  - Soil conditions (waterlogged, very dry)

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Photography quality is important, but framing your comparison is key

Troubleshooting with plant tissue analysis

Collect within 7-10 days after visible symptoms appear (results questionable later)

- Correct plant part for correct growth stage
- Do not forget soil samples (0-6” depth acceptable)

Handling the samples

- Bush off any soil or dust (Fe and Mn contamination)
- Ship sample immediately or keep cool in refrigerator
- Sample bags have holes to allow moisture to escape

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Interpreting analysis results

- Sufficiency range
  - Range deemed adequate for each nutrient
  - Specific for plant part and growth stage
  - University research on most crops
- DRIS Index (Diagnosis Recommendation Integrated System)
  - Numerical index calculated for each nutrient based on relative amount in the plant
  - Indexes within -20 to +20 are **normal**
  - Ranks nutrient of largest concern
  - University research only on major crops

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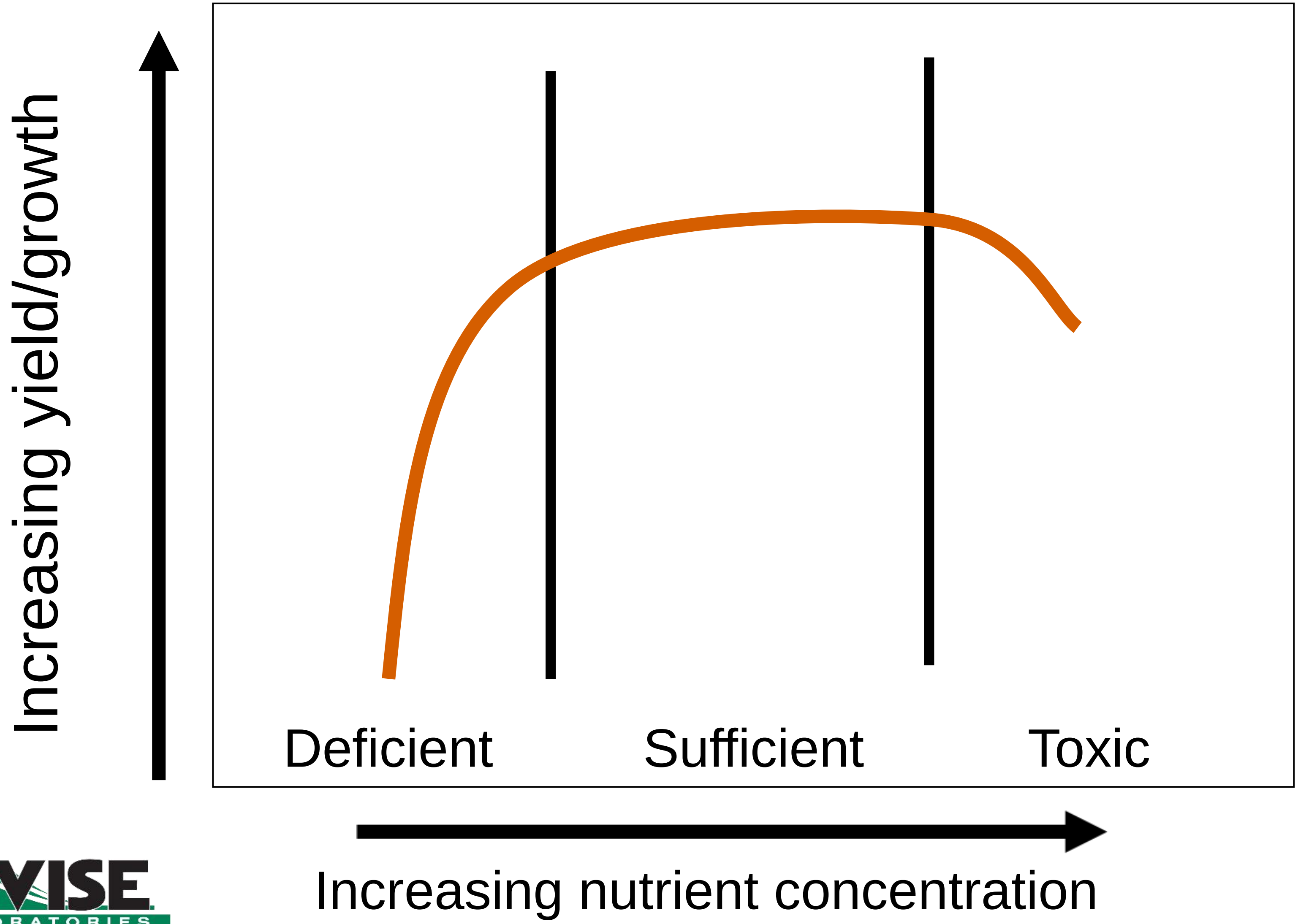
Sufficiency range interpretation



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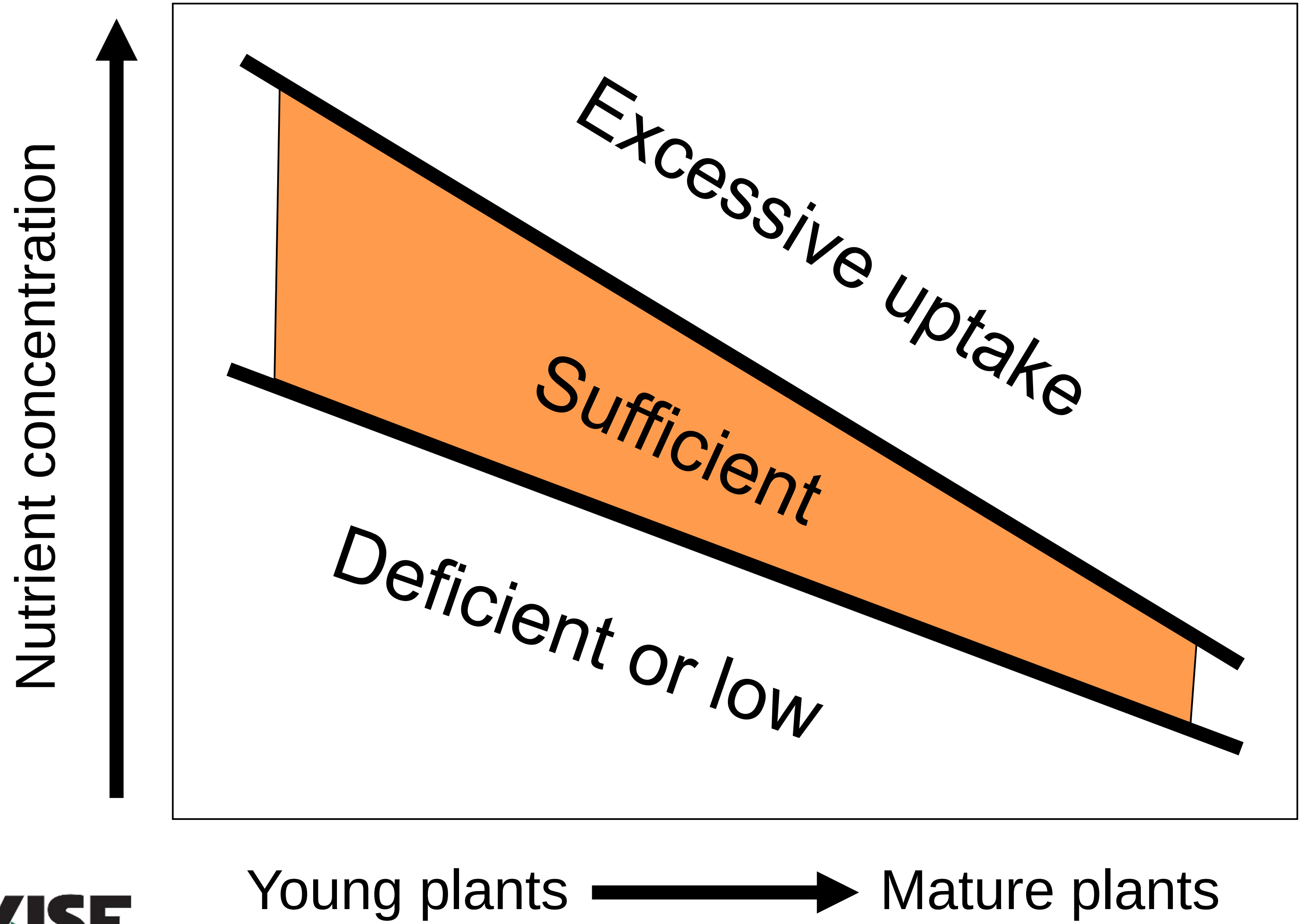
Sufficiency range interpretation



Diagnosis Recommendation Integrated System (DRIS)

Corn plant tissue analysis

Plant age (d)	Nutrient content ratio		
	N/P	**N/K**	**K/P**
30	15	1.4	11
60	15	1.6	9
80	14	1.8	8
110	15	1.7	9

Ratio of N/P stays the same as healthy plants age

Diagnosis Recommendation Integrated System (DRIS)

Corn plant tissue analysis
Shorter plants

N	P	K	S	Ca	Mg	Na	Zn	Fe	Mn	Cu	B
%							ppm				
3.4	0.49	**2.7**	0.30	0.97	1.14	0.03	**11**	871	208	13	11
L	S	**L**	S	S	H	S	**L**	VH	H	S	S
DRIS											
-18	-3	-2	**-16**	8	70		**-78**		46	-3	-3

DRIS indicates that zinc is the most limiting nutrient

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Real world troubleshooting

Classic examples from real customers

- Visible symptoms on plants (photographs)
- Information from good and bad areas
  - Soil samples
  - Plant tissue samples
- Field information from grower and agronomist

Example 1: Twisted wheat

Notes:
- Twisted, withered leaf tips after tillering
- ‘Rattail’ appearance

Good area

Bad area

Example 1: Twisted wheat

Soil analysis					Plant analysis					
		Good	**Bad**				**Good**		**Bad**	
N	lb/acre				**N**	%	5.9	H	5.6	H
P	ppm	23	29		**P**	%	0.38	S	0.37	S
K	ppm	207	202		**K**	%	3.5	H	3.4	H
S	lb/acre	22	15		**S**	%	0.35	S	0.32	S
Zn	ppm	1.22	0.39		**Zn**	ppm	38	S	28	S
Cu	ppm	0.69	0.40		**Cu**	ppm	4	L	3	L
B	ppm	0.5	0.2		**B**	ppm	10	S	8	S
Fe	ppm	80	48		**Fe**	ppm	106	S	106	S
Mn	ppm	26	17		**Mn**	ppm	98	S	109	H
Cl	lb/acre	5	4		**Cl**	%	0.19	L	0.13	L
pH		5.0	5.1							
EC	dS/m	0.57	0.17							
OM	%	3.8	1.5							
CEC	cmol(+)/kg	12.4	8.4							

Example 1: Twisted wheat

Soil analysis					Plant analysis					
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N	lb/acre				N	%	5.9	H	5.6	H
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K	ppm	207	202		K	%	3.5	H	3.4	H
S	lb/acre	22	15		S	%	0.35	S	0.32	S
Zn	ppm	1.22	0.39		Zn	ppm	38	S	28	S
Cu	ppm	**0.69**	**0.40**		Cu	ppm	**4**	**L**	**3**	**L**
B	ppm	0.5	0.2		B	ppm	10	S	8	S
Fe	ppm	80	48		Fe	ppm	106	S	106	S
Mn	ppm	26	17		Mn	ppm	98	S	109	H
Cl	lb/acre	**5**	**4**		Cl	%	**0.19**	**L**	**0.13**	**L**
pH		5.0	5.1							
EC	dS/m	0.57	0.17							
OM	%	**3.8**	**1.5**							
CEC	cmol(+)/kg	**12.4**	**8.4**							

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Coarse-textured soil, likely eroded

Visual deficiency symptoms

Copper deficiency

Withered, twisted leaf tips

'Rattail' appearance

Chloride deficiency

Non-distinct symptoms

Manifests as leaf disease spots

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Example 1: Twisted wheat

- Plant tissue: low Cu, low Cl
- Soil test: low Cu, low organic matter, coarse-textured soil
- Visual symptoms verify Cu deficiency

- Apply Cu with small grains
- Select non-Cu sensitive crops

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Example 2: Thin, stressed durum

Notes:

- Chlorosis and necrosis starting in lower canopy
- Drought-stress appearance

Example 2: Thin, stressed durum

Soil analysis					Plant analysis					
		Good	Bad				Good		Bad	
N	lb/acre	26	182		N	%	4.5	S	3.0	D
P	ppm	21	25		P	%	0.31	S	0.25	S
K	ppm	611	631		K	%	2.1	S	1.8	S
S	lb/acre	360+	360+		S	%	0.41	S	0.50	S
Zn	ppm	1.30	1.84		Zn	ppm	19	L	13	L
Cu	ppm	1.00	1.11		Cu	ppm	8	S	7	S
B	ppm	1.0	6.8		B	ppm	202	VH	1872	VH
Na	ppm	35	301		Na	%	0.07	S	0.30	VH
Cl	lb/acre	24	68		Cl	%	1.17	VH	0.42	S
EC 1	dS/m	0.23	0.44							
EC 2	dS/m	1.24	3.52							

Example 2: Thin, stressed durum

Soil analysis					Plant analysis					
		Good	Bad				Good		Bad	
N	lb/acre	**26**	**182**		**N**	%	**4.5**	**S**	**3.0**	**D**
P	ppm	21	25		**P**	%	0.31	S	0.25	S
K	ppm	611	631		**K**	%	2.1	S	1.8	S
S	lb/acre	360+	360+		**S**	%	0.41	S	0.50	S
Zn	ppm	1.30	1.84		**Zn**	ppm	19	L	13	L
Cu	ppm	1.00	1.11		**Cu**	ppm	8	S	7	S
B	ppm	**1.0**	**6.8**		**B**	ppm	**202**	**VH**	**1872**	**VH**
Na	ppm	**35**	**301**		**Na**	%	**0.07**	**S**	**0.30**	**VH**
Cl	lb/acre	**24**	**68**		**Cl**	%	**1.17**	**VH**	**0.42**	**S**
EC 1	dS/m	**0.23**	**0.44**							
EC 2	dS/m	**1.24**	**3.52**							

Boron > 3 ppm toxic?

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Example 2: Thin, stressed durum

- Plant tissue: deficient N, excessive B, high Na
- Soil test: toxic B, high Na, very high subsoil salinity

- Crop rotation and selection: boron toxicity, subsurface salinity
  - No issues during sunflower years (more tolerant to boron toxicity)

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Case studies from 2018

Cooperative project with customers across the region

1. Purple corn in southern MN
2. Stunted safflower in southwest ND
3. Yellow wheat in northern ND

Case study 1: Purple corn

Notes:

- Shorter (V3 vs. V6)
- Purpling on leaves, striped appearance
- Necrosis on lowest leaf margin

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Case study 1: Purple corn

Soil analysis					Plant analysis					
		Good	**Bad**				**Good**		**Bad**	
N	lb/acre	80	50		**N**	%	3.55	S	2.33	L
P	ppm	11	7		**P**	%	0.18	L	0.12	D
K	ppm	175	190		**K**	%	3.2	H	2.8	S
S	lb/acre	120	120		**S**	%	0.20	S	0.29	S
Ca	ppm	6611	9417		**Ca**	%	0.60	S	1.13	VH
Mg	ppm	493	471		**Mg**	%	0.41	S	0.35	S
Zn	ppm	0.85	0.77		**Zn**	ppm	24	S	19	L
Cu	ppm	0.61	0.69		**Cu**	ppm	8	S	6	S
B	ppm	2.2	2.1		**B**	ppm	7	S	9	S
Fe	ppm	6.9	8.2		**Fe**	ppm	176	S	674	VH
Mn	ppm	1.2	1.8		**Mn**	ppm	75	S	79	S
pH		7.9	7.7							
EC	dS/m	0.74	2.19							

Case study 1: Purple corn

Soil analysis					Plant analysis					
		Good	Bad				Good		Bad	
N	lb/acre	80	50		N	%	3.55	S	2.33	L
P	ppm	11	7		P	%	0.18	L	0.12	D
K	ppm	175	190		K	%	3.2	H	2.8	S
S	lb/acre	120	120		S	%	0.20	S	0.29	S
Ca	ppm	6611	9417		Ca	%	0.60	S	1.13	VH
Mg	ppm	493	471		Mg	%	0.41	S	0.35	S
Zn	ppm	0.85	0.77		Zn	ppm	24	S	19	L
Cu	ppm	0.61	0.69		Cu	ppm	8	S	6	S
B	ppm	2.2	2.1		B	ppm	7	S	9	S
Fe	ppm	6.9	8.2		Fe	ppm	176	S	674	VH
Mn	ppm	1.2	1.8		Mn	ppm	75	S	79	S
pH		7.9	7.7							
EC	dS/m	0.74	2.19							

Case study 1: Purple corn

- Plant tissue: deficient P, low Zn
- Soil test: low P, low Zn, high salinity

- Starter P & Zn to correct problem
  - Seed safety with salinity
  - Salinity limits plant nutrient uptake
- Recognize salinity stress in crop choice

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Case study 3: Poor stand, stunted safflower

Notes:
- Poor germination, small plants
- Pattern follows landscape

Case study 3: Stunted safflower

Soil analysis					Plant analysis					
		Good	Bad				Good		Bad	
N	lb/acre	36	37		N	%	5.52	H	5.40	H
P	ppm	25	23		P	%	0.32	L	0.27	L
K	ppm	400	257		K	%	5.6	H	4.8	H
S	lb/acre	17	12		S	%	0.3	S	0.32	S
Ca	ppm	1285	884		Ca	%	1.19	S	1.42	S
Mg	ppm	542	223		Mg	%	0.47	L	0.66	S
Zn	ppm	1.42	0.94		Zn	ppm	53	H	68	H
Cu	ppm	0.83	0.45		Cu	ppm	12	S	7	S
B	ppm	0.40	0.33		B	ppm	17	S	23	S
Fe	ppm	87	93		Fe	ppm	1540	VH	1438	VH
Mn	ppm	28	37		Mn	ppm	244	H	809	VH
pH		5.6	4.5							
EC	dS/m	0.30	0.15							

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Case study 3: Stunted safflower

Soil analysis					Plant analysis					
		Good	Bad				Good		Bad	
N	lb/acre	36	37		N	%	5.52	H	5.40	H
P	ppm	25	23		P	%	0.32	L	0.27	L
K	ppm	400	257		K	%	5.6	H	4.8	H
S	lb/acre	17	12		S	%	0.3	S	0.32	S
Ca	ppm	1285	884		Ca	%	1.19	S	1.42	S
Mg	ppm	542	223		Mg	%	0.47	L	0.66	S
Zn	ppm	1.42	0.94		Zn	ppm	53	H	68	H
Cu	ppm	0.83	0.45		Cu	ppm	12	S	7	S
B	ppm	0.40	0.33		B	ppm	17	S	23	S
Fe	ppm	87	93		Fe	ppm	1540	VH	1438	VH
Mn	ppm	28	37		Mn	ppm	244	H	809	VH
pH		5.6	4.5							
EC	dS/m	0.30	0.15							

Aluminum toxicity when pH < 5.0-5.5

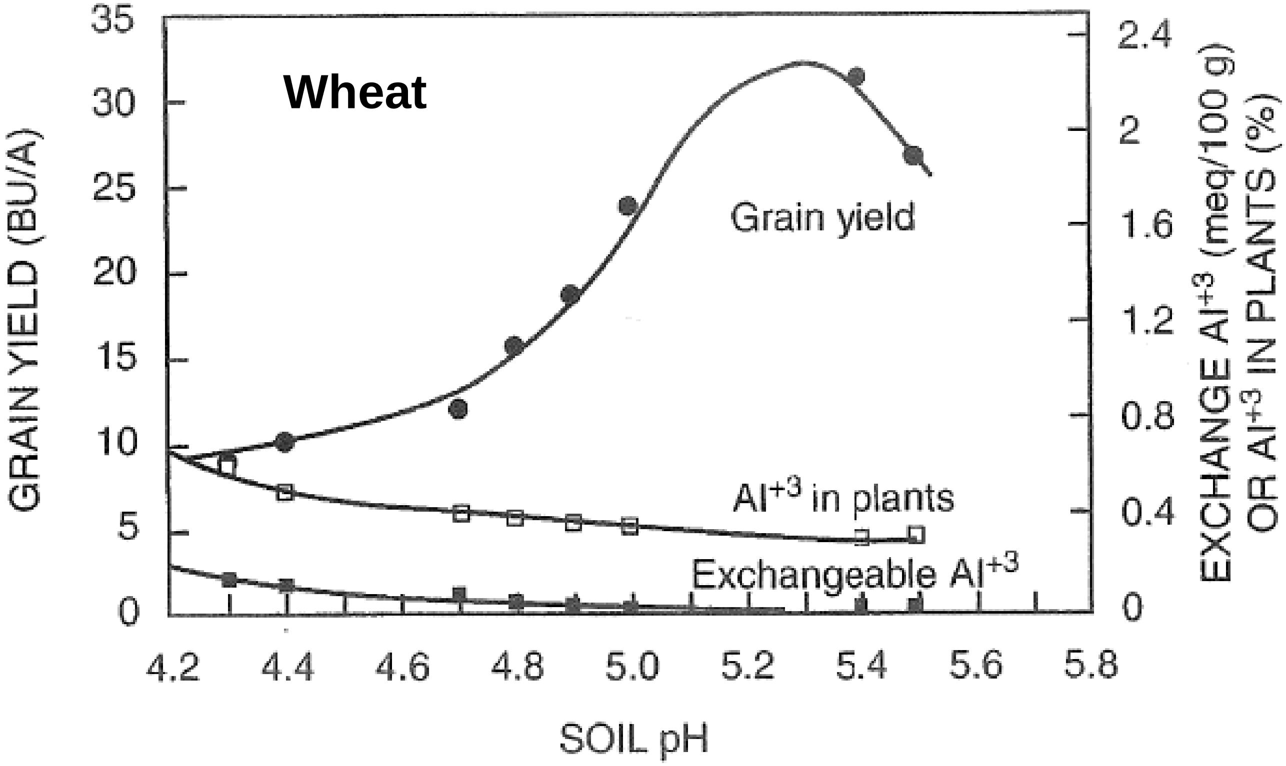
Aluminum toxicity on wheat seedlings

High Al^{3+}

No Al^{3+}

Photo credit: S. Carr. https://www.agric.wa.gov.au/soil-acidity/effects-soil-acidity

Low pH makes more exchangeable Al^{3+}
More Al^{3+} reduces grain yield



Havlin, J.L., J.D. Beaton, S.L. Tisdale, and W.L. Nelson. 2005. Soil Fertility and Fertilizers: An Introduction to Nutrient Management. 7th ed. Pearson Prentice Hall, Upper Saddle River, NJ.

Patiram, R.N. Rai, and R.N. Prasad. 1990. Effect of liming on aluminum and yield of wheat in acidic soils. J. Indian Soc. Soil Sci. 38(4):719-722.

Case study 3: Stunted safflower

Property	Depth (inch)	Good	Bad
pH	0-2	**4.5**	**4.3**
	2-6	**6.1**	**4.6**
	6-12	6.1	5.8
Aluminum (ppm)	0-2	**24**	**91**
	2-6	**1.8**	**25**
	6-12	0.3	0.4
Manganese (ppm)	0-2	52	52
	2-6	16	30
	6-12	7.5	4.6

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For pH>6, aluminum should be near 0 ppm

Case study 3: Stunted safflower

- Plant tissue: low P in both, very high Mn
- Soil test: low pH, VERY high Al

- Crop choice, Al-tolerant varieties
- High seed-placed P rate
- Lime application
- Other land use?

Case study 4: Yellow durum wheat

Notes:

- Yellowing of upper leaves
- Worse on hilltops, thin stand

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Case study 4: Yellow durum wheat

Soil analysis					Plant analysis					
		Good	Bad				Good		Bad	
N	lb/acre	102	62		N	%	4.85	S	4.46	S
P	ppm	9	7		P	%	0.34	S	0.37	S
K	ppm	234	277		K	%	4.2	H	3.6	H
S	lb/acre	36	22		S	%	0.30	S	0.29	S
Zn	ppm	0.38	0.29		Zn	ppm	21	S	22	S
Cu	ppm	0.50	0.52		Cu	ppm	7	S	6	S
B	ppm	1.67	1.45		B	ppm	5	S	7	S
Fe	ppm	8.7	6.9		Fe	ppm	535	VH	522	VH
Mn	ppm	2.12	2.72		Mn	ppm	64	S	46	S
Cl	lb/acre	19	5		Cl	%	0.65	H	0.38	S
Ca	ppm	5221	5996		Ca	%	0.80	H	0.76	H
Mg	ppm	404	488		Mg	%	0.23	S	0.25	S
Na	ppm	49	29		Na	%	0.01	S	0.09	S
pH		8.0	8.2							
EC	dS/m	0.60	0.46							
CCE	%	3.2	5.8							

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Case study 4: Yellow durum wheat

- Plant tissue: same
- Soil test: same

- Based on visual symptoms, S deficiency most likely
- Symptoms were not corrected with AMS application
- Inconclusive, other factors:
  - Herbicide carryover (dry conditions, surface pH)
  - Water availability, positional nutrient availability

Summary

- Single plant tissue analysis report is usually not enough
- Plant tissue concentrations are affected by:
  - Plant size, growth stage
  - Fertilizer rate, placement, timing, source (4Rs)
  - Soil moisture, compaction
- Both soil and plant tissue samples are needed
  - Soil nutrient supply truly lacking?
  - Other factors limiting nutrient uptake

Each field needs a discussion

Troubleshooting is:

- Symptoms
- Causes
- Management

Soil sampling after banded nitrogen application

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Common questions

"How much anhydrous ammonia did you put down?"

"Did I lose fall-applied nitrogen over the winter?"

"I cannot remember if nitrogen was even applied!"

"Was that enough sidedress nitrogen?"

All questions about auditing banded nitrogen application with soil testing.

How do you sample after banded N application?

- Fertilizer concentration in band will be much (MUCH) higher than surrounding soil

- University research trying to assess the average, usually for fall soil sampling
  - Certain number of off-band soil cores for each on-band soil core (usually 3 or 4)
  - Certain distance between band and crop row
  - Dependent on locating band, band-center spacing and orientation

In-season banded N project

Banded urea (46-0-0) application

- Rate: 75 and 150 lb N/acre
- Depth: 4 inch
- Center: 30 inch

Three weeks later…

- Collected soil samples (0-6 inch) across entire 30-inch row
- Analyzed for ammonium and nitrate

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Urea bands are really concentrated 150 lb N/acre, 30-inch center

Knock-Yourself-Out™ Soil Sampler

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Phew…now that's done!

Knock-Yourself-Out™ Soil Sampler

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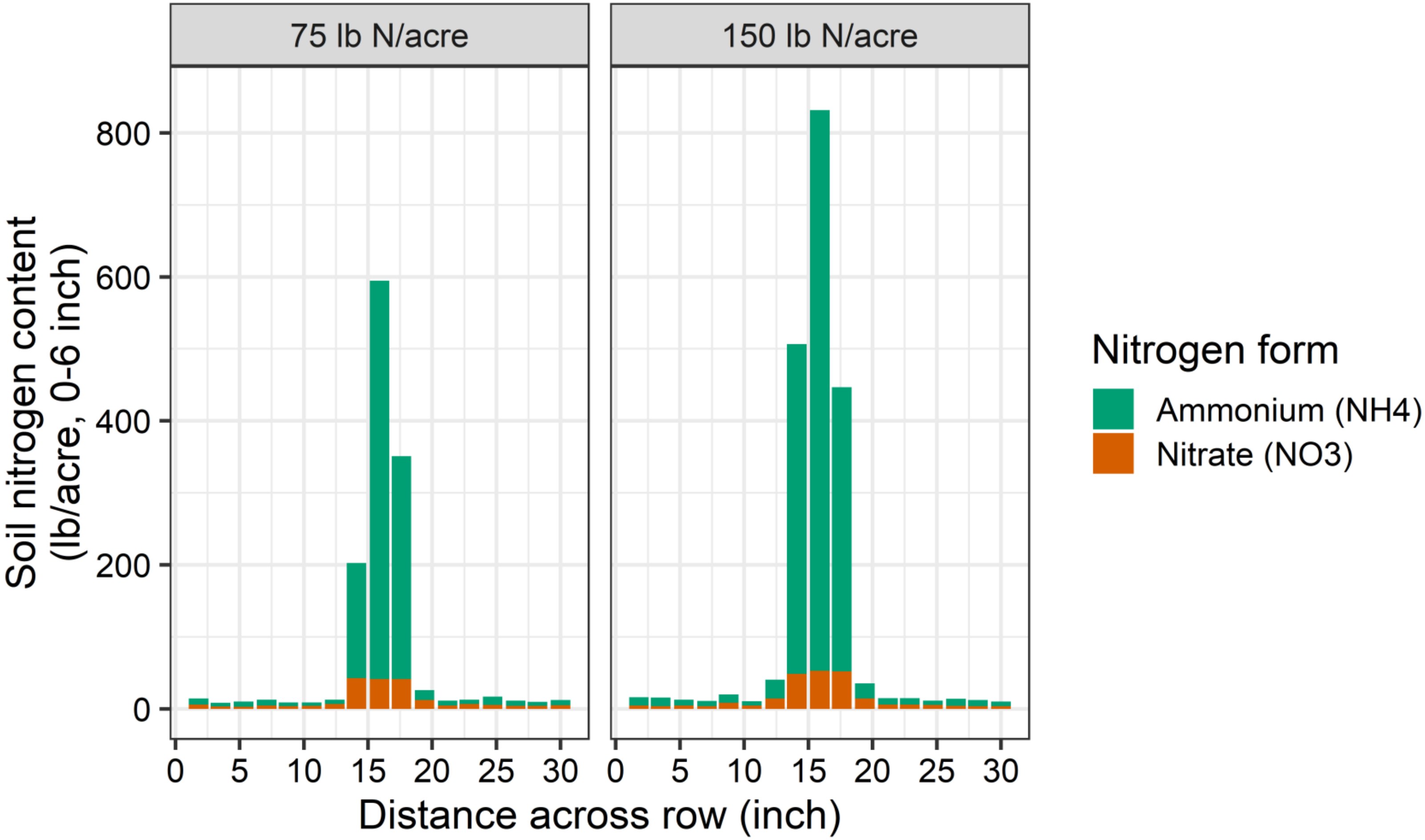
(2x4s not included)

Soil nitrogen distribution across row



AGVISE Laboratories, Northwood, ND

What is the N rate?

In-band area (5 inch), averaged

Applied N rate lb/acre	Inorganic N recovery (NH_4 + NO_3) lb/acre, 0-6 inch depth
75	**383**
150	**595**

Across entire row (30 inch), averaged

Applied N rate lb/acre	Inorganic N recovery (NH_4 + NO_3) lb/acre, 0-6 inch depth
75	**78**
150	**119**

Nitrification inhibition

- Only 10% of fertilizer N converted from ammonium to nitrate in three weeks
  - Soil temperature and moisture were conducive for rapid nitrification
- Concentrated ammonium bands delay nitrification

- Limitations on near-seed fertilizer placement
- Issues for fertilizer co-application in band

How do will you sample banded N applications?

- Collect all soil across the row
  - Shovel, measuring tape, massive soil sample
  - Knock-Yourself-Out™ Soil Sampler, patent pending
  - Repeat 15-20 times across field

- Collect selective soil cores
  - Take 3-4 off-band cores for each on-band core
  - You must know location of band-center
  - Hitting the band-edge will throw result average
  - Error, error, error…

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Soil sampling after banded N applications

- Extreme variability between on-band and off-band soil cores
- You must obtain all soil across the row for a *reasonable* average
  - Error still exists
  - Beyond the realm of practical

- You can learn if *some* N was applied; however, the application rate remains elusive

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Improving saline and sodic soils with tile drainage

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Long-term tile drainage projects

- Saline soil near Northwood, ND
  - Drain tile installed Summer 2002
  - Ten GPS-marked sampling sites
- Saline-sodic soil near Mayville, ND
  - Saline-sodic and saline areas in field
  - Drain tile installed 2007
  - Gypsum applied, total 5 ton/acre in 2008 & 2009

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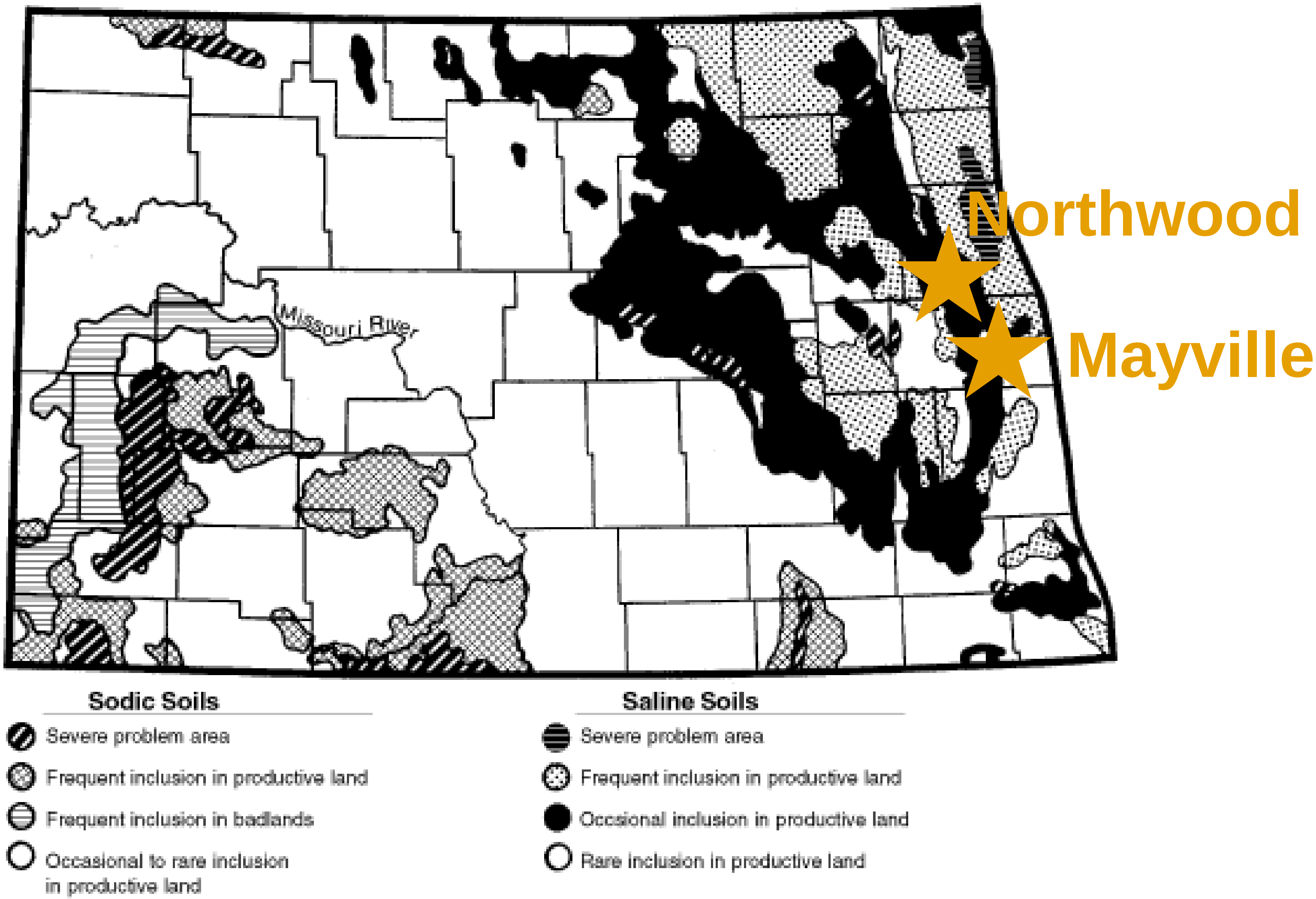
Saline and sodic soils in North Dakota



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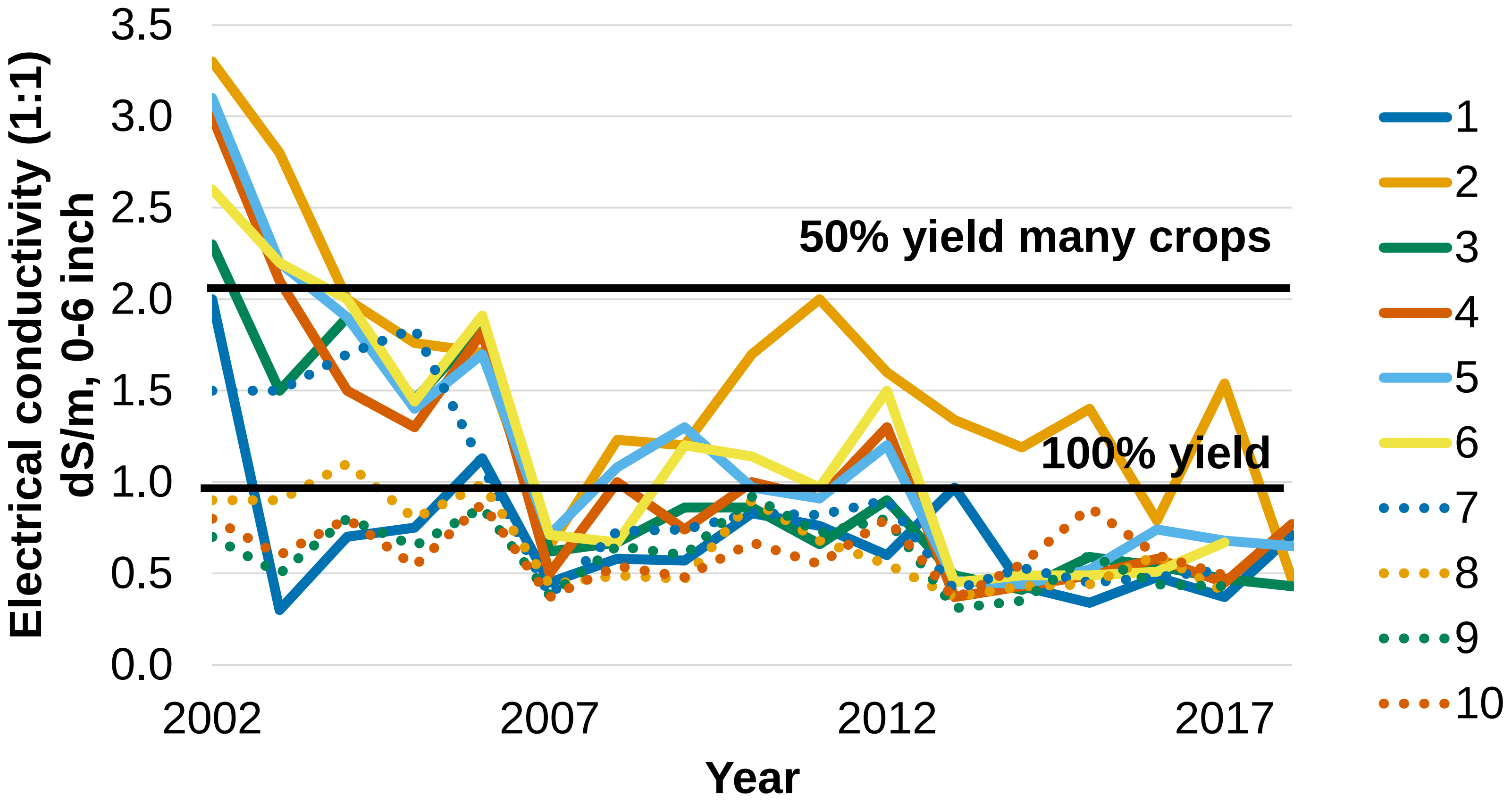
2003 soybean
Grady Thorsgard, farmer
Sandy loam to loam
pH 7.9-8.2
Carbonate (CCE) 3-6%
Organic matter 4.0-5.5%

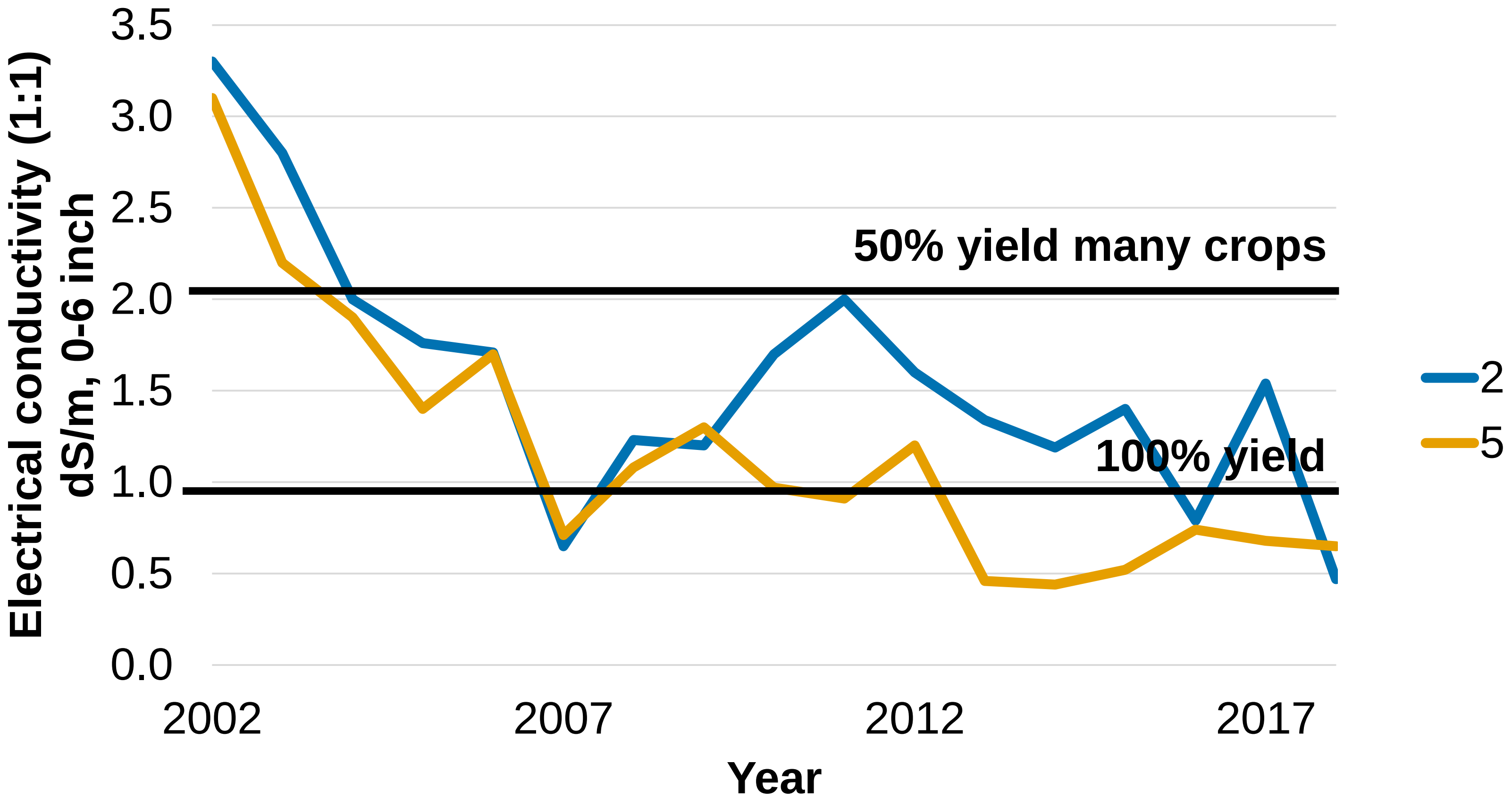

2004 corn

Saline soil, topsoil
Change in salinity (soluble salts)



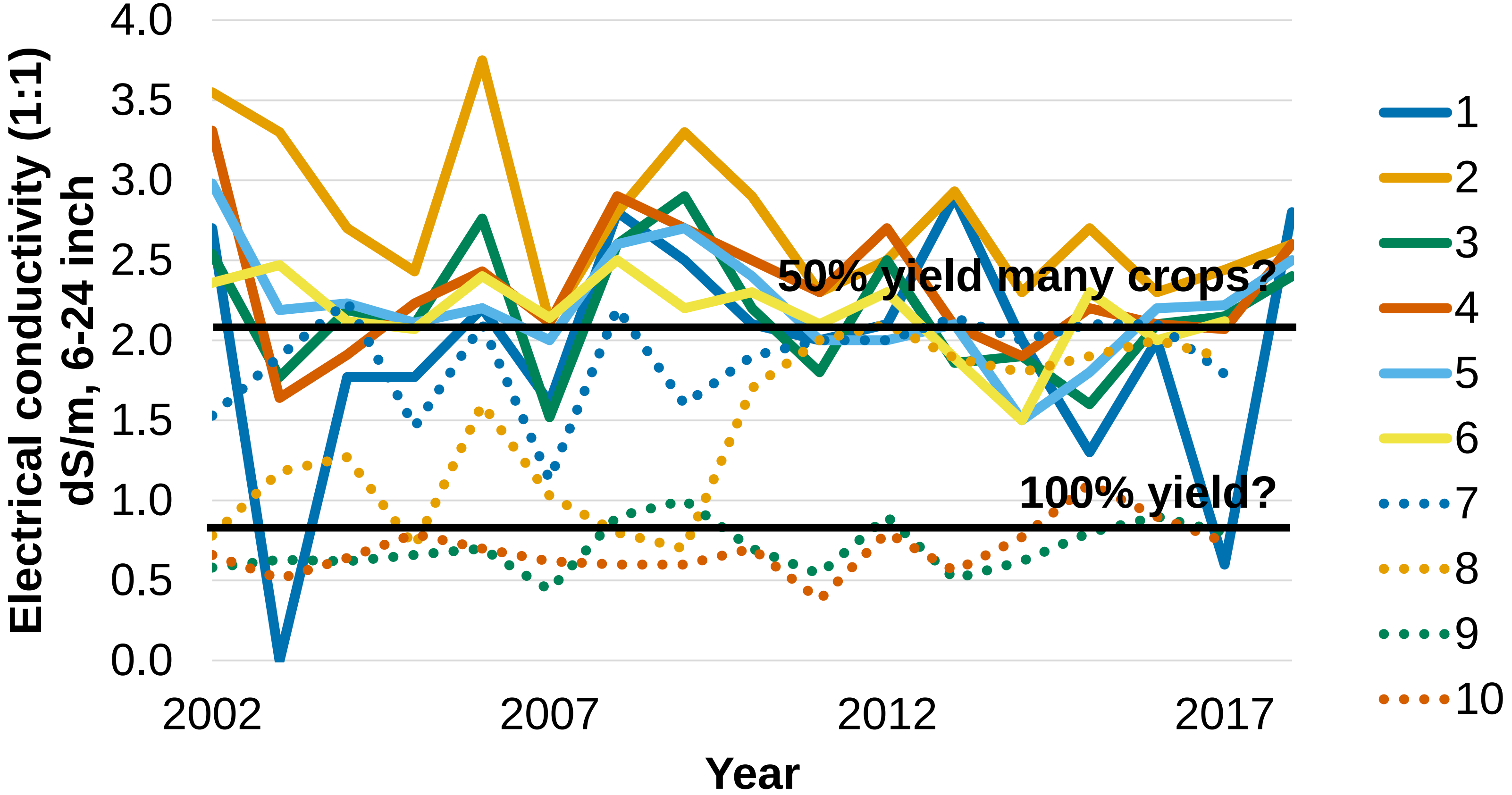
Sites 6-10 last sampled in 2017, manure applied 2018

Saline soil, topsoil
Change in salinity (soluble salts)



Sites 6-10 last sampled in 2017, manure applied 2018

Saline soil, subsoil
Change in salinity (soluble salts)



Subsoil salinity remains high until topsoil is leached
Sites 6-10 last sampled in 2017, manure applied 2018

Tile drainage project
Saline soil, Northwood, ND

- Topsoil salinity declined in years with excessive spring or fall rainfall
- Several crops now produce good yields
  - Corn, soybean, sunflower
  - Soybean iron deficiency chlorosis (IDC) reduced
- Subsoil salinity will take longer to decline
- High subsoil salinity do not affect yield as badly as topsoil salinity
- Salinity can increase in dry years if upward capillary rise > downward leaching

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Long-term tile drainage projects

- Saline soil near Northwood, ND
  - Drain tile installed Summer 2002
  - Ten GPS-marked sampling sites

- Saline-sodic soil near Mayville, ND
  - Saline-sodic and saline areas in field
  - Drain tile installed 2007
  - Gypsum applied, total 5 ton/acre in 2008 & 2009

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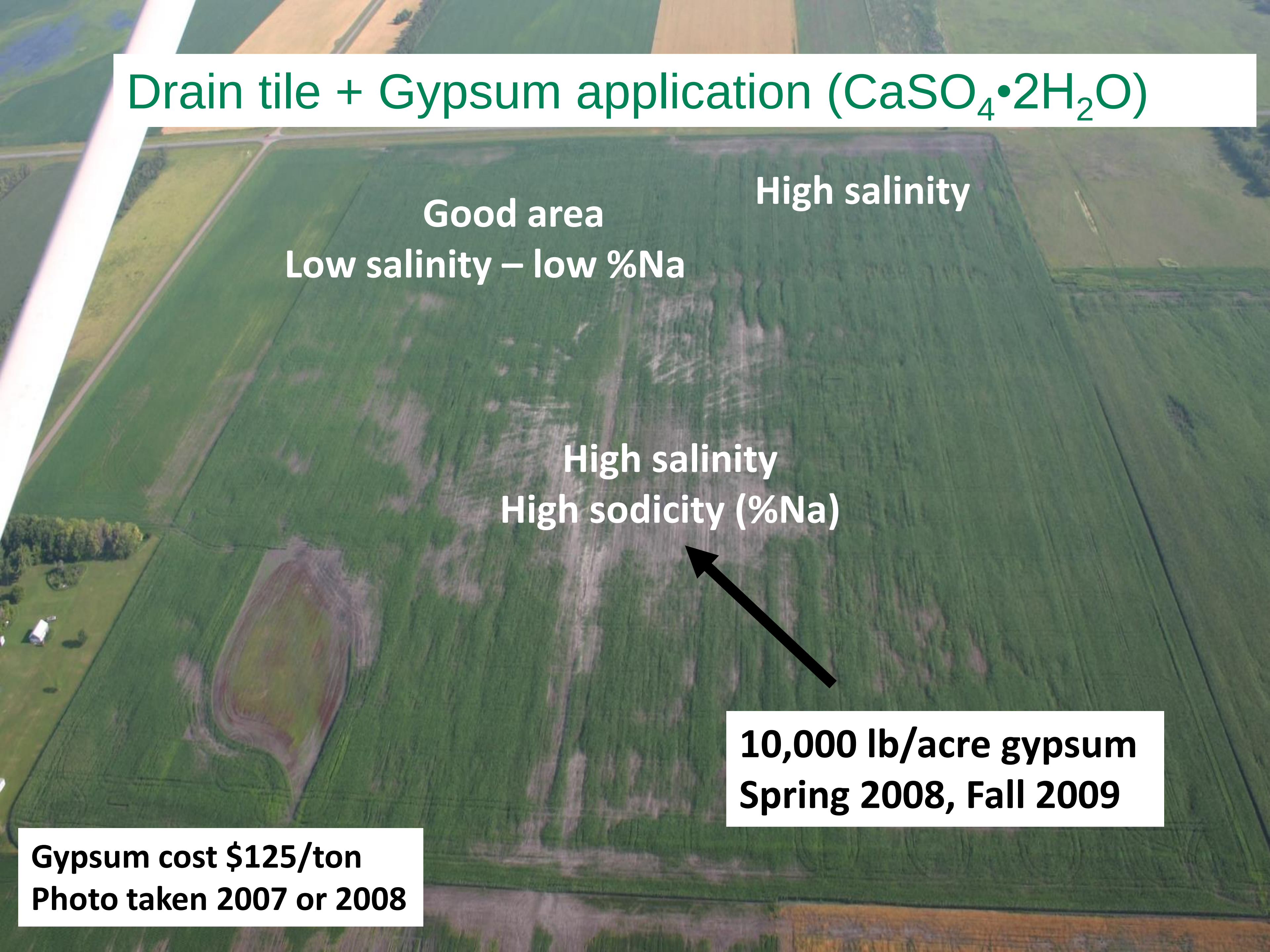
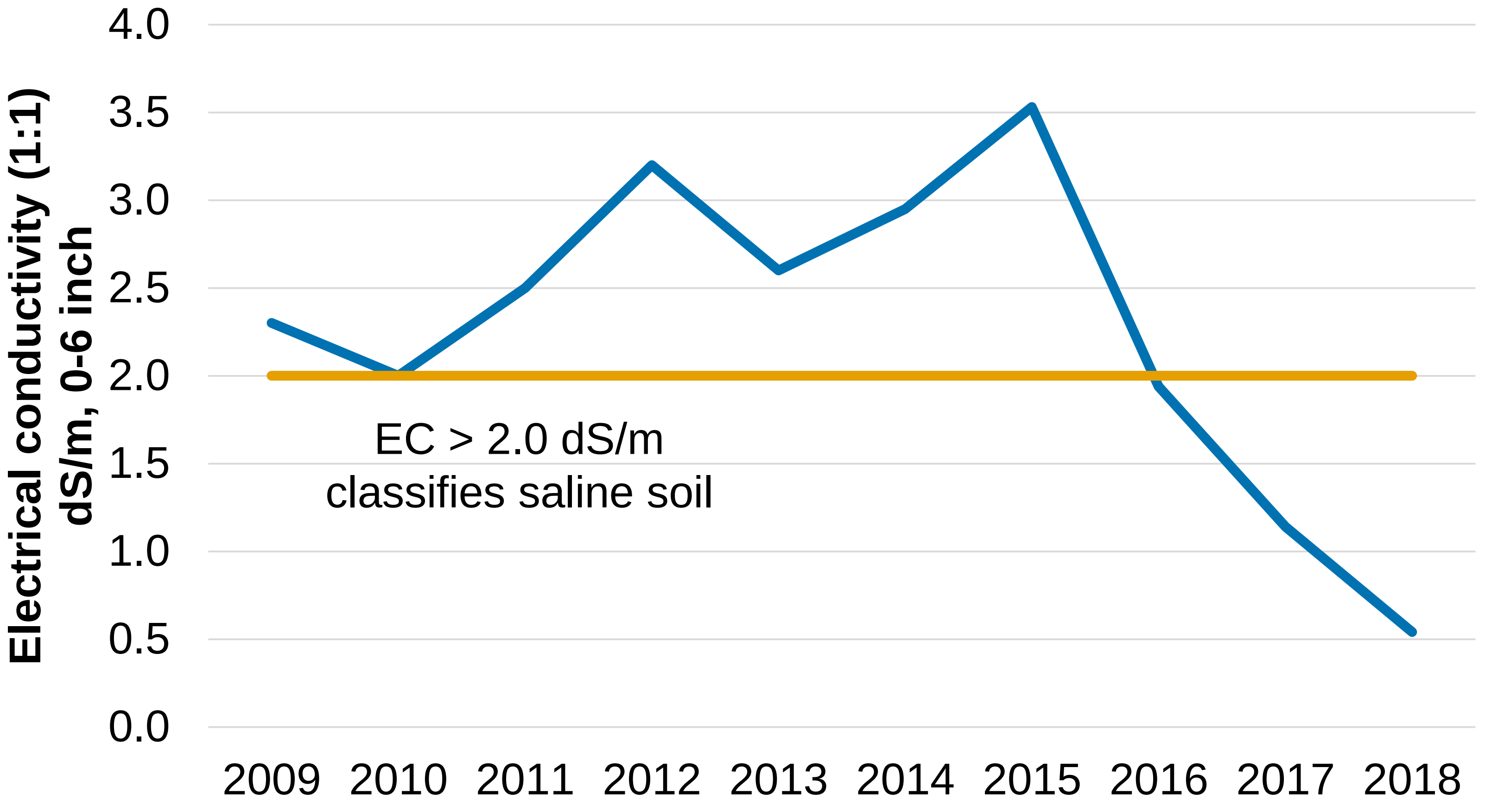
Drain tile + Gypsum application ($CaSO_4 \cdot 2H_2O$)



Saline-sodic soil
Change in salinity (soluble salts)



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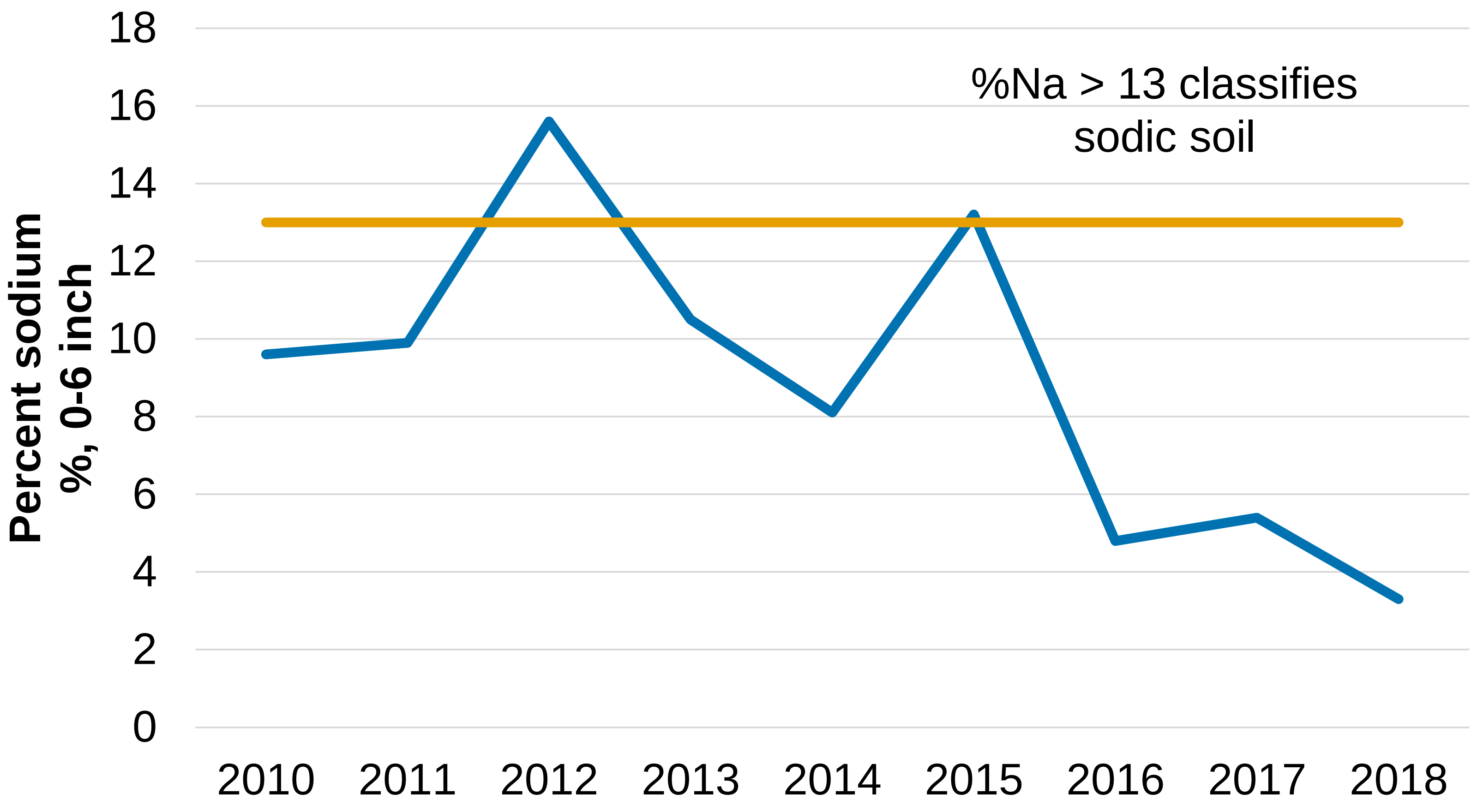
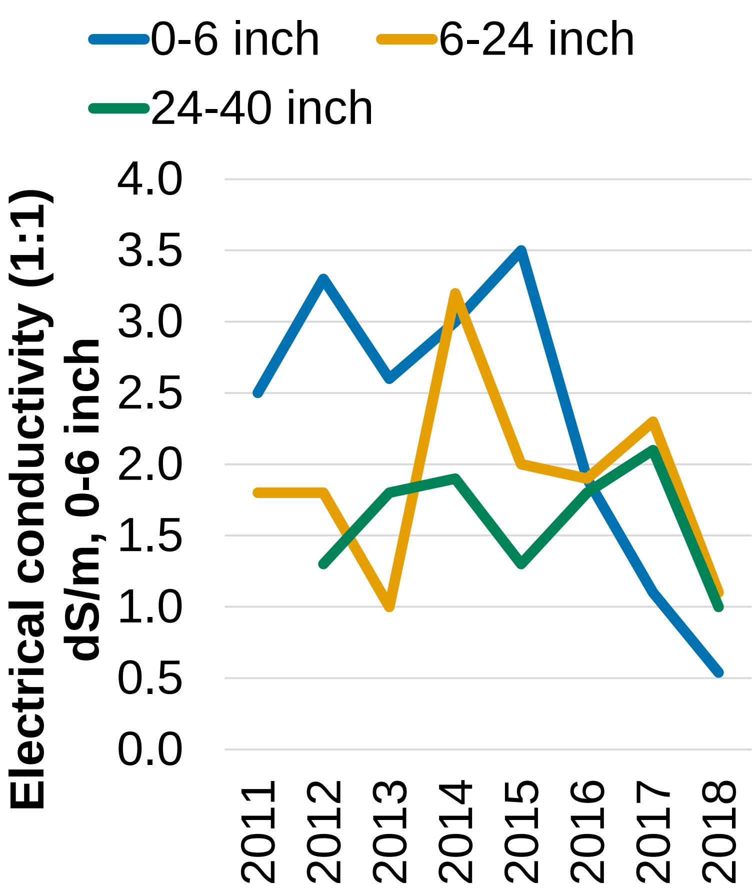
Decrease in salinity occurs slower on fine-textured soils, excessive leaching rainfall required

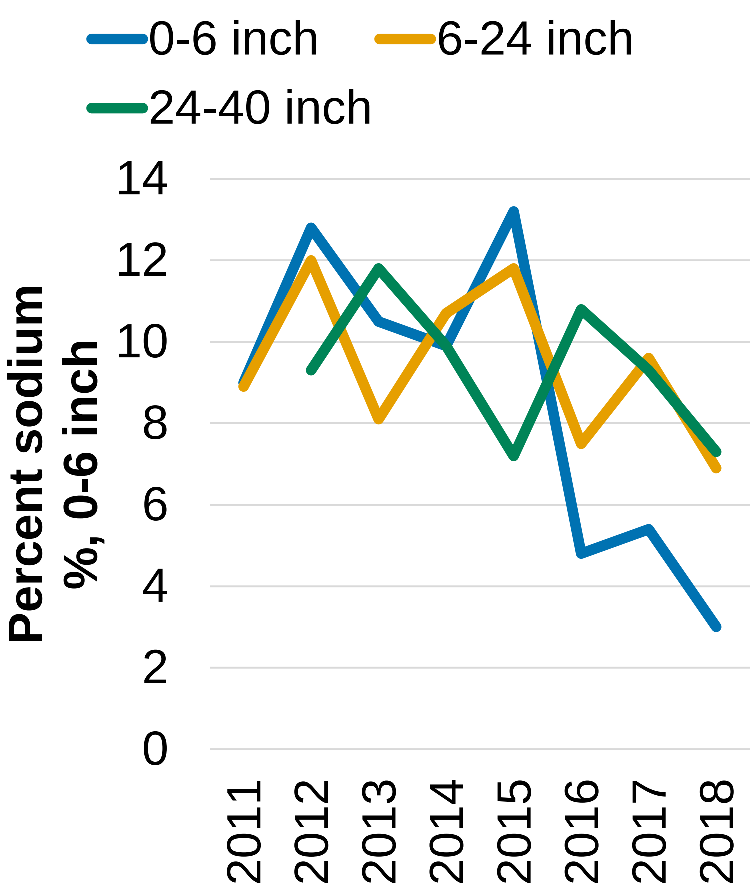
Saline-sodic soil
Change in sodicity (%Na = SAR)



Request K, Ca, Mg, Na on routine test for %Na

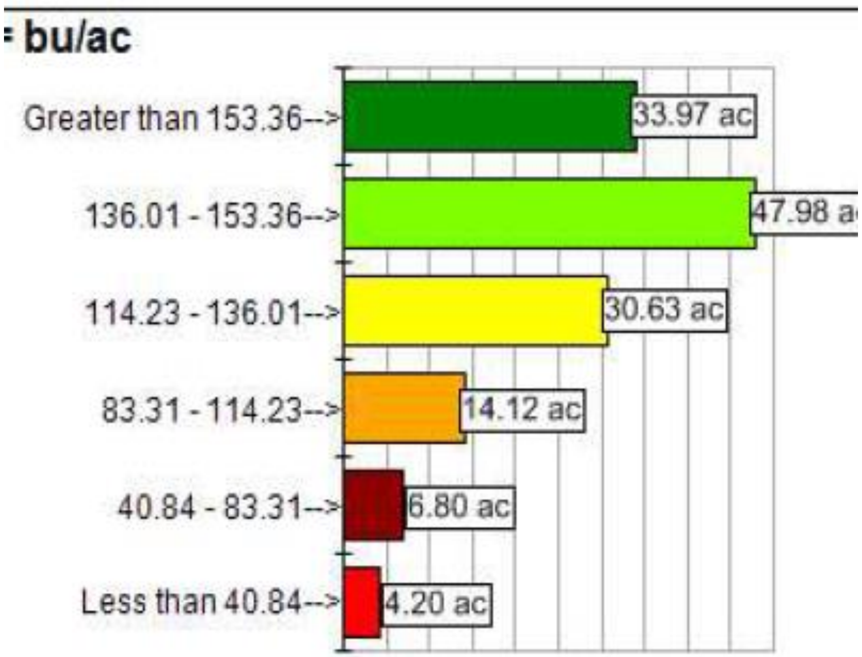
Saline-sodic soil
Changes in salinity and sodicity with depth

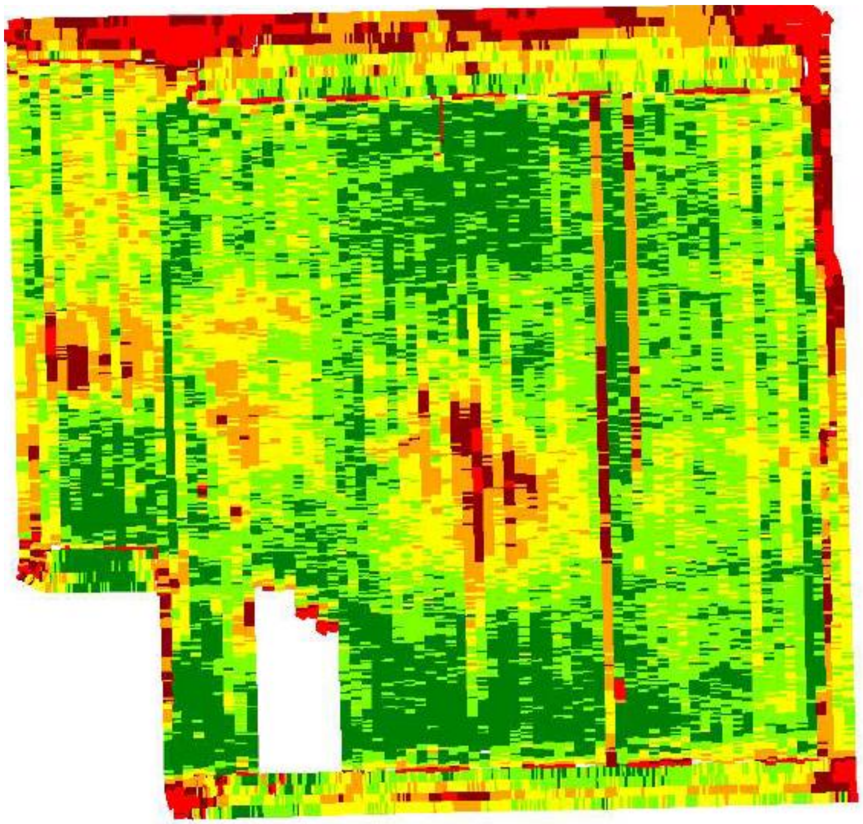




Corn yield 2014

Average 133 bu/acre dry corn

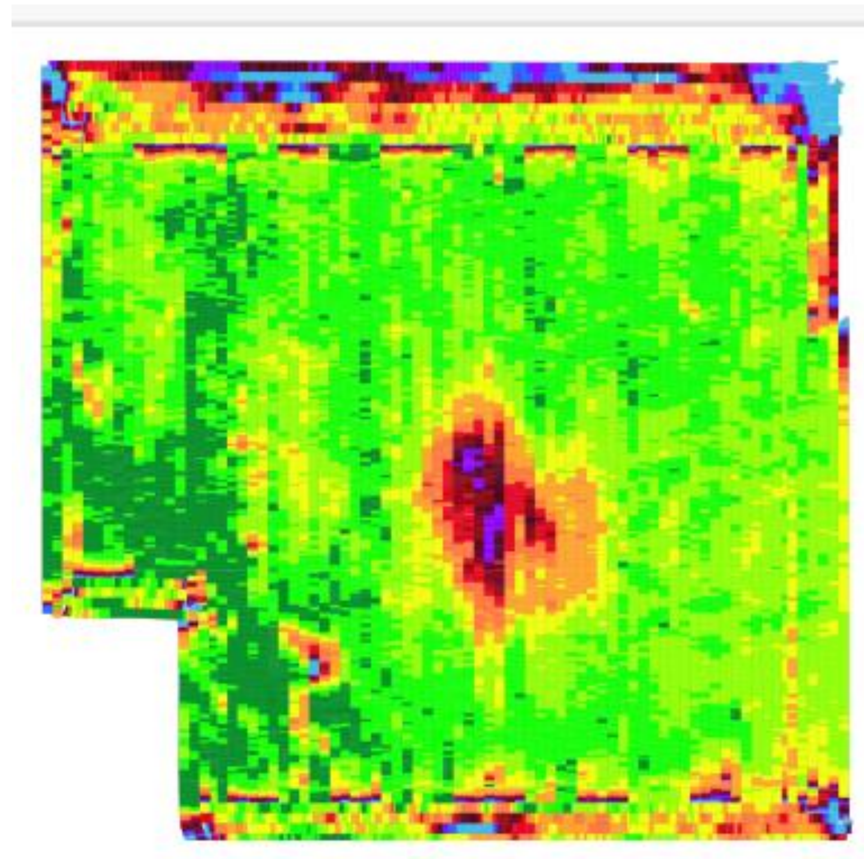




Corn yield 2016

Average 184 bu/acre corn (17.9% moisture)

> 207 bu/ac
194 - 207 bu/ac
181 - 194 bu/ac
167 - 181 bu/ac
154 - 167 bu/ac
141 - 154 bu/ac
128 - 141 bu/ac
115 - 128 bu/ac
101 - 115 bu/ac
88 - 101 bu/ac
75 - 88 bu/ac
< 75 bu/ac



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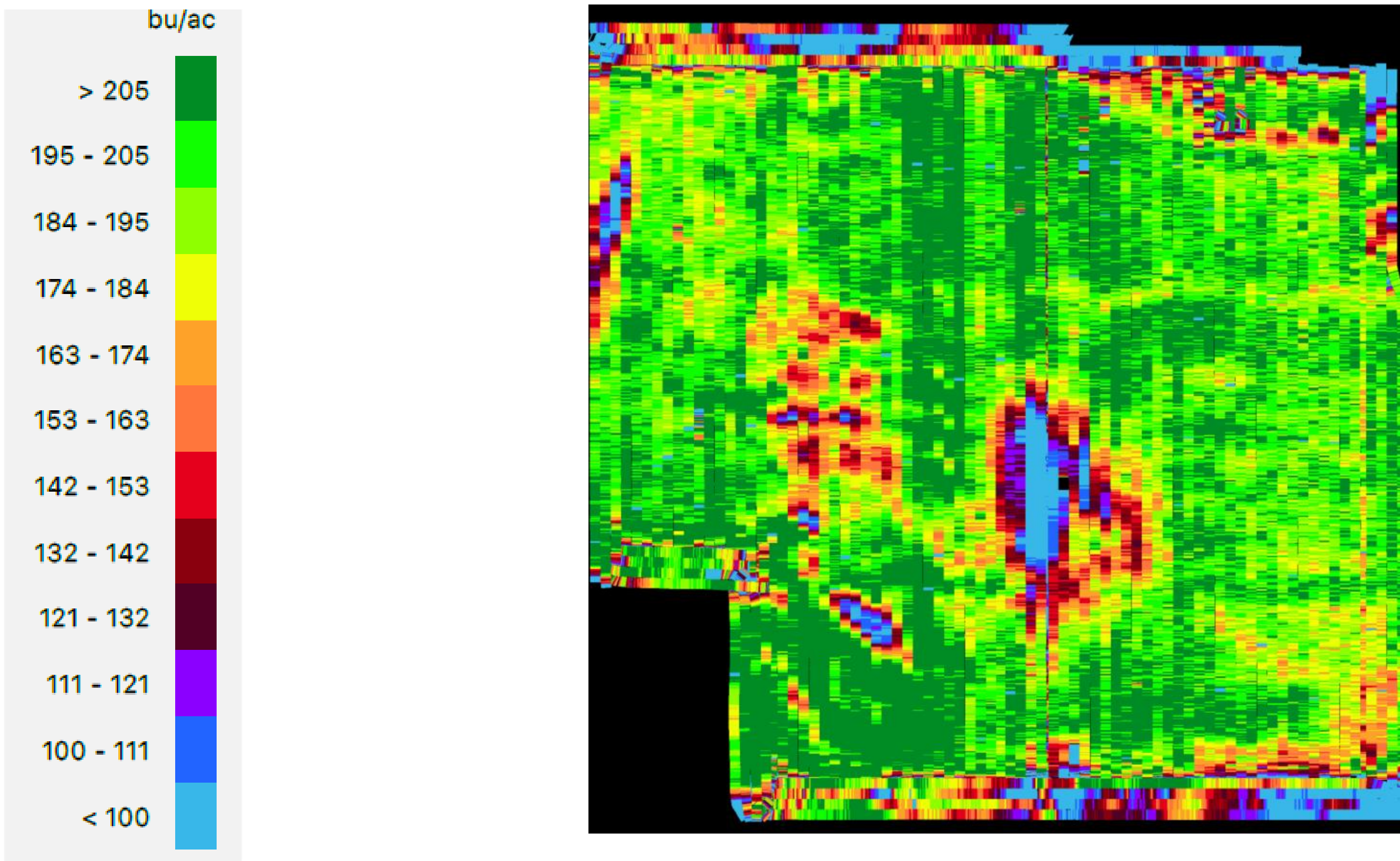
Corn yield 2018

Average 187 bu/acre corn



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Tile drainage project
Saline-sodic soil, Mayville, ND

- Topsoil salinity and sodicity (%Na) consistently reduced past three years
- Subsoil salinity and sodicity (%Na) has not noticeably changed yet
- Saline-sodic area has become smaller, improved corn and soybean yields
- Saline area has not improved, water sits along road ditch and remains wet year-round

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Thank you for your kind attention!

Are there any questions?

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