Soil Erosion Woes: What is tillage costing you?

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Outline

??

What is it?

- US and regional erosion
- 3 types of erosion
  - Wind
  - Water
  - Tillage

So What?

- Less OM
- Less water infiltration
- Lose nutrients
- Crop growth
- Lower yields
- Sedimentation

Now What?

- SH factors
- Tillage
- Keep soil covered

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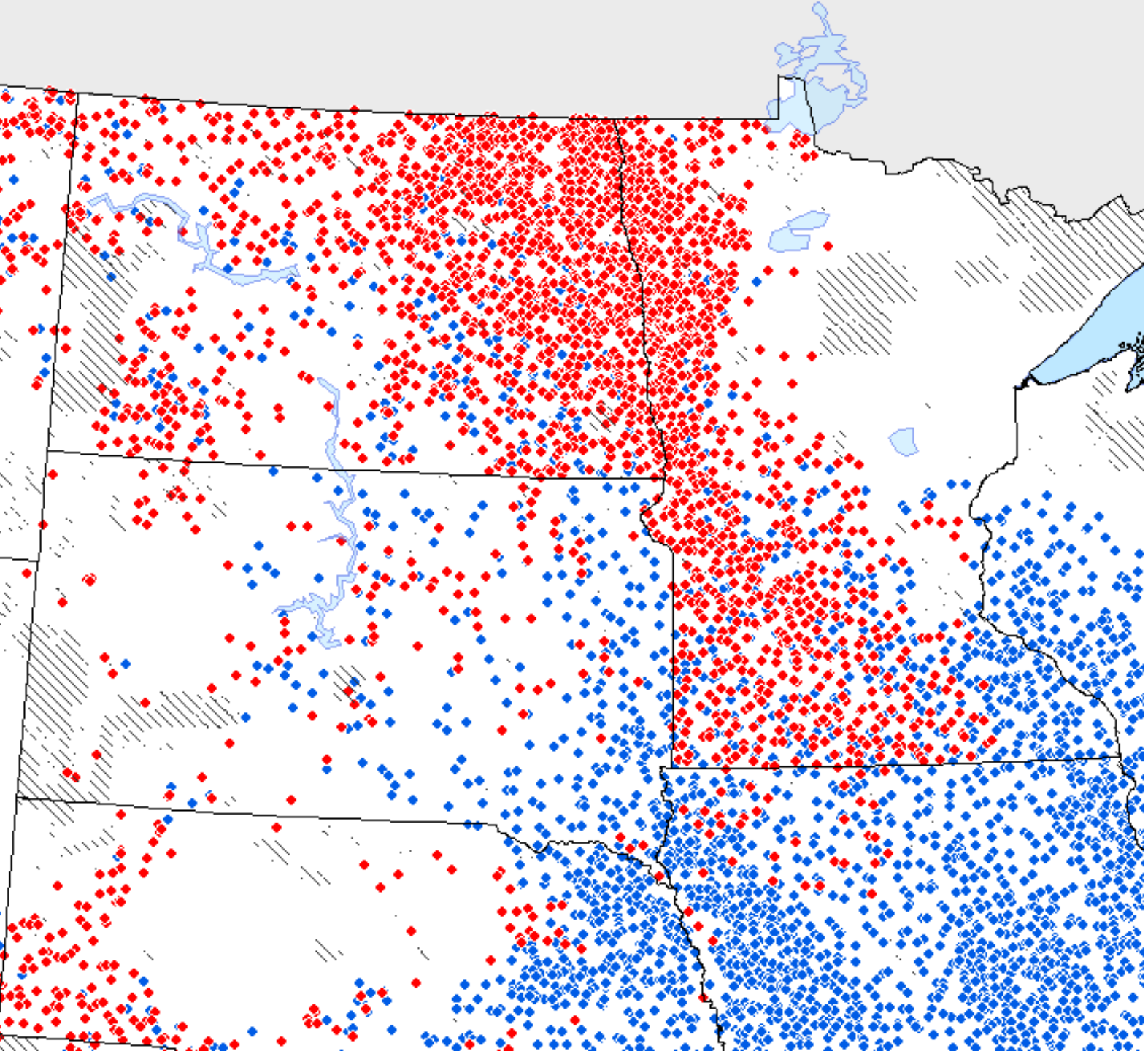


Wind and Water Erosion - 2017

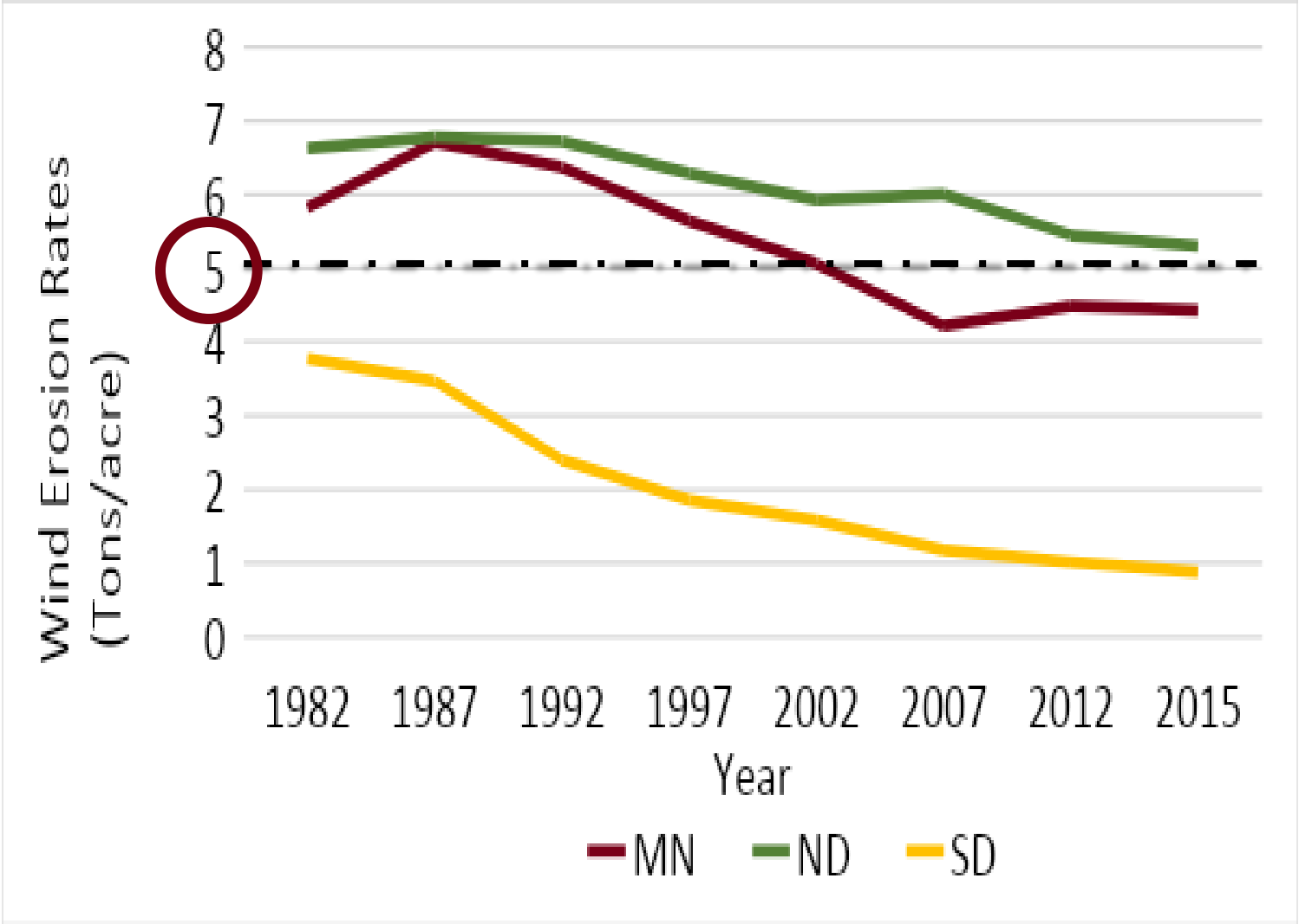
Each dot represents
100,000 tons per year

- Water (Sheet & Rill) Erosion
- Wind Erosion
- Federal Land

USDA-NRCS

Wind Erosion has Improved

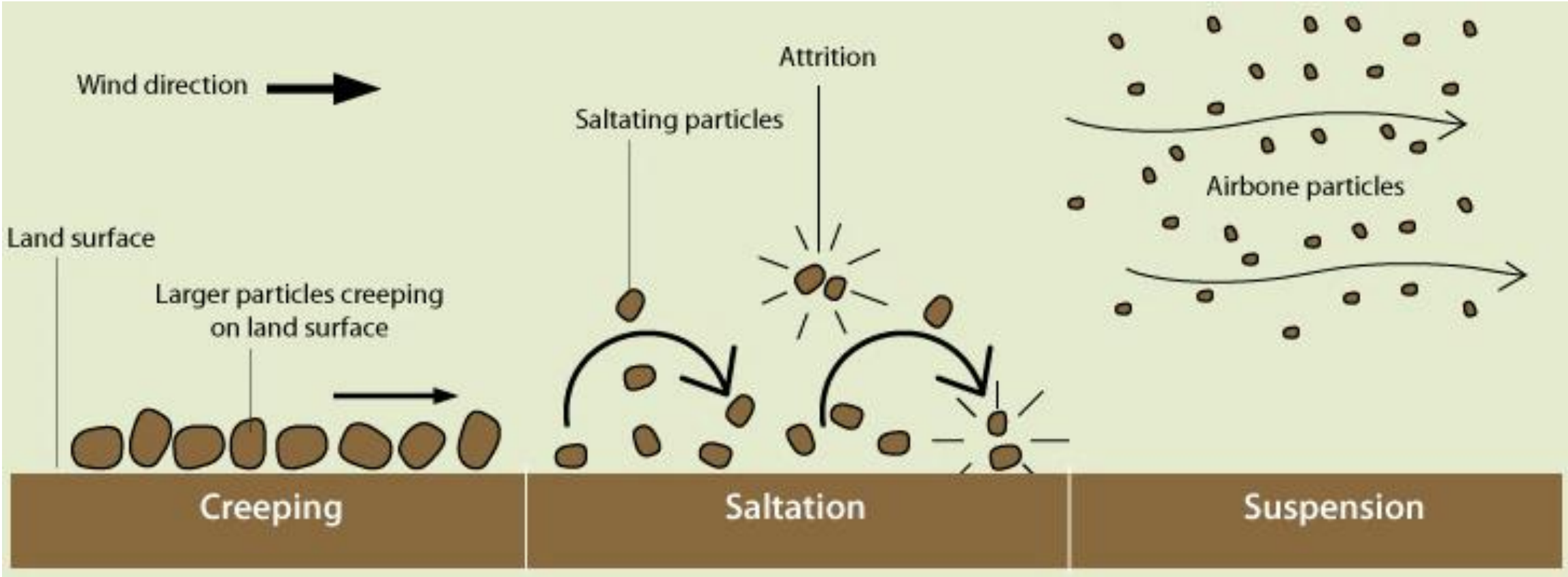
but is still too high in ND and MN



What is Wind Erosion?

Wind can pick up soil particles at 13 mph 1 foot above the soil surface

<25% 50-80% <20%



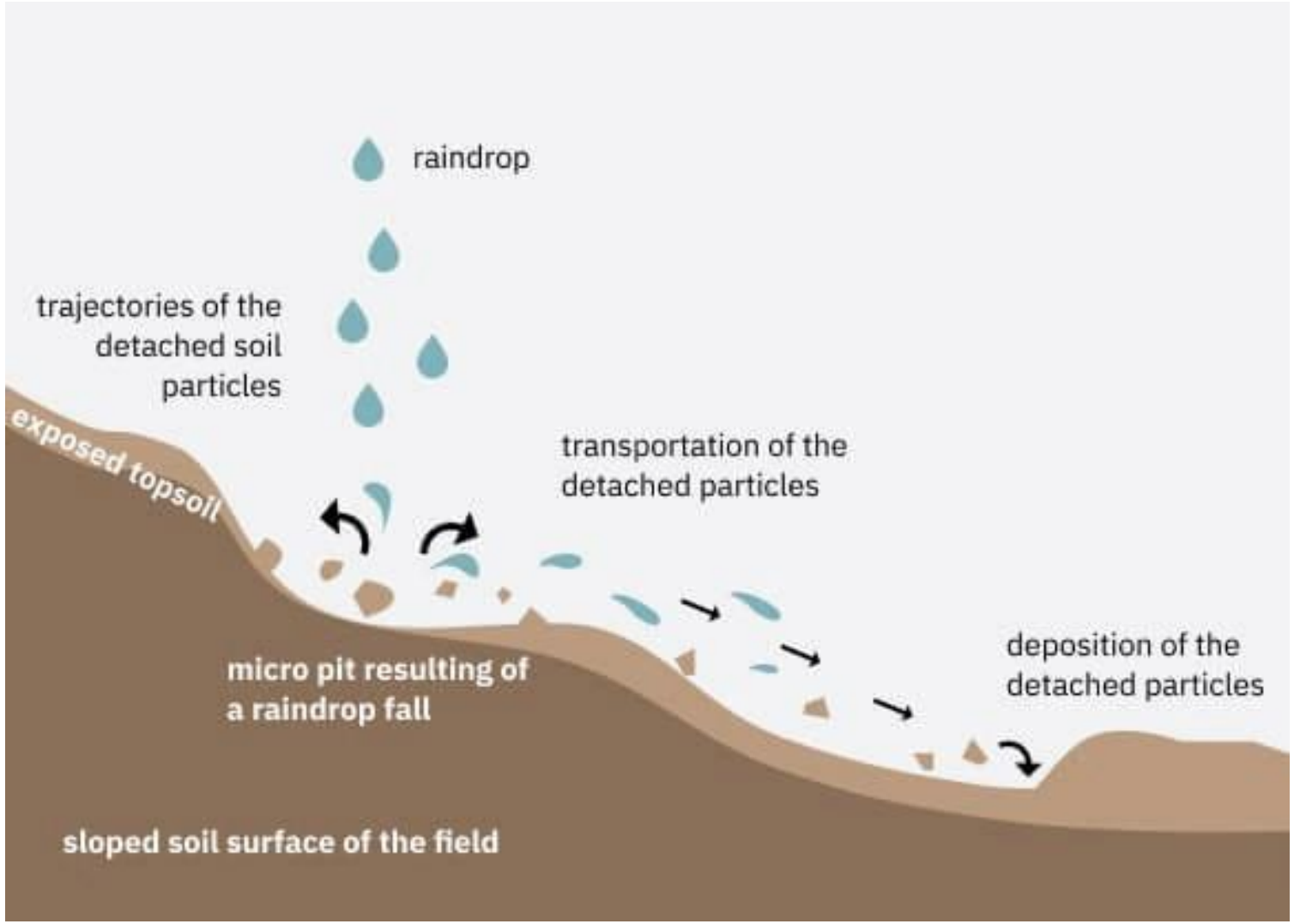
Wind Erosion Factors

1. Wind speed
2. Soil texture
3. Type and timing of tillage
4. Residue or cover crop coverage
5. Unsheltered distance

Photo courtesy of Dorian Gatchell

What is Water Erosion?

Raindrops can throw soil particles almost 5’ downhill



https://eos.com/blog/water-erosion/

Water Erosion Factors

1. Rainfall intensity and duration
2. Soil texture
3. Slope length and steepness
4. Type and timing of tillage
5. Residue or cover crop coverage
6. Farming direction, contour farming

Tillage Erosion

- Moves soil up and forward
- Creates smaller sized particles
- Reduces soil organic matter over time
- Buries residue
- Dries the soil
- Exposes subsoil which is highly erodible

Tillage Erosion Factors

1. Length and steepness of slope
2. Soil texture
3. Tillage implement
   - depth
   - aggressiveness
   - number of passes
   - tractor speed

Photo courtesy of Micheal Lindstrom, ARS, Morris, MN

Erosion Removes Organic Matter

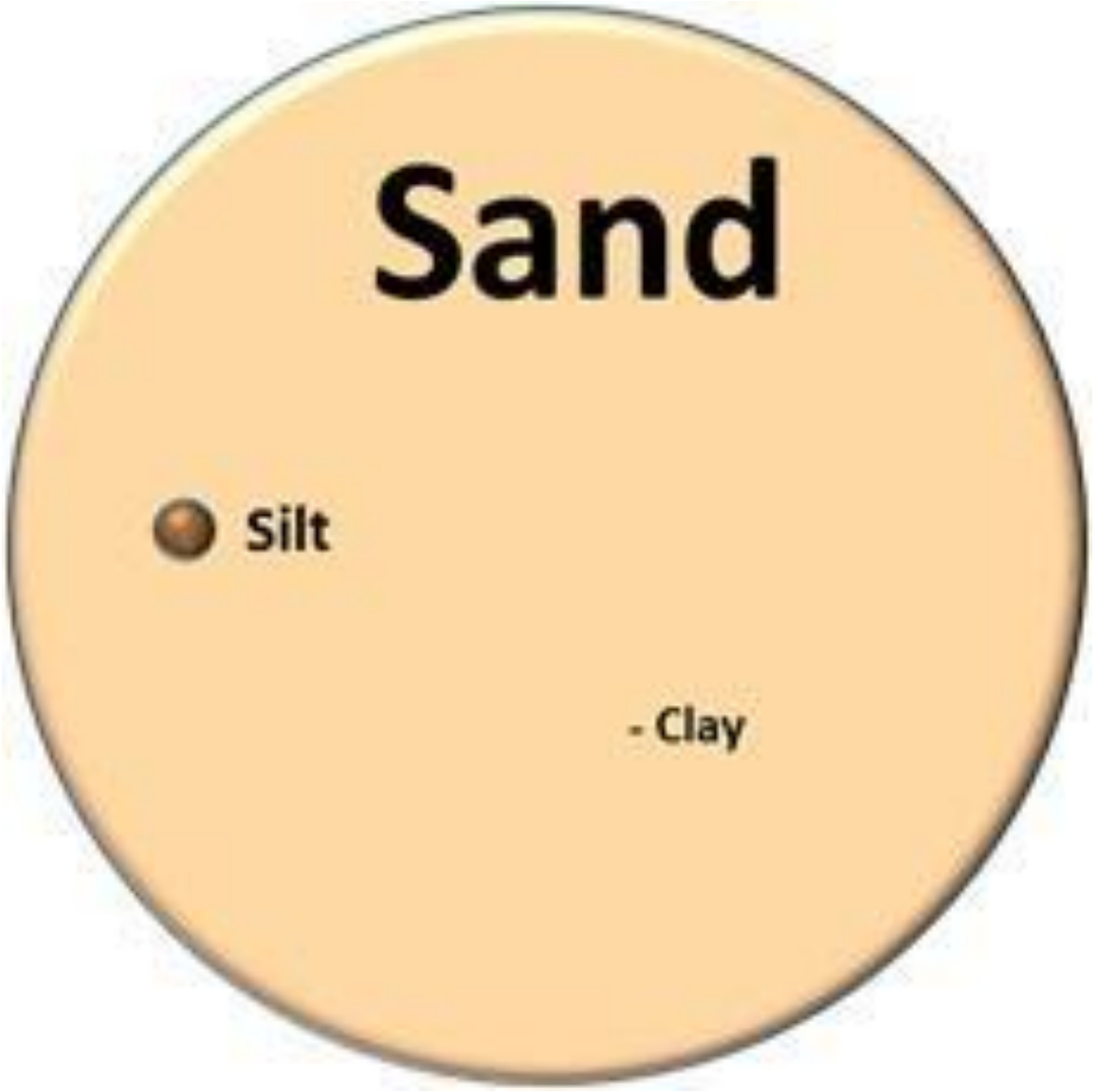
1. Less aggregates
   - Higher bulk density
   - More crusting and compaction
2. Less water infiltration
   - Less water for plants
   - Less water to recharge groundwater
3. Delay emergence and plant development
4. Loss of nutrients (N, P, S)

= REDUCED YIELD

Soil Erodibility

Texture

- Clay is microscopic and is more prone to suspension
- Sand moves mainly by surface creep and saltation



Clay particles can move 1,000’s of miles

Photo: Dorian Gatchell

Slope

The steeper and longer the slope- the more energy water will have

But can happen in a flat field

Photo courtesy of Jonathan Wolff

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Annual Cost of Erosion Across Corn Belt

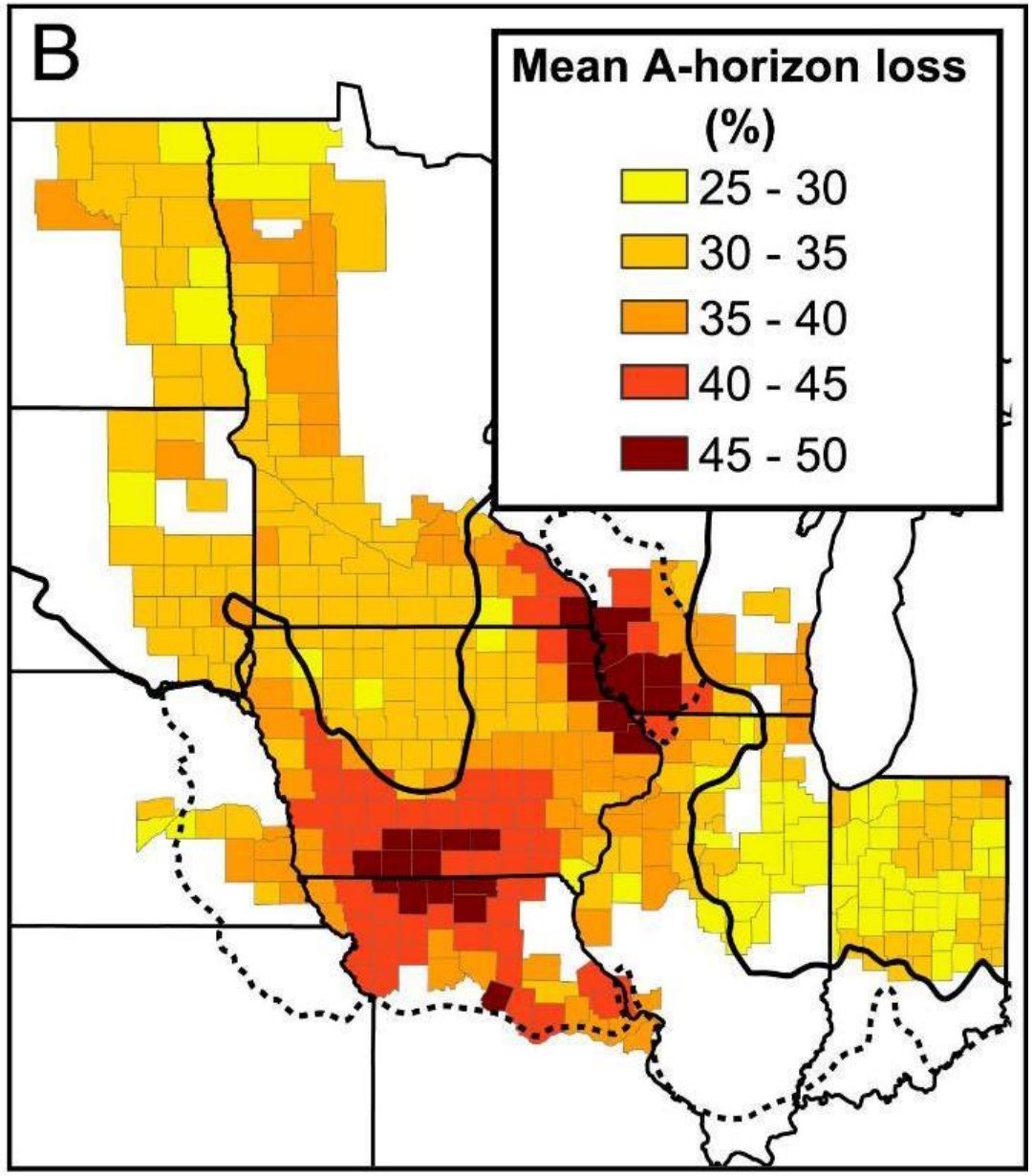
- 35% of the region has lost its most fertile topsoil
- Average of 6% reduction in crop yields per year
- Resulting in annual loss of $2.8 billion per year

Thaler et al, 2021

Loss of Topsoil

Comparing crop land to areas of native forest or prairie

30% of 20” = 6.6 inches of lost soil!



https://www.pnas.org/doi/10.1073/pnas.1922375118

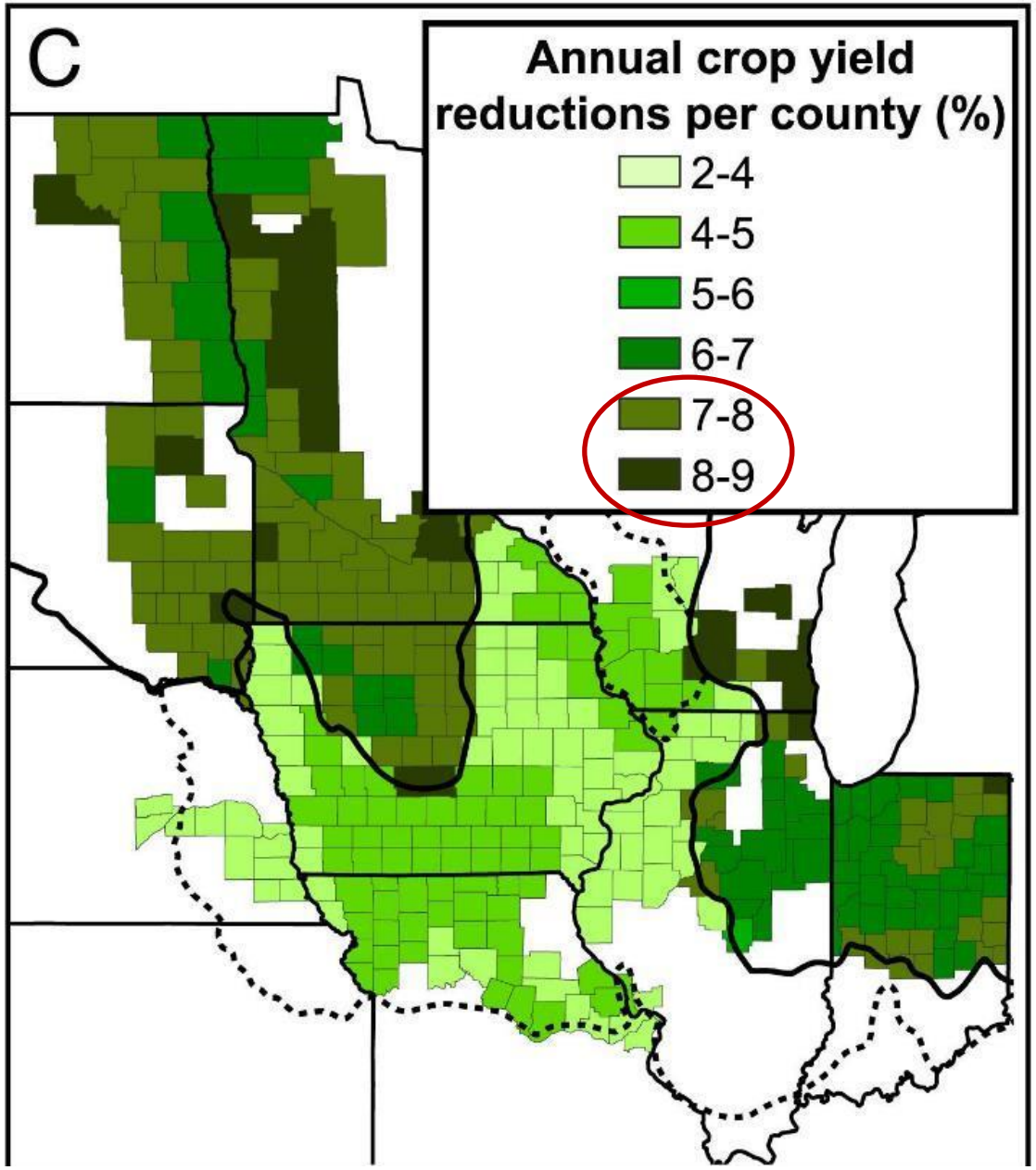
Yield Loss

Glaciated land have lower yields (darker green) due to erosion than non-glaciated land (light greens)

8% yield loss

200 bu/ac corn = 16 bu/ac

50 bu/ac beans = 4 bu/ac



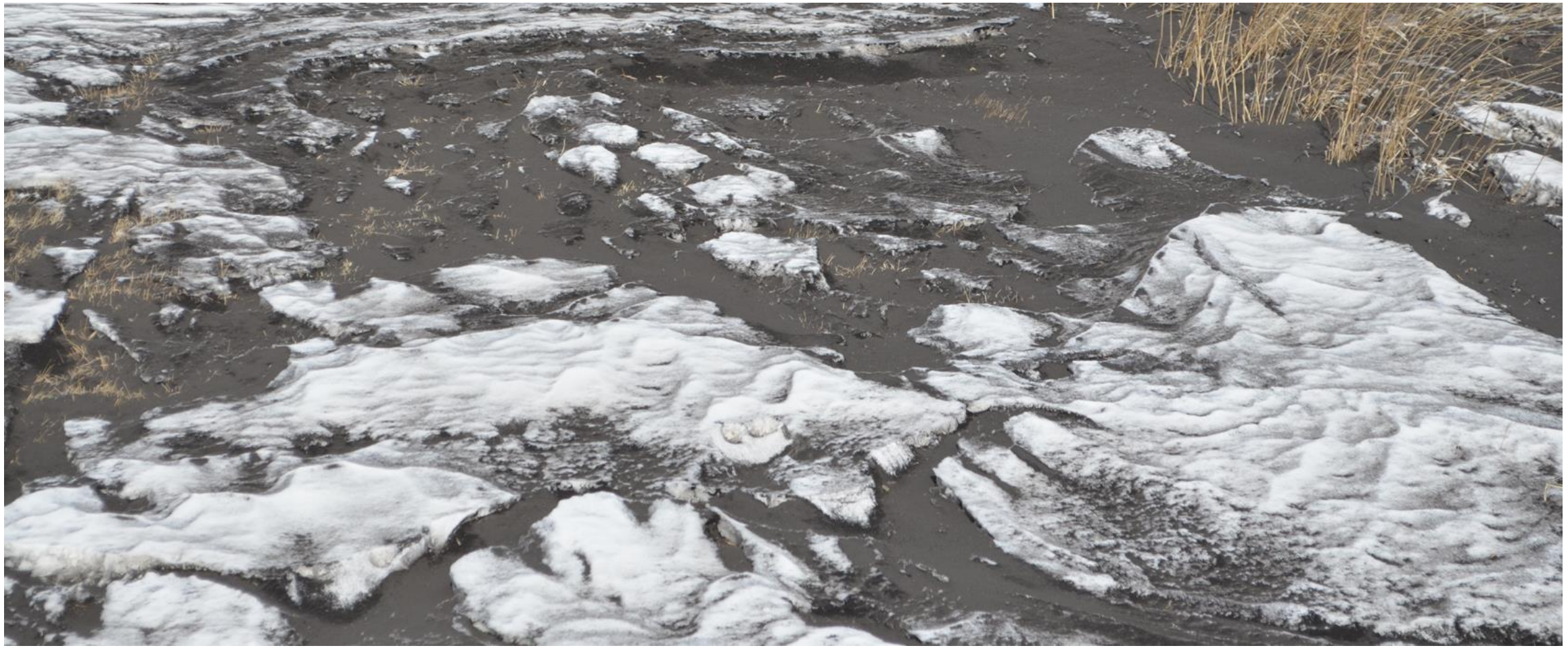
https://www.pnas.org/doi/10.1073/pnas.1922375118

5T/ac is a Tolerated Soil Loss

40 Acres = ***16 dump trucks*** of soil!

400,000 pounds of soil!

Nutrients Lost with Wind Erosion



2014 Sample	Soil Loss (pounds)
1	3,200
2	5,200
3	5,600
4	11,000
5	18,600
6	65,200
AVE	**18,200**

J. DeJong-Hughes and D. Gatchell

Nutrient	Low (3,200 #)	Ave (18,200 #)	High (65,200 #)
Anhydrous ($550/T)	$2.31	$15.13	$47.55
MAP ($583/T)	$0.55	$3.67	$13.67
Potash K_20 ($406/T)	$0.99	$7.45	$25.25
Total	**$3.86**	**$26.25**	**$86.47**

Loss not including the B, Fe, Mn, Mg, Cu, Ca, Co, N

J. DeJong-Hughes and D. Gatchell

Washes away soil and nutrients

Soil Loss Due to Water Erosion and Tillage Method

	Runoff (inches)
MBP	5.2
CP/FC	4.8
NT	4.2

Average of 10 Iowa soils at 5% and 9% slopes

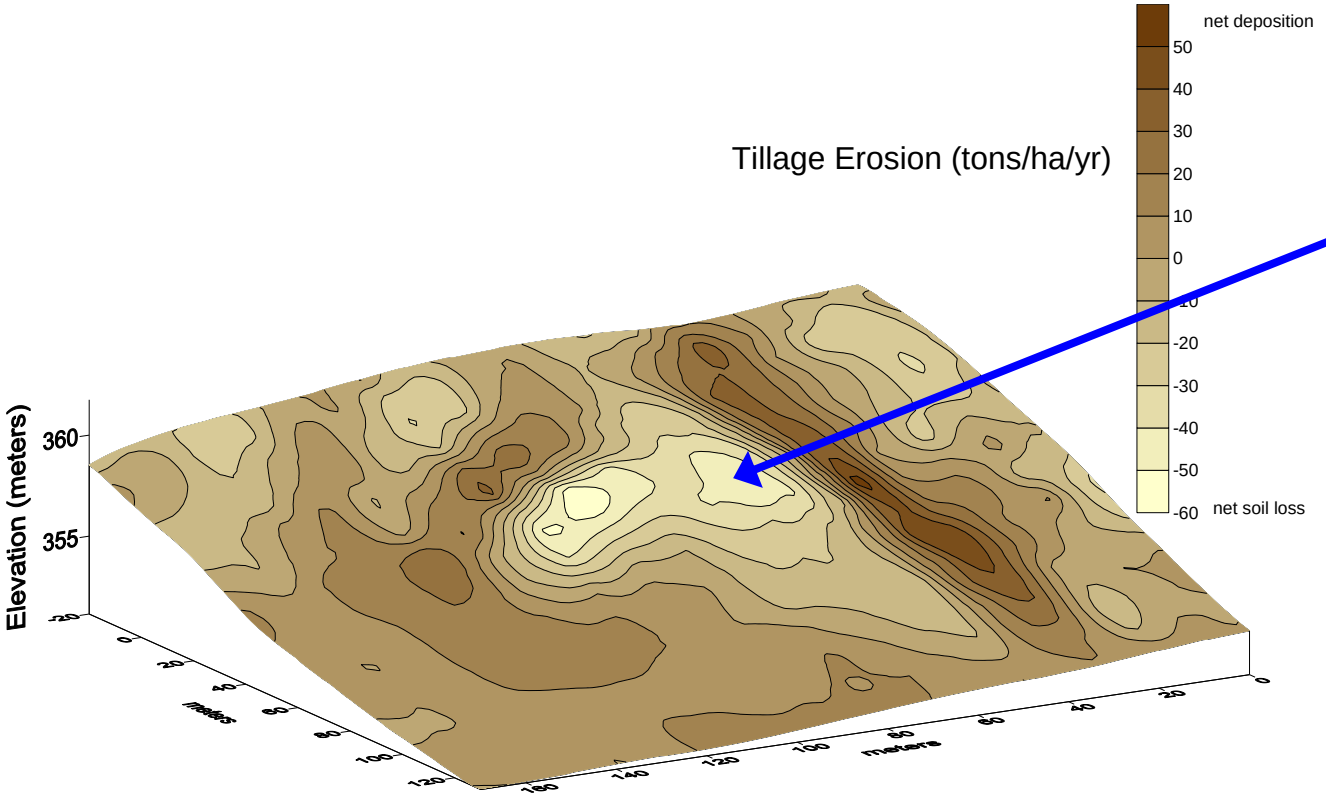
Effects of Erosion Control Practices on Nutrient Loss. Czapar et al. U of IL

Tillage Erosion Study W. Minnesota

Water, wind and tillage erosion

Long term MBP field

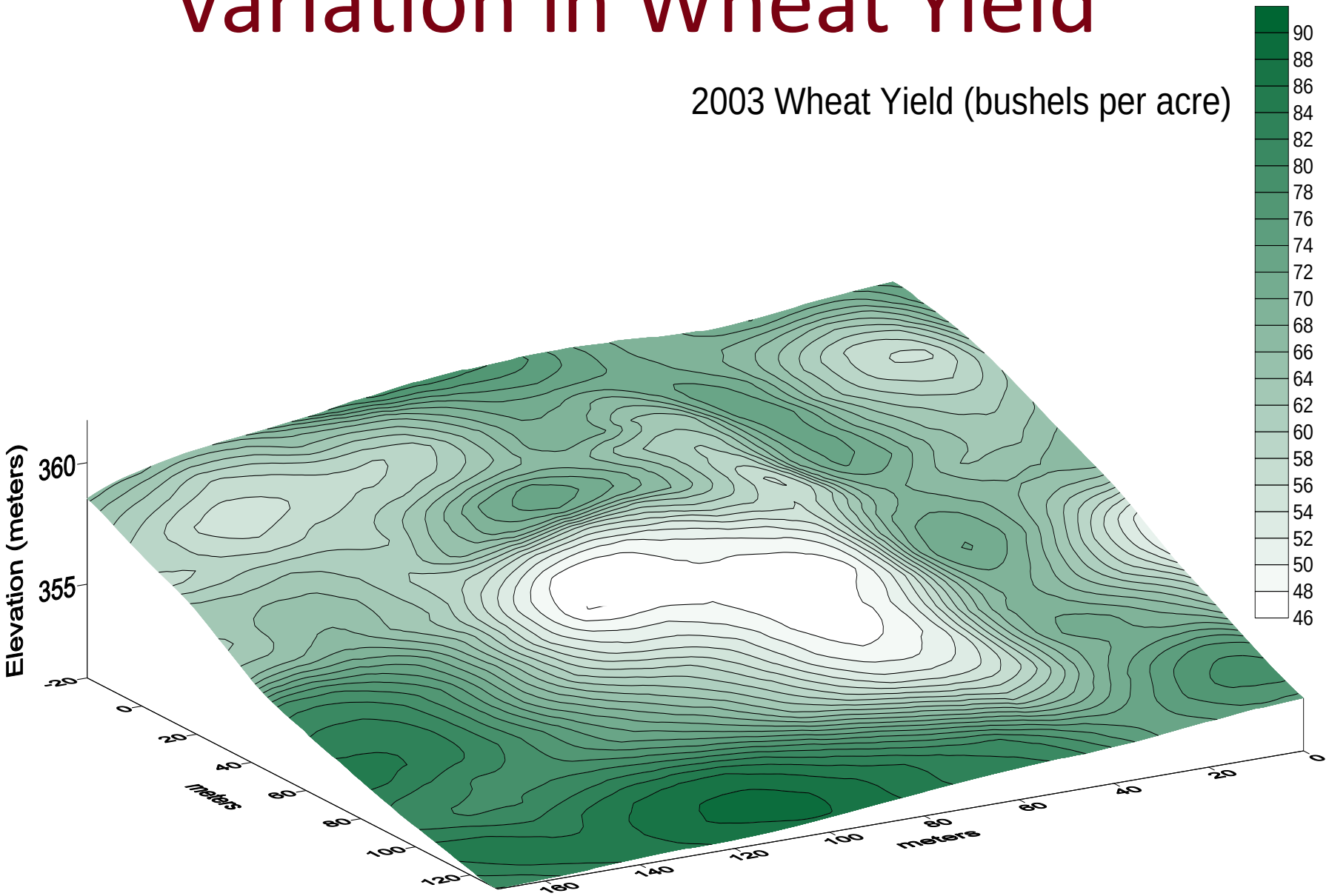
Lindstrom et al, USDA-ARS in Morris MN



Net soil loss by tillage erosion exceeded 27 T/ac/yr

Lindstrom et al, USDA-ARS in Morris, MN

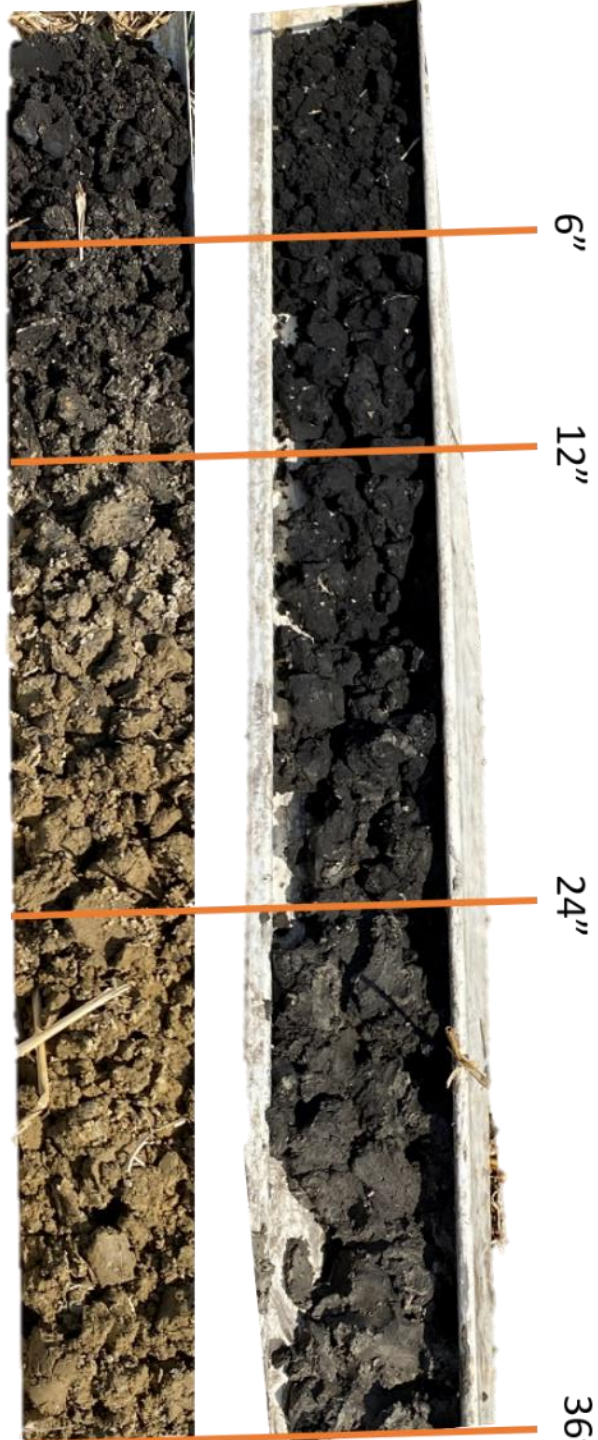
Variation in Wheat Yield



Lindstrom et al, USDA-ARS in Morris

How do you manage this much variation?

	Eroded Area	Bottom of Slope
Organic Matter	1.3%	4.0%
pH	8.4	7.3
Phosphorus	6 ppm	20 ppm
Potassium	115 ppm	175 ppm



Can Fertility Make-up for Soil Loss?

Sometimes

But fertilizer does not make up for lost organic matter or water infiltration and storage

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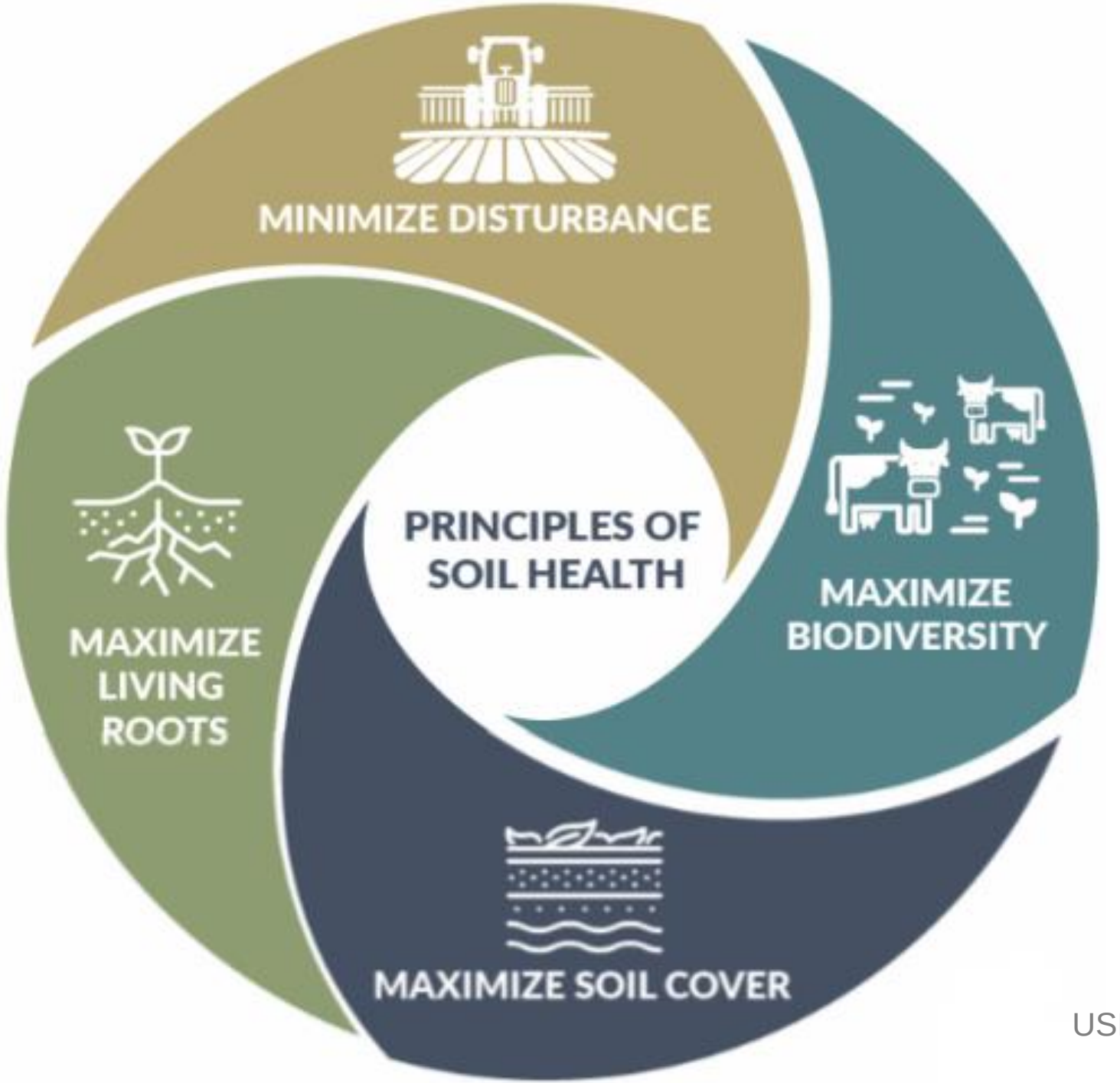

MINIMIZE DISTURBANCE
MAXIMIZE BIODIVERSITY
MAXIMIZE SOIL COVER
MAXIMIZE LIVING ROOTS
PRINCIPLES OF SOIL HEALTH

USDA-NRCS

Maximize Soil Cover

-single most important factor influencing erosion

Soil Structure/Aggregation

Tillage

Residue and Cover Crops

- protects soil from raindrop impact
- decreases soil detachment
- decreases soil crusting and sealing
- decreases velocity of water and wind
- increases infiltration

Soil cover (%)	*Relative soil loss reduction (%)*
0	0
10	35
20	60
30	70
40	80
50	85
60	90
70	93
80	96
90	98
100	99

UNL, Wind Erosion and Its Control #G1537, March 2010

40-50% soil cover can reduce wind erosion by 80%

May 2017 Crop Residue Satellite Data

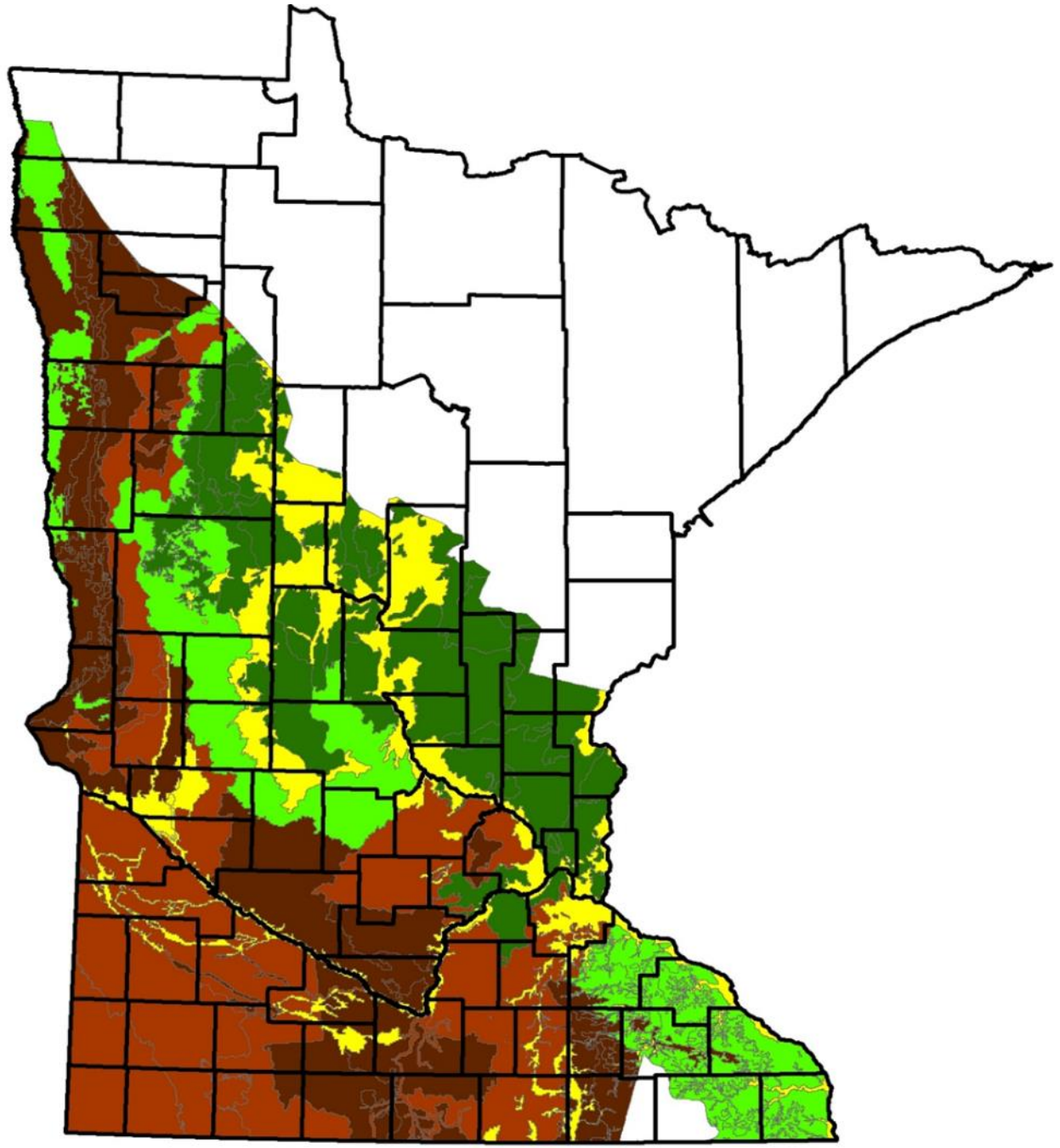
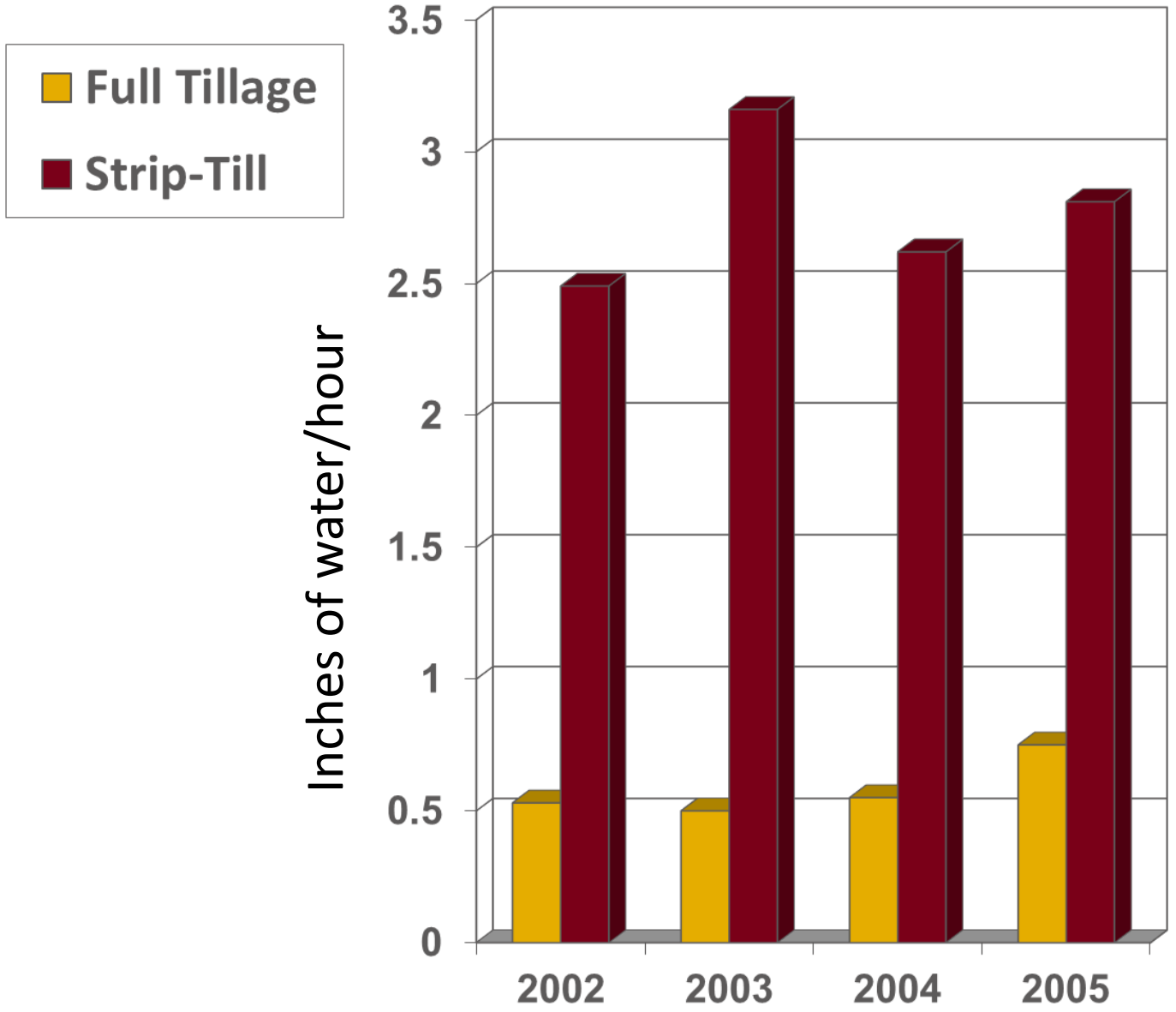


Figure by Matt Drewitz, BWSR

Standing Residue

- Act like straws, quickly soaking in rain
- 5x more effective than flat residue

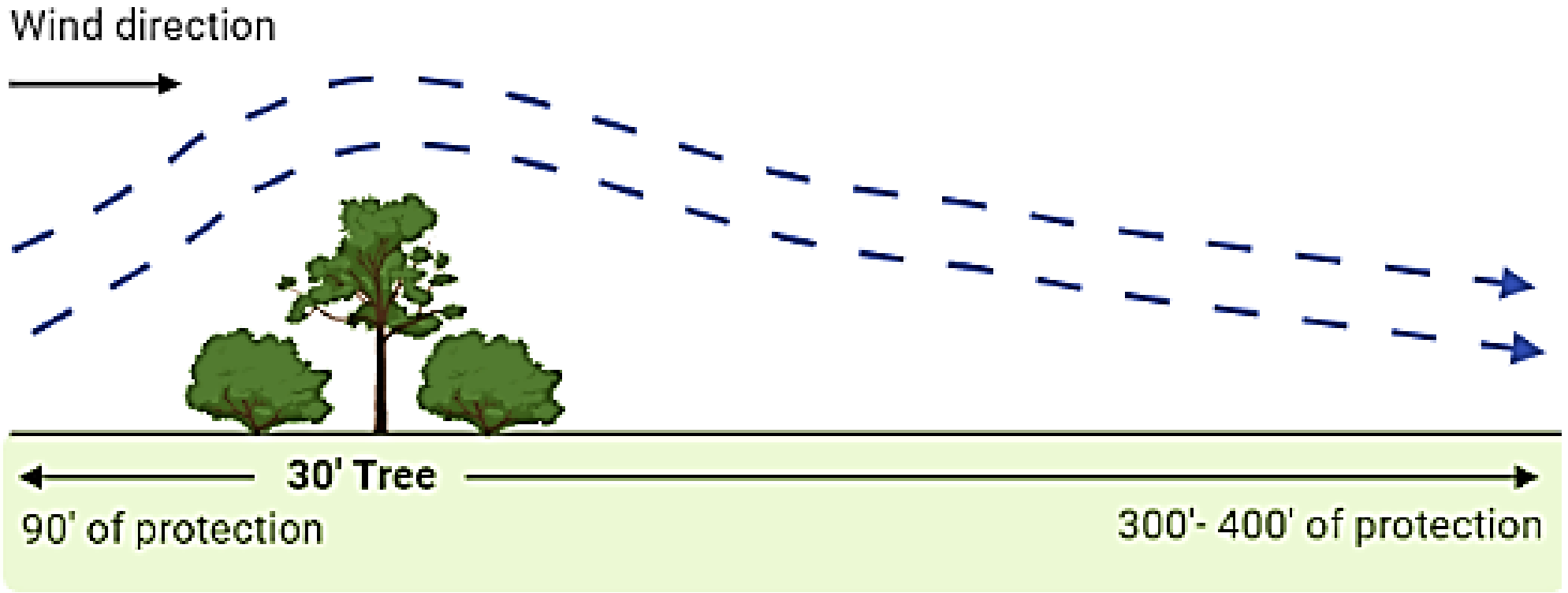


Standing Residue Improves Water Infiltration

Measurements with Cornell Sprinkle Infiltrometer on moist soil IRF – Irrigation Research Foundation – Yuma, CO

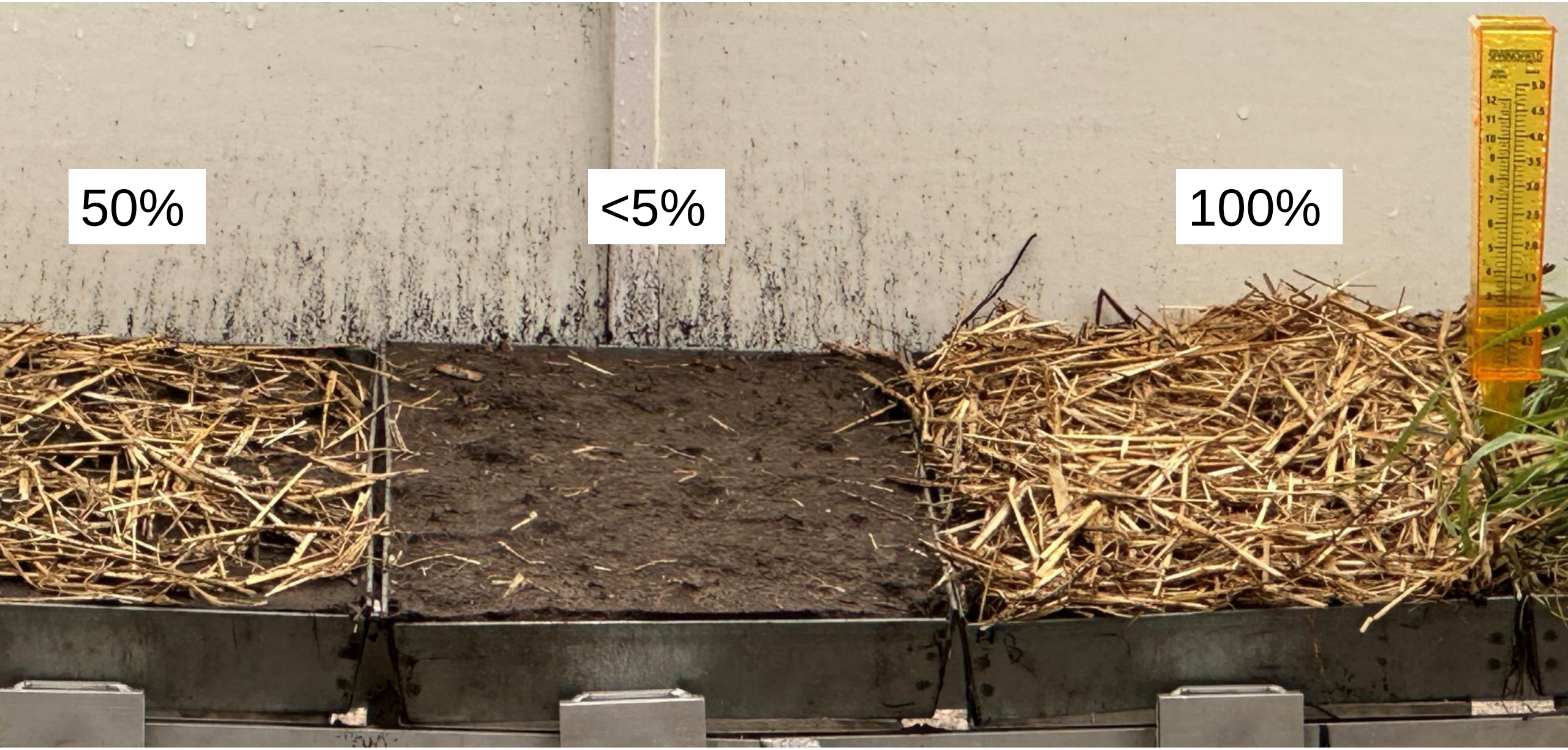
Unsheltered Distance (when residue isn't enough)

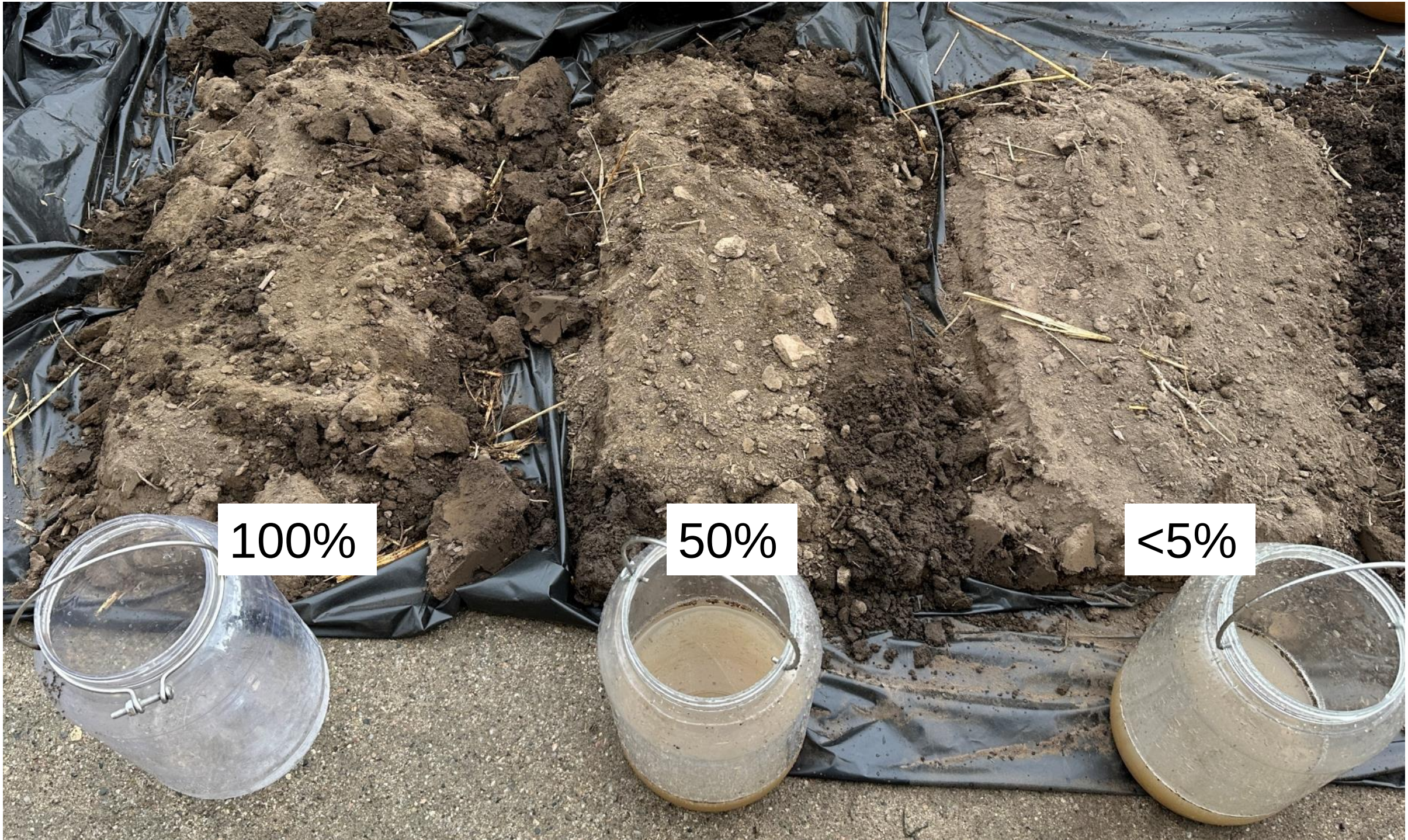
Wind can pick up speed and intensity along flat landscapes. Shelterbelts protect the leeward soil for a distance of 10x the height of trees.




Infiltration in back jars
Run off in front jars


Infiltration
Run off


50%
<5%
100%


100%
50%
<5%

Minimize Soil Disturbance

- Less tillage
- Add cover crops
- Add manure

Points and Shanks:

- Lifts and separates the soil
- Less destruction of soil aggregates
- Less erosion potential

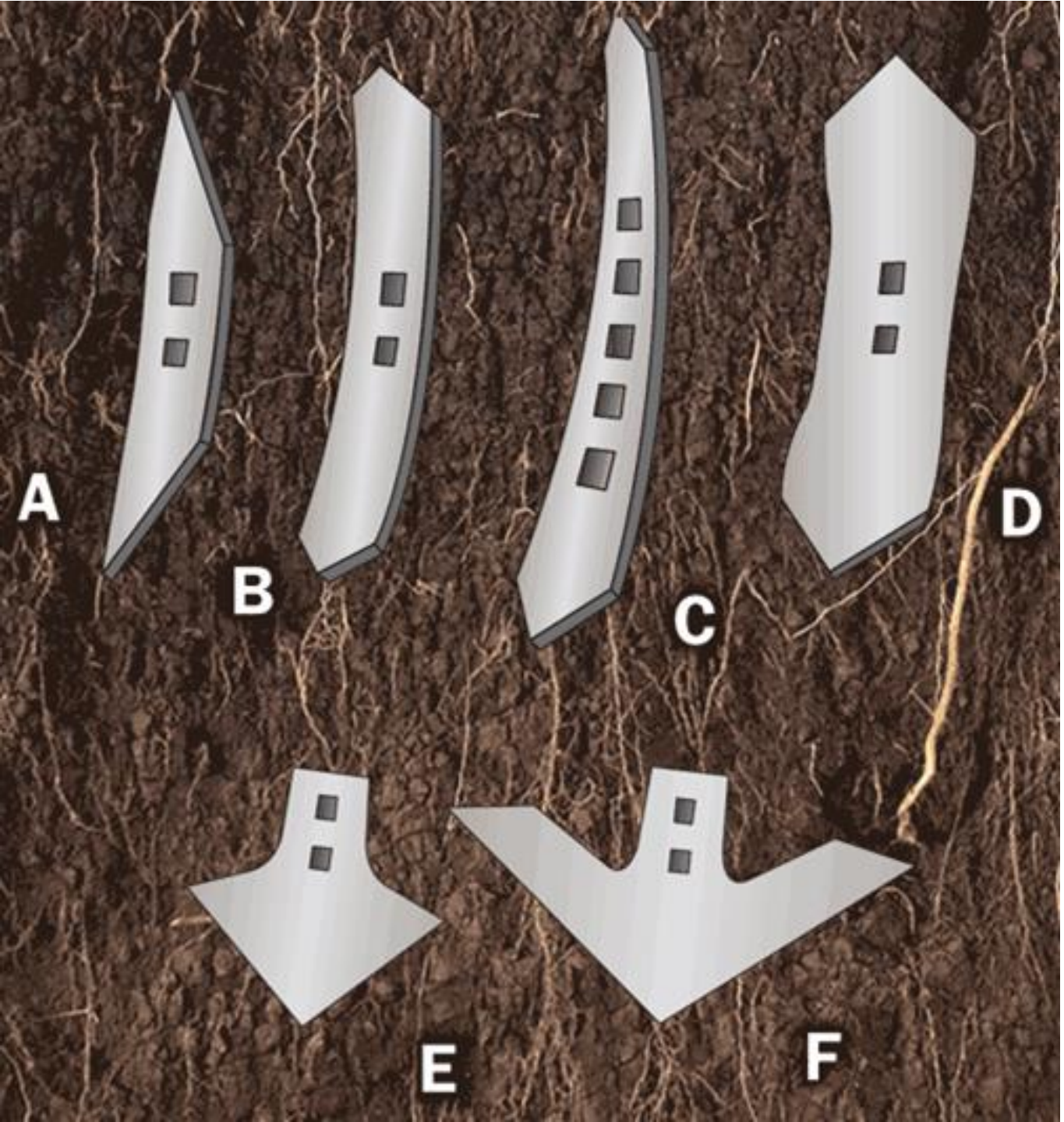
Disks

- Shears and cuts the soil
- Destroys more structure than shanks
- Higher erosion potential

Chisel Plow

- 6-9” deep
- Full field tillage
- Conventional tillage
- Varies in aggressiveness
- Slower speeds than shallow tillage

Photo courtesy of Dick Wolkowski, UW



Chisel Plow Points

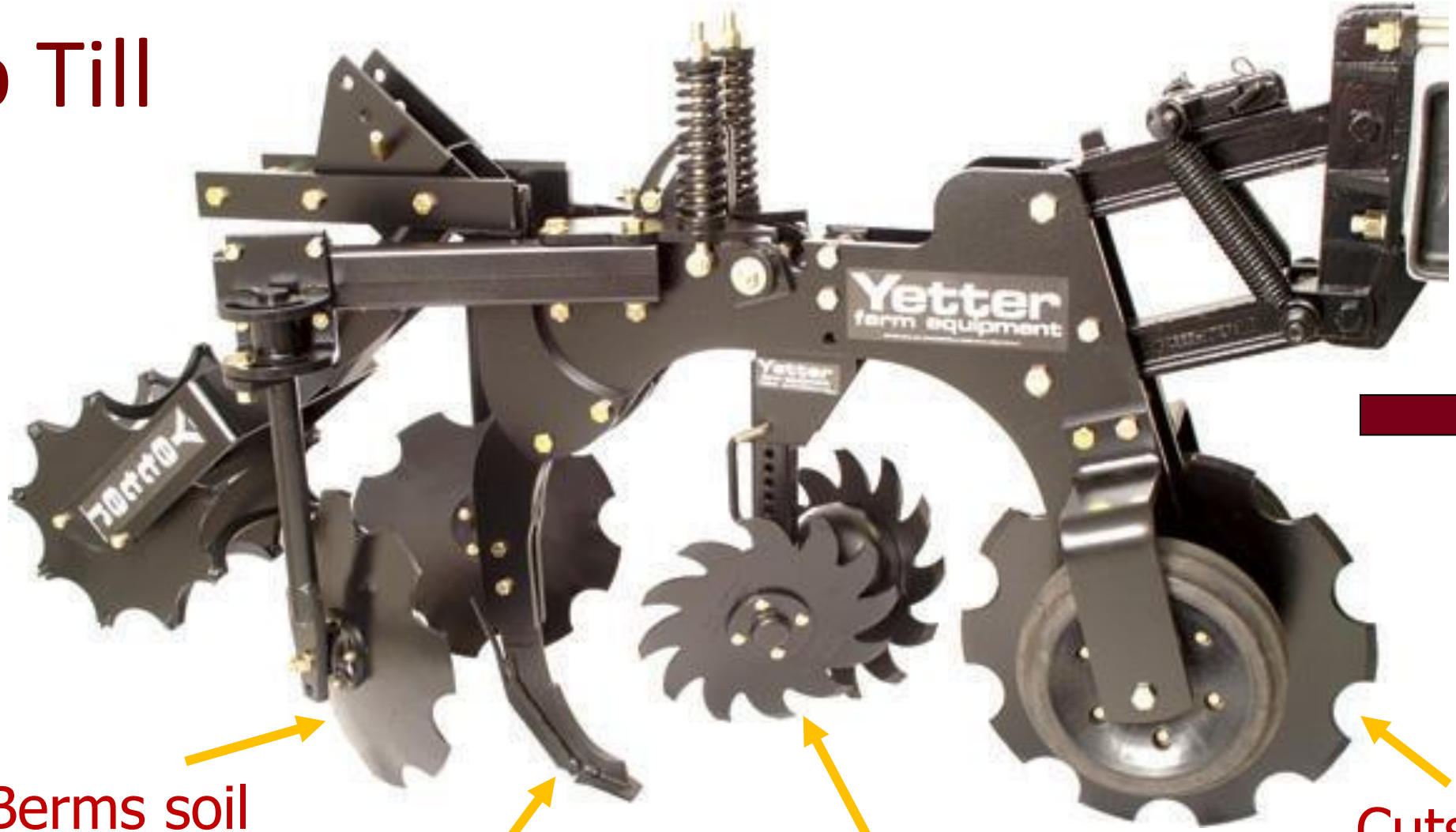
- Soil disturbance
- Depth
- Residue burial
- Smeared soil potential

Twisted Shovel vs. Sweep

Provided by Dick Wolkowski, UW)

Strip Tillage

Strip Till



Berms soil

Tills and injects fertilizer (6-8”)

Moves residue

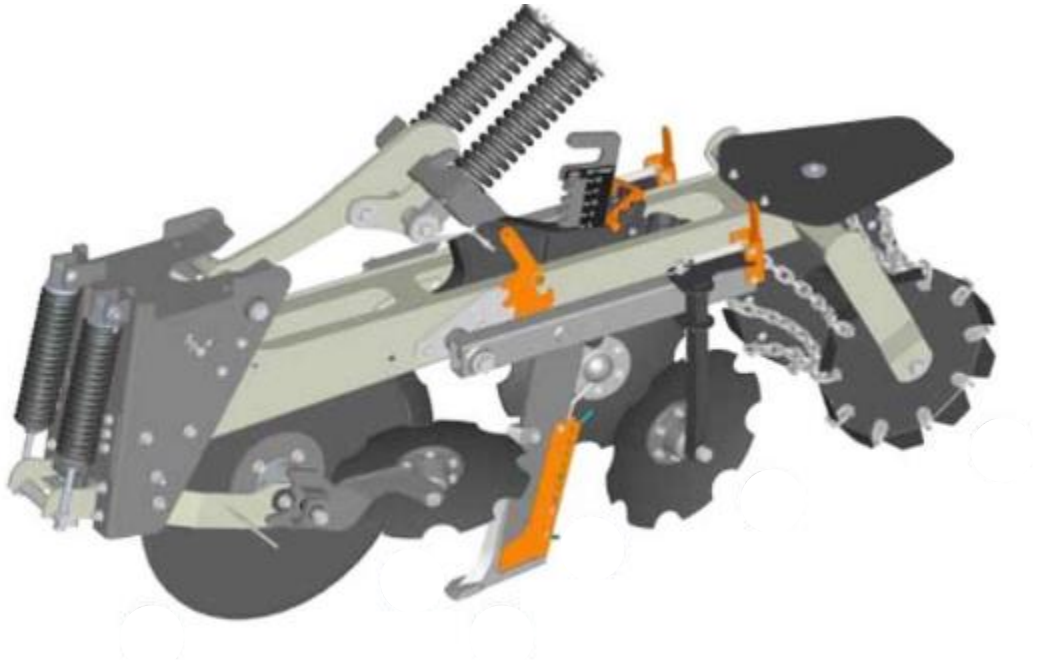
Cuts residue

Disturbs only 1/3 of the soil

Leaves 60% of stalks standing

Plant and fertilize into tilled area

Stalks can protect against wind damage to crops



Shanked Strip Till Units

Best for fall use

Banded nutrients

More tillage

Residue moved out of berm

Deeper tilled zone (6-8”)

Don’t forget to purchase rock trippers

Coulter
Strip Till Units

Fall and Spring usage

Fertilizer mixed in 5” x 5”

Residue chopped and mixed

Less aggressive tillage

Success Starts with the Combine

Even distribution of chaff and straw =

- Even temp and moisture
- Better planter performance
- Even germination

Photo: Dorian Gatchell, MN Ag Services

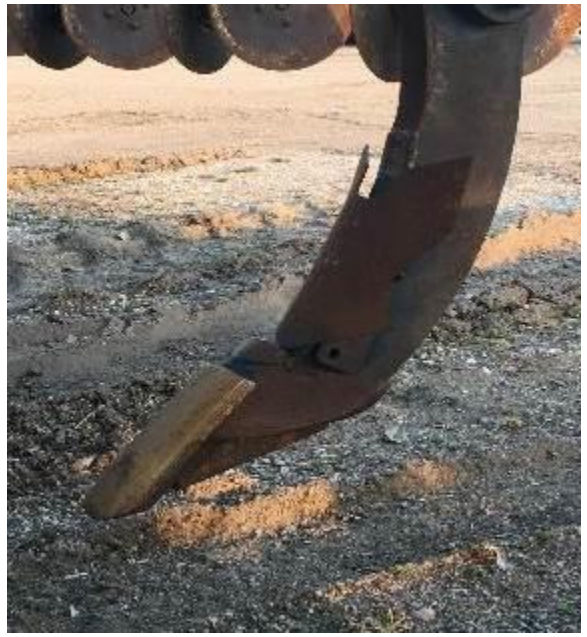
Many Add-on Products to Assist

Disk Ripper

Disk Ripper

- 10-16” deep
- Different sized shank options
- Very aggressive tillage
- Deep tillage but more residue remaining than chisel plow

Soil movement ahead of shanks



Emergency Wind Erosion Control

- Need to chunk up the soil
- Do not use disks or deep equipment
- Take off rolling baskets and straight tine harrows
- Use S tine harrow or non-aggressive field cultivator
- Drive slow

Reduced Tillage Concern

Yield Will Suffer

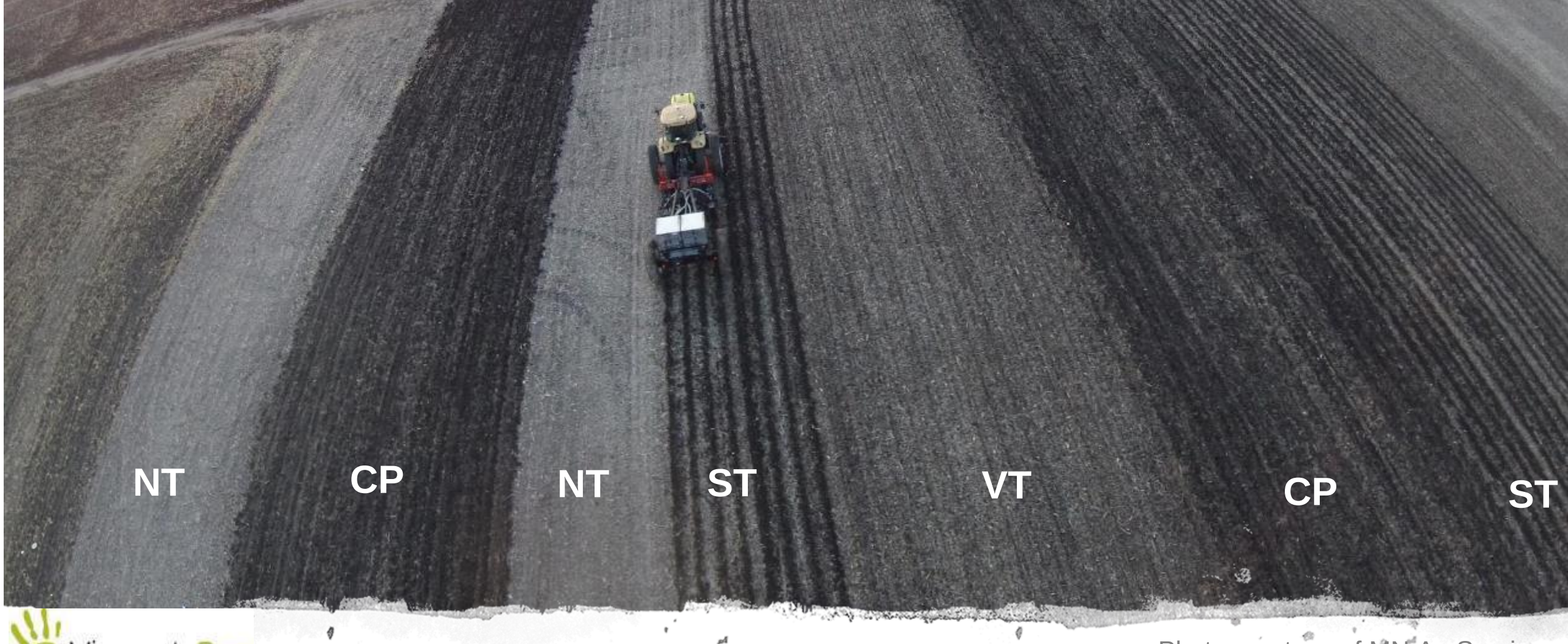


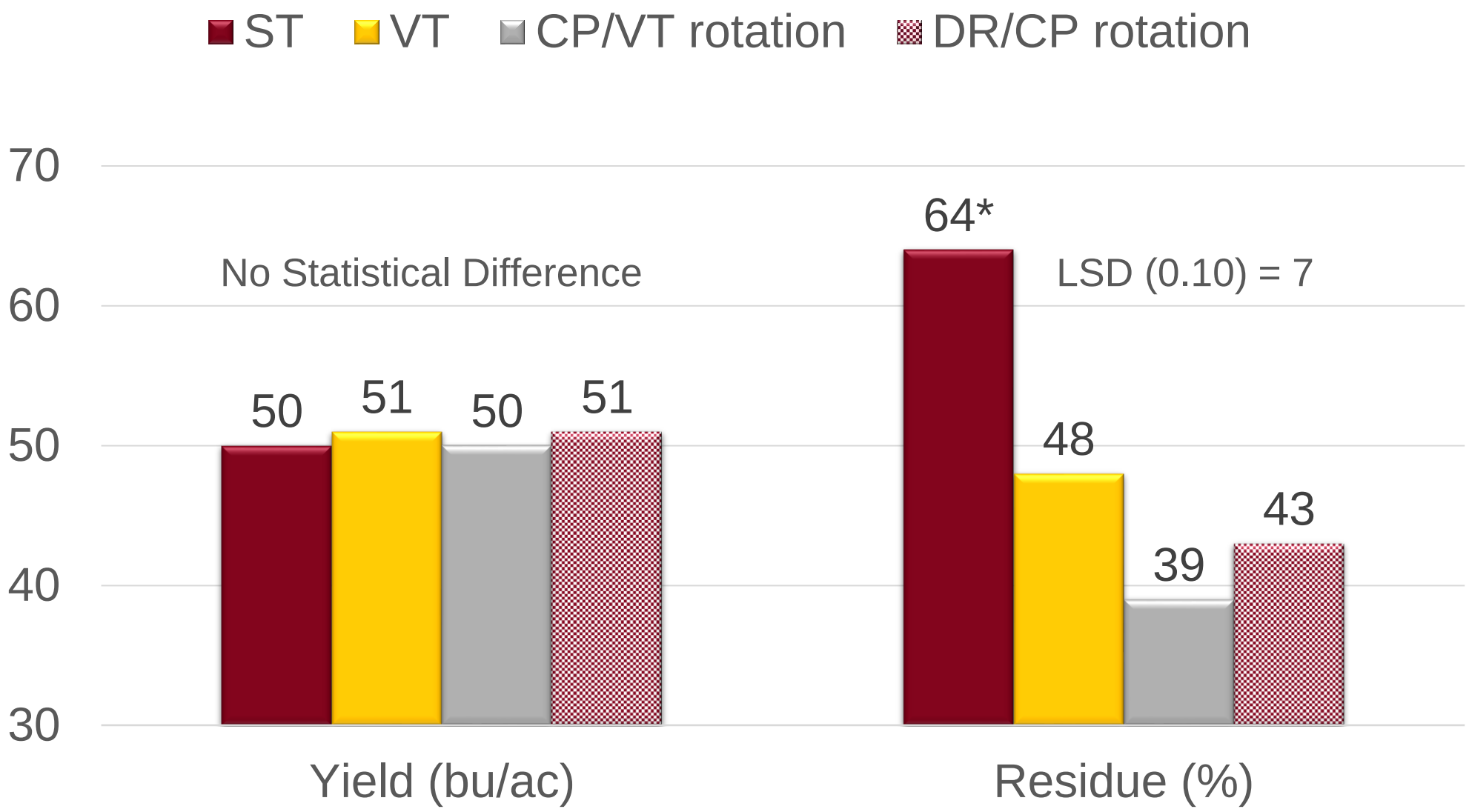
Photo courtesy of MN Ag Services

MinnesotaCorn GROWERS ASSOCIATION

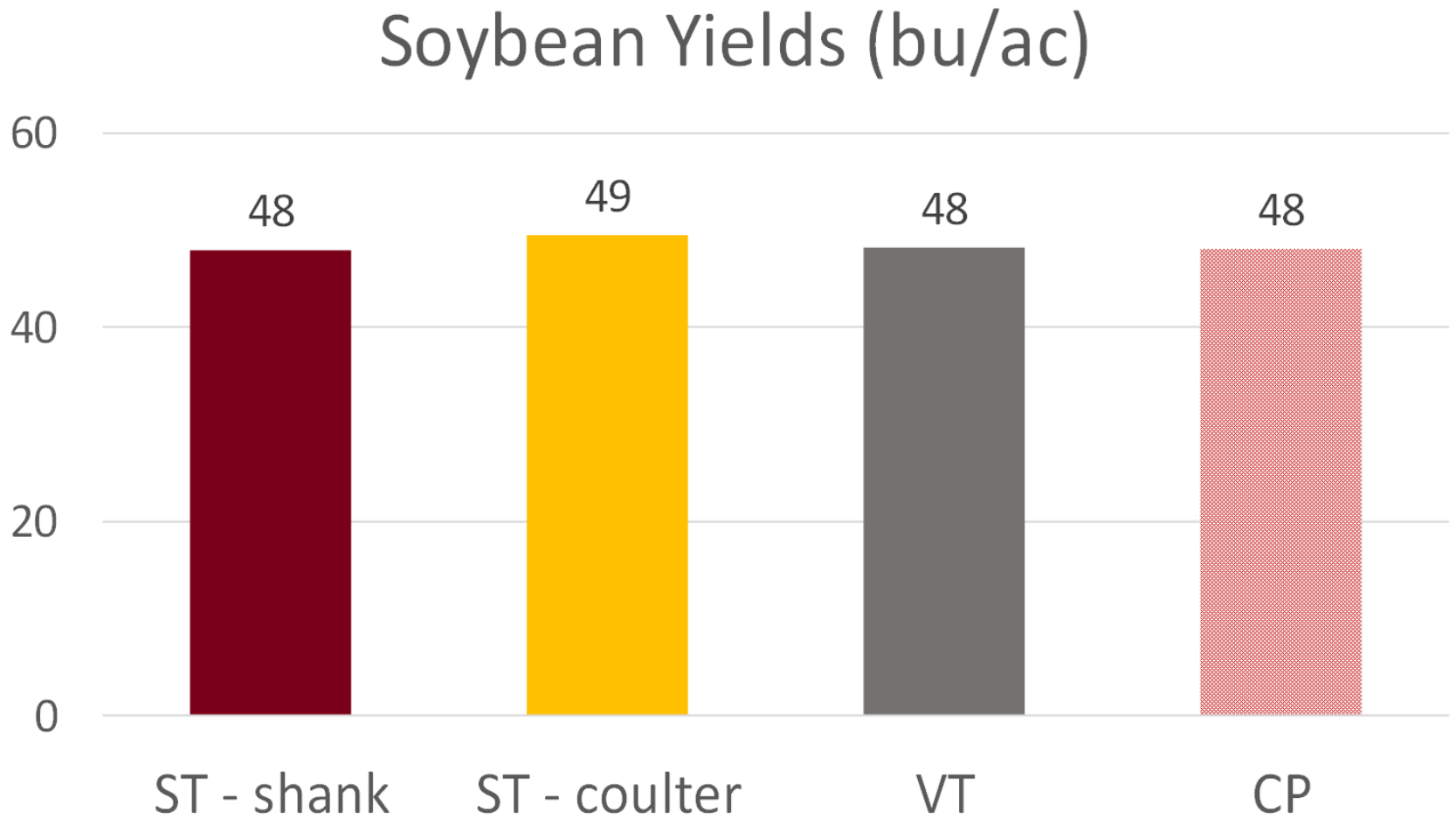
MINNESOTA SOYBEAN

UMN Research – 90% Conducted in Farmer's Fields

3-Year Yield and Residue Averages in WC MN (2010-12)

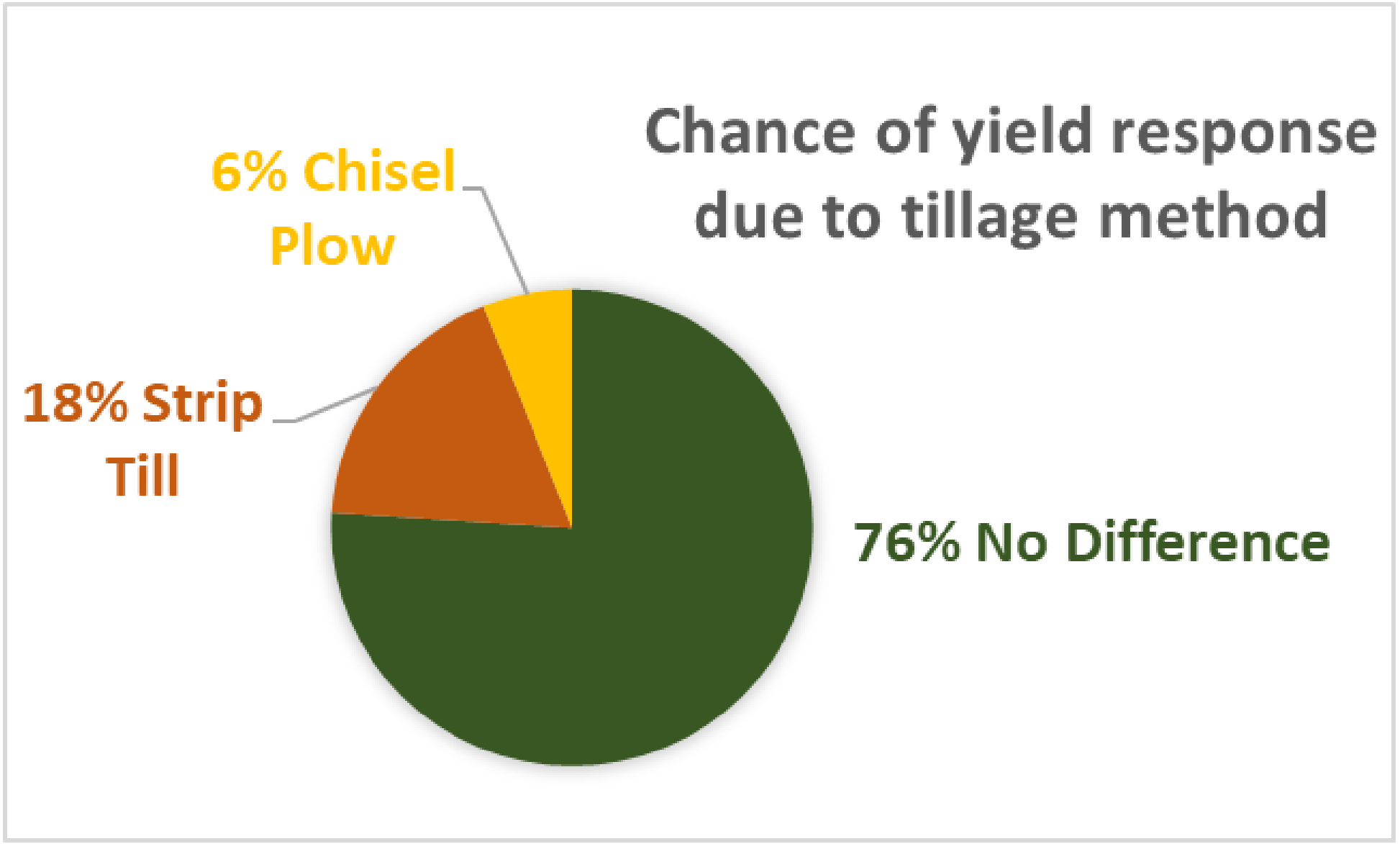


4 Site Years of Soybean Yields
Fergus Falls and Barney (2015-18)



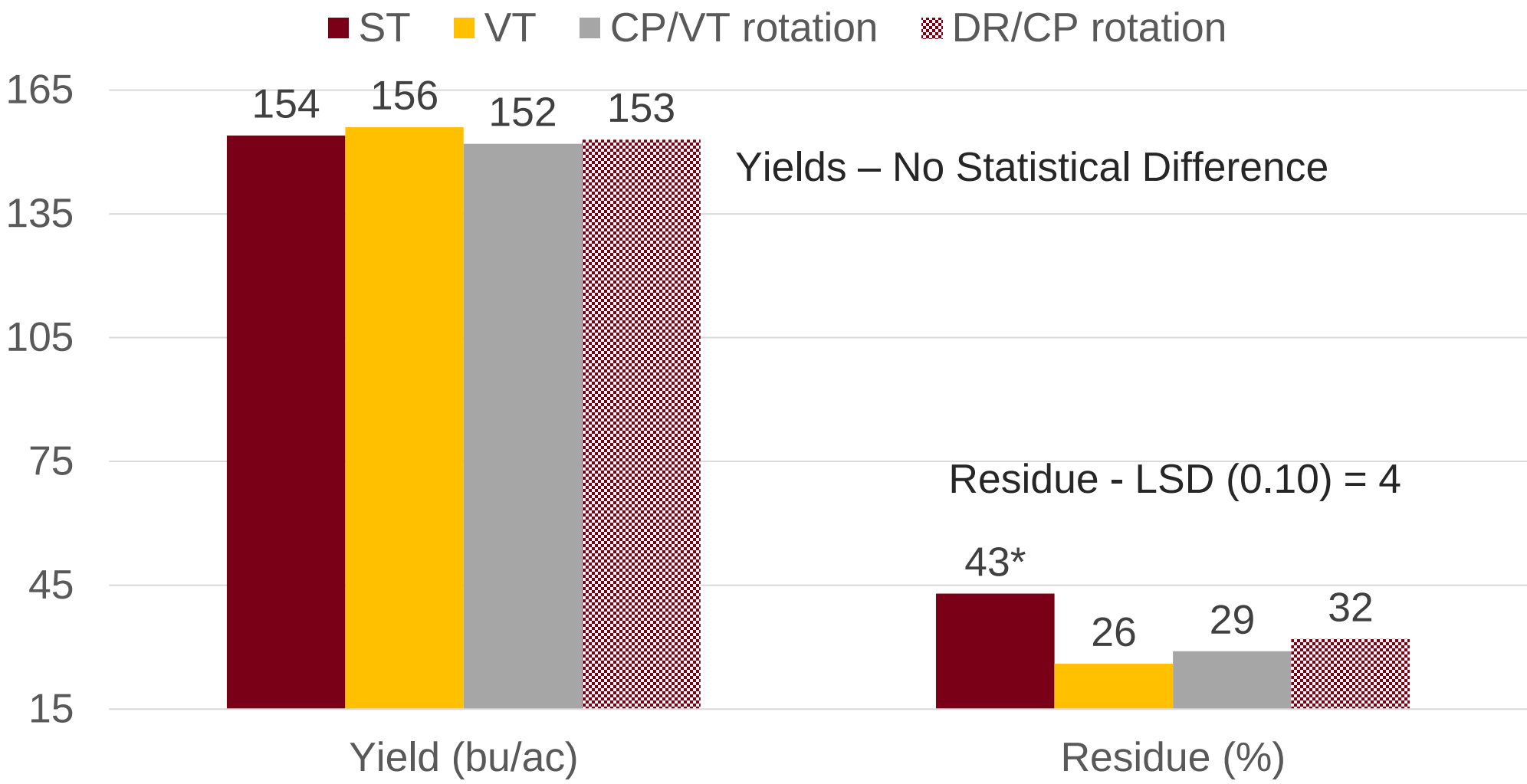
No statistical difference

DeJong-Hughes, Daigh, Gatchell

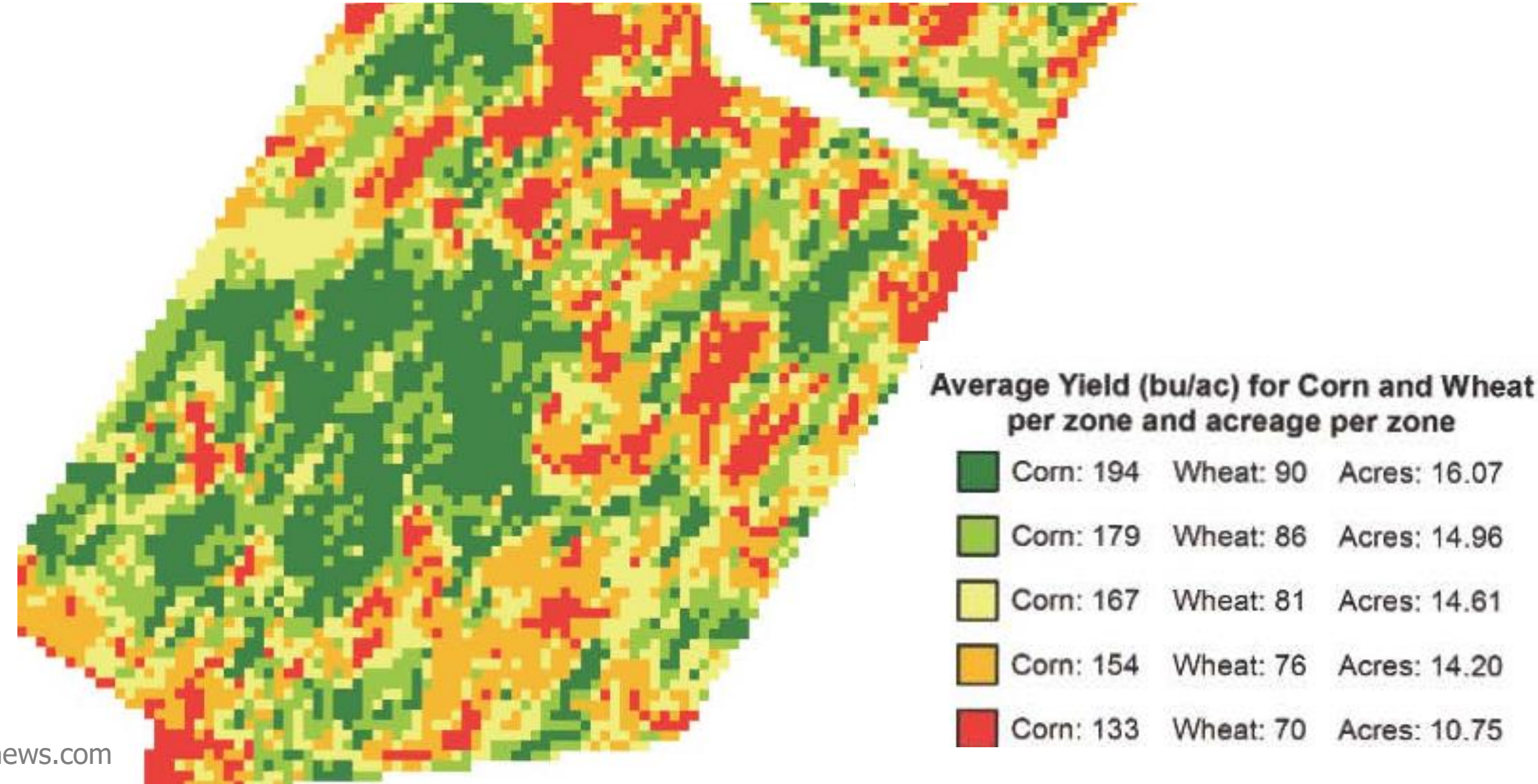


Soybean yield response to tillage for 17 site years in E. North Dakota and NW Minnesota (2005 – 2012)

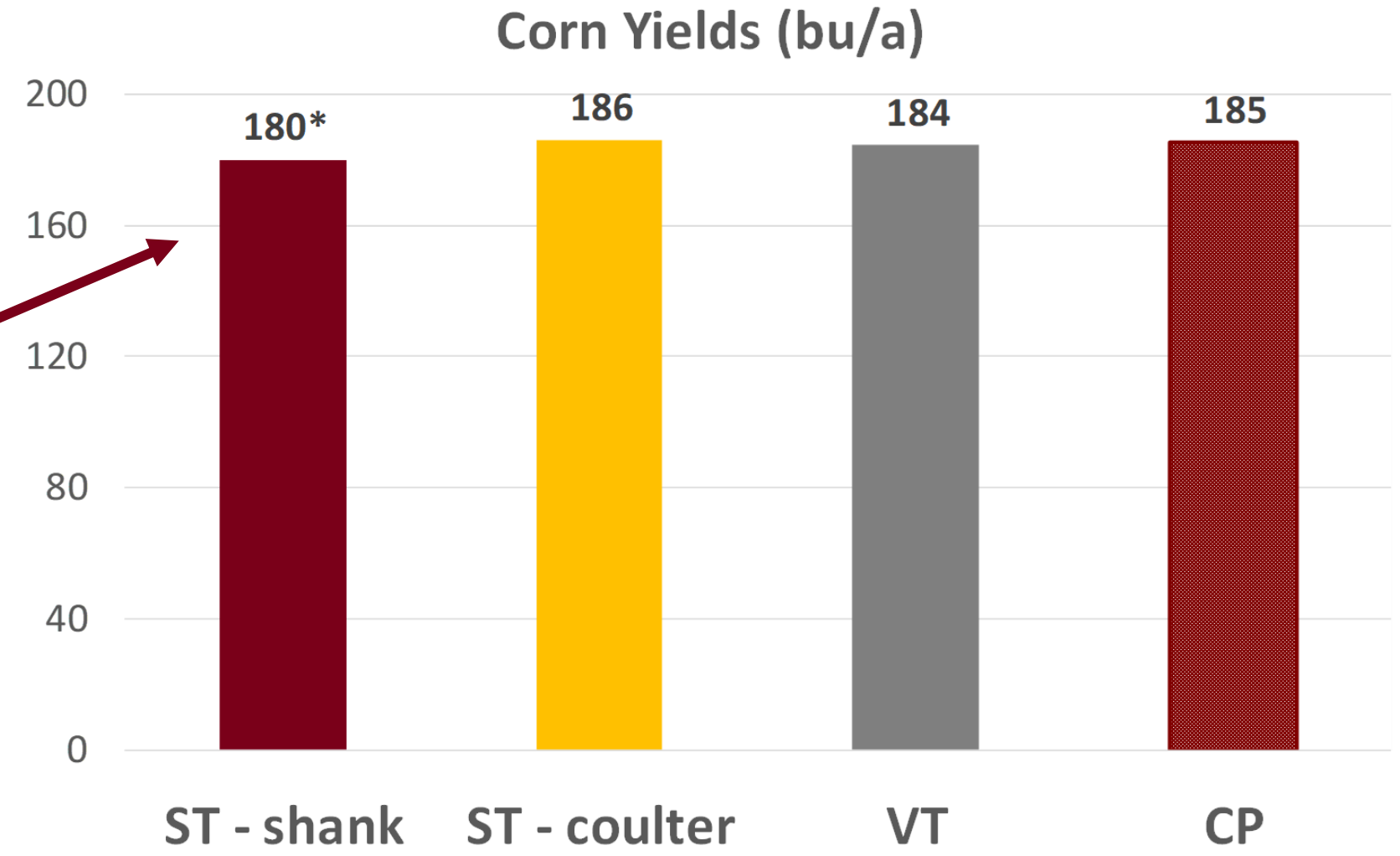
3-Year Yield and Residue Averages in WC MN (2010-12)



Yield Variability and Statistics

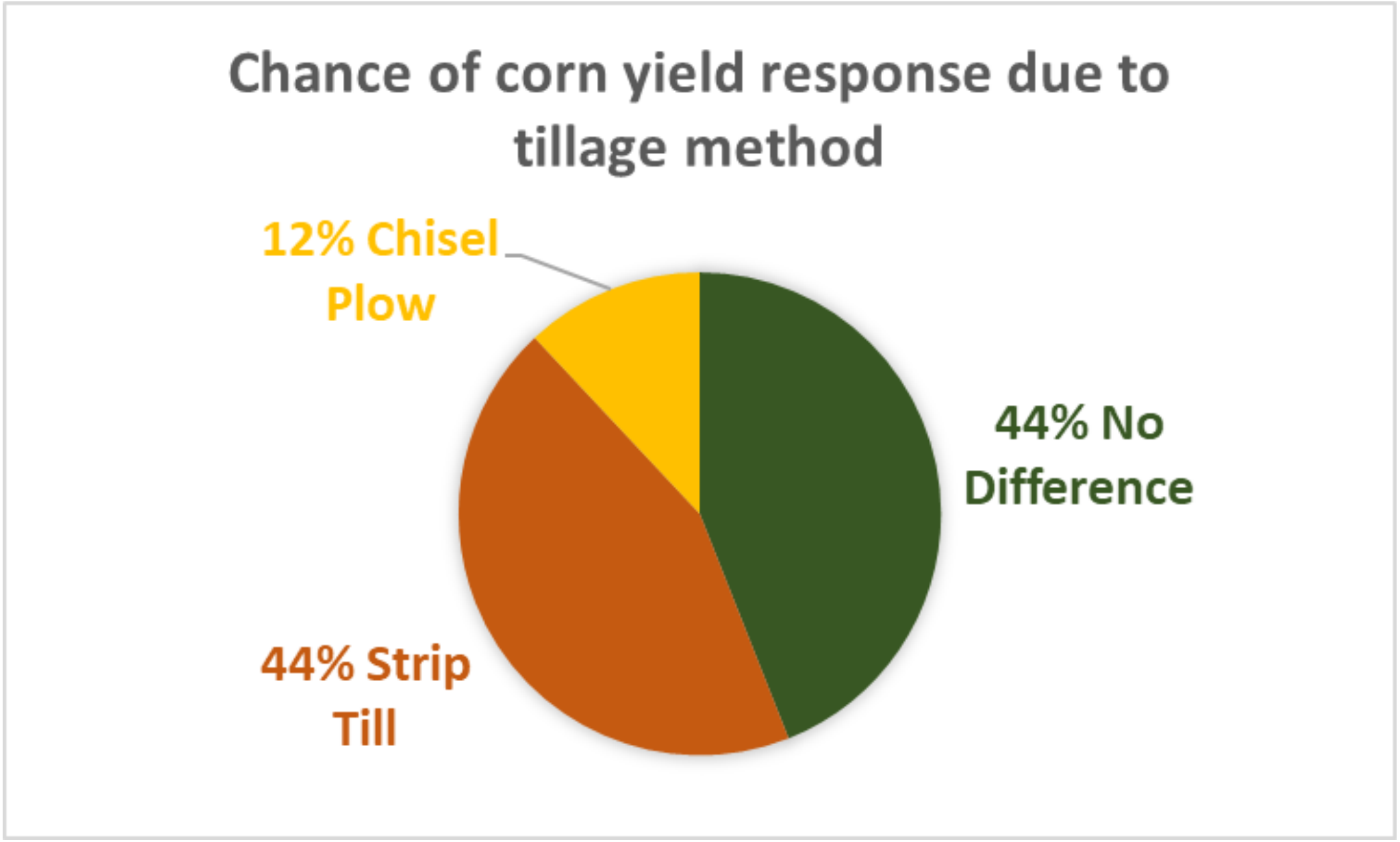


Ave of 4 Site Years of Corn Yields Fergus Falls and Barney (2015-18)



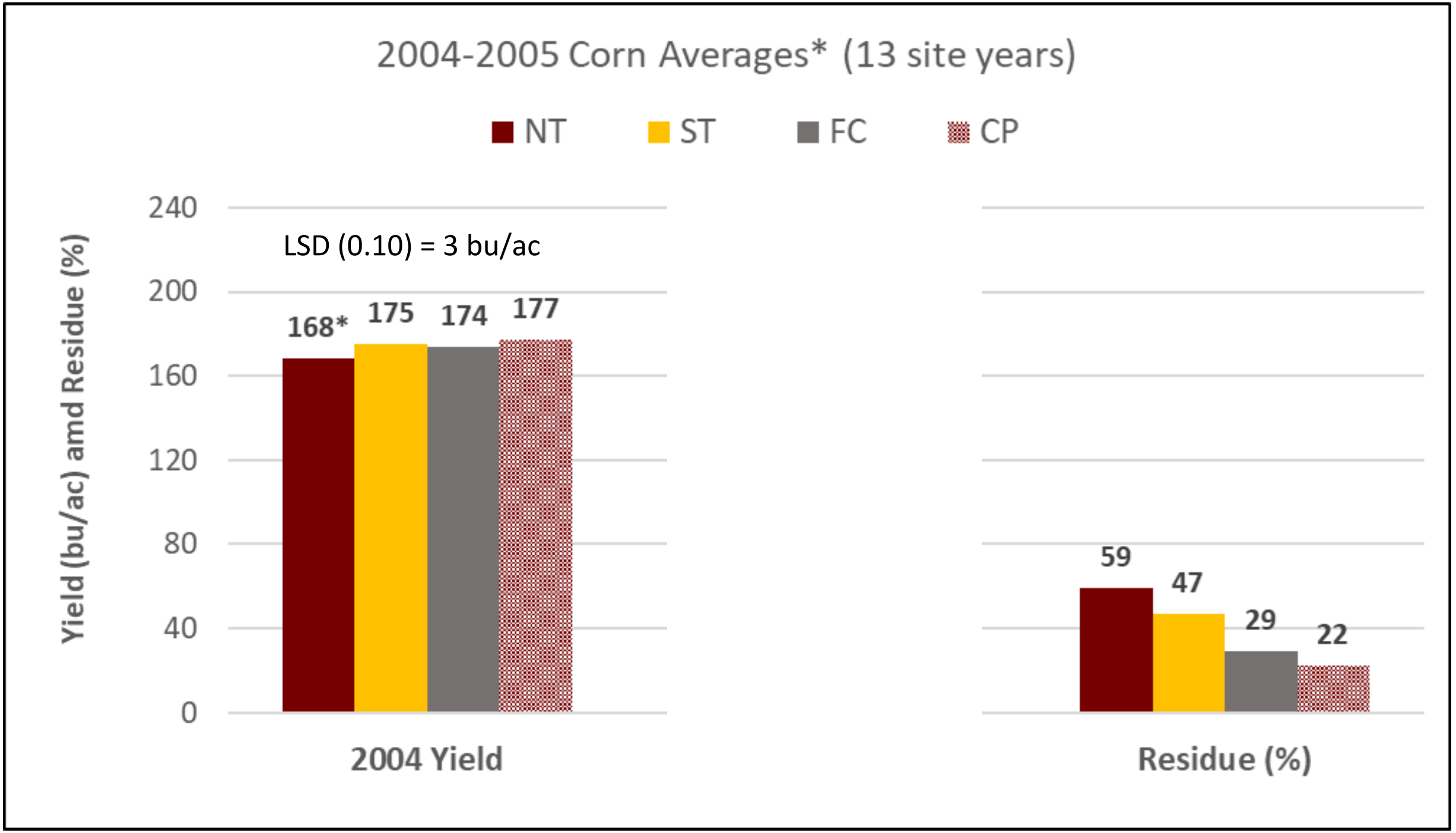
*1 site – planted after rain and smeared soil

DeJong-Hughes, Daigh, Gatchell



Corn yield response to tillage for 18 site years across E. North Dakota and NW Minnesota through 2005 - 2012.

Weather Has More Effect on Yield Then Tillage


2004-2005 Corn Averages* (13 site years)
NT
ST
FC
CP
Yield (bu/ac) amd Residue (%)
240
200
160
120
80
40
0
LSD (0.10) = 3 bu/ac
168*
175
174
177
59
47
29
22
2004 Yield
Residue (%)

Tillage Costs per Acre

Assumptions:

- $2.75 diesel
- $20.00 labor
- 1,400-acre grain farm
- New tractor and implement overhead
- Not adding additional cost of chopping head
- Costs include overhead (depreciation, interest, insurance, housing and repairs), fuel and labor charges.

Source: July 2022, Farm Business Management, University of Illinois Extension

Soybean Tillage Costs

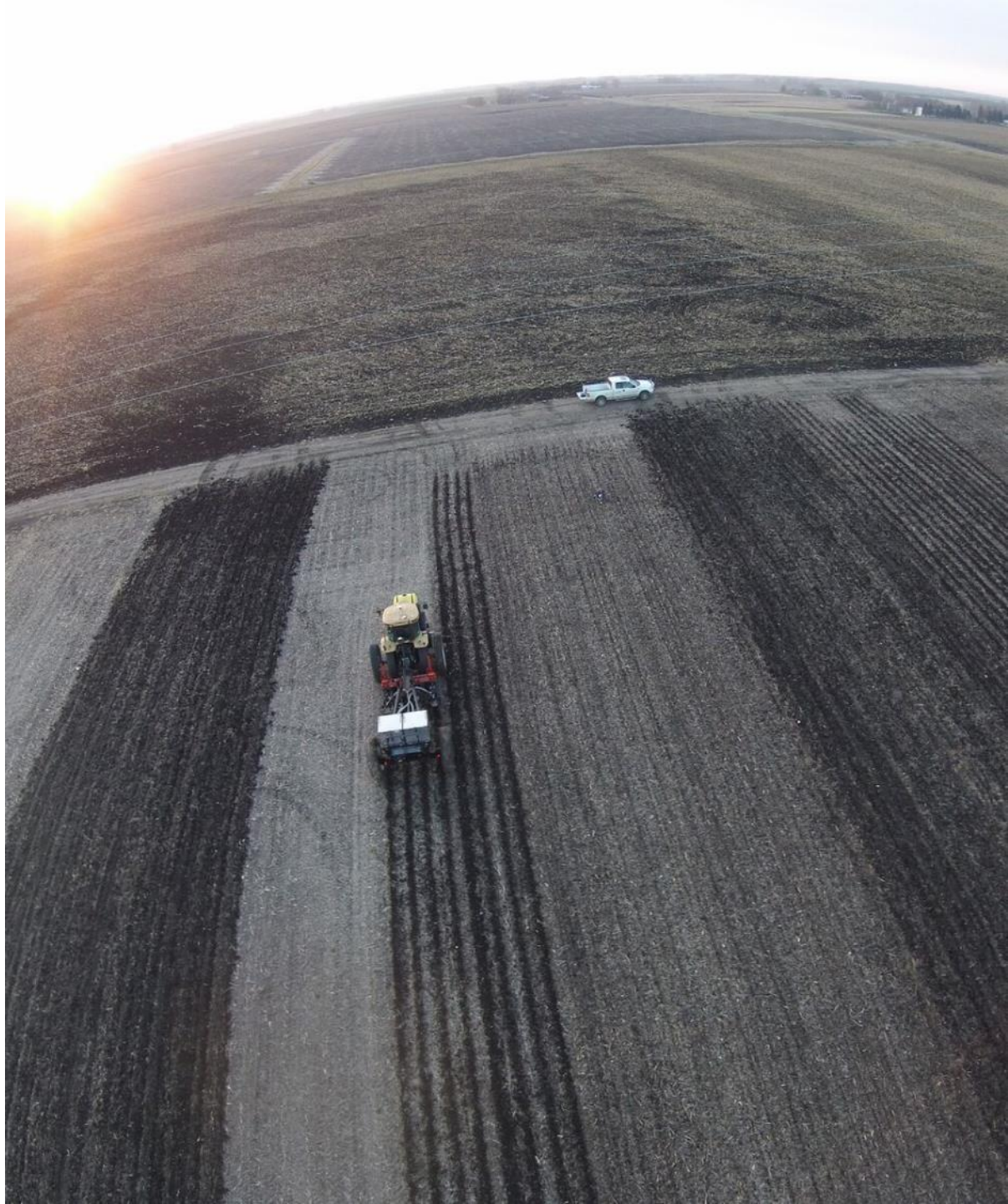
	No-till ($)
First Implement	0
No-till or Conventional Planter	19.00
Total cost/ac	19.00
Total fuel use/ac	0.5
Total cost/1,000 ac (incl. fuel costs)	**$19,000**

Corn Tillage Costs

	Strip Till ($)
First Implement	17.30
Liquid fert applicator (40’)	0
Second Implement	0
No-till or Conventional Planter	19.00
Total cost/ac	36.30
Total fuel use/ac	1.1
Total cost/1,000 ac (incl. fuel costs)	**$36,300**

Tillage has been Overrated

- Reduce the number of tillage passes
- Be less aggressive
- Shallow up the implement
- Change out shanks
- Rotate tillage to match field conditions



Bottom Line

To minimize erosion and keep soil productivity

- Keep the soil covered with at least 40% residue
- Chunk up the soil after crops with little residue
- Add manure to hilltops

May need to move the soil back up the hill

Jodi DeJong-Hughes
UMN Extension
JDH@umn.edu
@SoilLorax

z.umn.edu/TillageGuide
z.umn.edu/CompGuide
z.umn.edu/SOMpub

Soil Landscape Rehabilitation

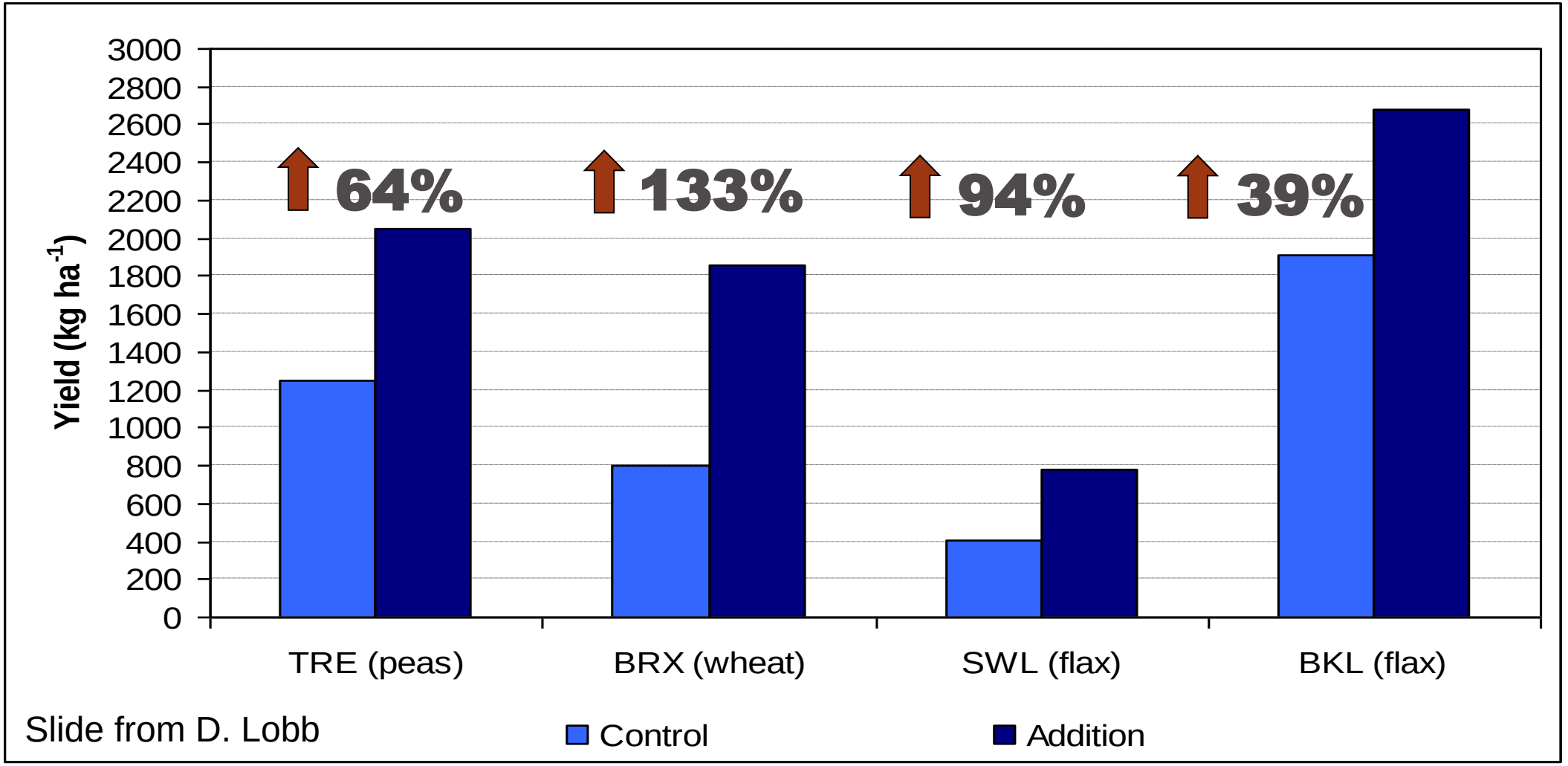
Treherne, Manitoba

~David Lobb

Soil Landscape Rehabilitation

Research Findings for Upper Slope:

**All significant at P<0.10*

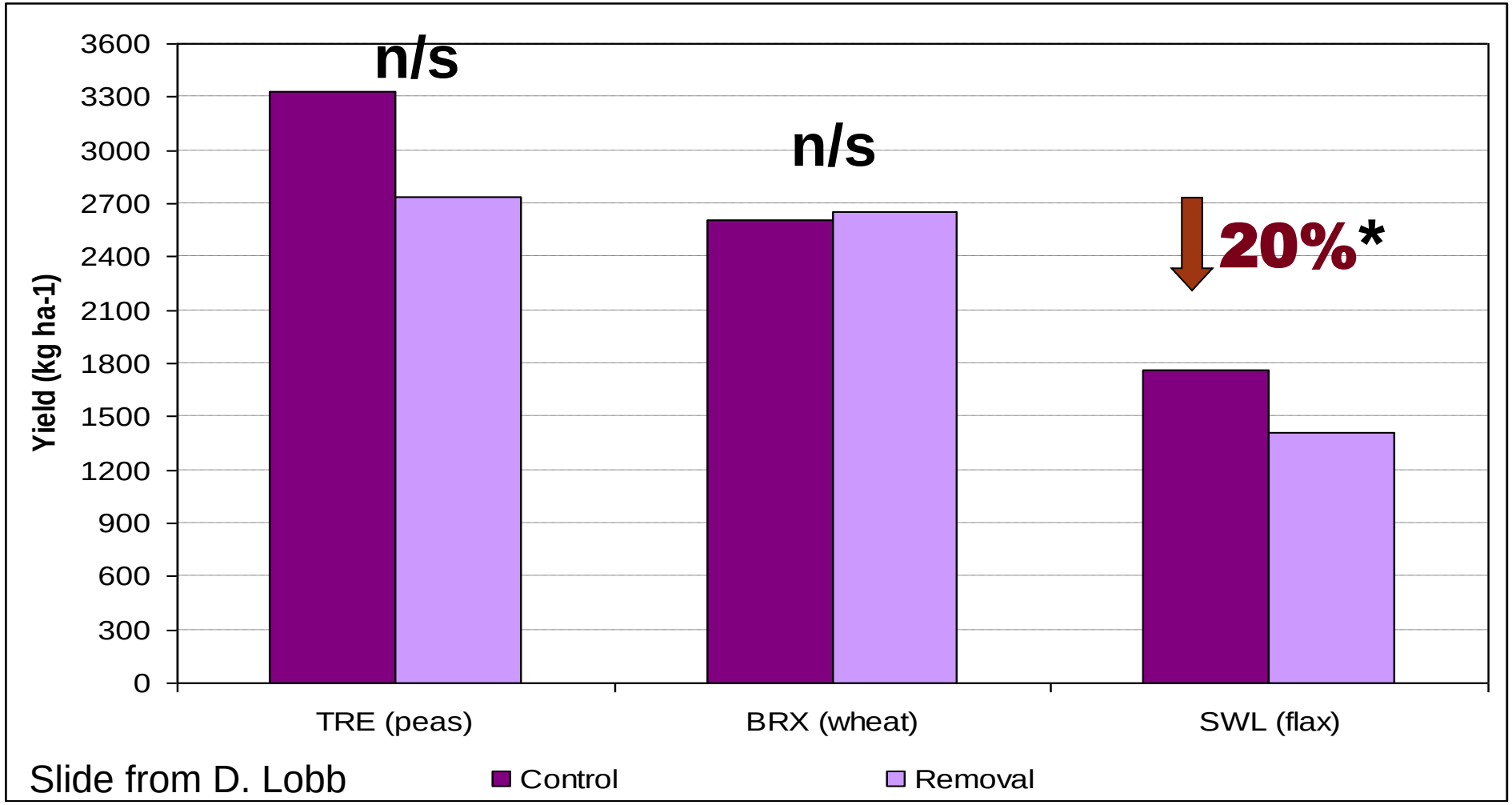


Slide from D. Lobb

Soil Landscape Rehabilitation

Research Findings for Lower Slope:

**Significant at P<0.10*



Slide from D. Lobb

Combat Wind, Water, and Tillage Erosion

We can’t change climate or soil texture

But we can manage for:

- Surface roughness
- Shelter belts
- Calcium carbonate content
- Tillage timing and aggressiveness
- Keeping the soil covered as many months as possible

Table 1. Tillage practices in seven corn belt states for soybean production (CTIC, 2004).

State	Soybean Acres	No-Till	Mulch-Till (30% residue)	Reduced-Till (15-30% residue)	Conventional-Till (0-15% residue)
Illinois	10,316,344	46.2%	20.9%	19.2%	13.7%
Indiana	5,487,069	61.5%	15.2%	10.0%	13.2%
Iowa	10,179,278	33.1%	47.3%	14.6%	4.3%
Minnesota	7,176,774	7.1%	46.1%	24.6%	21.4%
Missouri	5,143,354	40.1%	9.5%	19.9%	30.1%
Ohio	4,630,915	63.7%	9.0%	8.3%	19.0%
Wisconsin	1,540,605	36.6%	21.4%	15.8%	26.2%
Total	44,474,339	39.6%	27.8%	16.7%	15.6%

Table 2. Tillage practices in seven corn belt states for corn production (CTIC, 2004).

State	Corn Acres	No-Till	Mulch-Till (30% residue)	Reduced-Till (15-30% residue)	Conventional-Till (0-15% residue)
Illinois	11,165,908	14.0%	12.1%	22.2%	51.8%
Indiana	5,350,414	18.8%	8.6%	17.3%	55.1%
Iowa	12,348,317	14.4%	26.6%	36.5%	22.2%
Minnesota	7,388,154	1.5%	15.7%	34.1%	48.1%
Missouri	2,887,237	20.2%	7.4%	23.2%	48.9%
Ohio	3,527,939	23.5%	9.9%	13.1%	53.4%
Wisconsin	3,520,402	14.5%	18.1%	20.7%	46.5%

Effects of Erosion Control Practices on Nutrient Loss

George F. Czapar, University of Illinois John M. Laflen, Iowa State University Gregory F. McIsaac, University of Illinois Dennis P. McKenna, Illinois Department of Agriculture

Table 3. Estimated annual soil and nutrient losses under various erosion control practices. Central Iowa climate, average over 10 Iowa soils and a 72.6 foot long slope of 9% and a 300 foot long slope of 5%)

Practice	Runoff	Soil erosion/ Sediment yield	Nutrient enrichment ratio*		Losses in surface runoff water (lb/ac)		Losses in eroded soil (lb/ac)		Total water and soil losses (lb/ac)	
	(in)	(t/a/y)	Sediment	Water	NH_4-N + NO_3-N	PO_4-P	Total N	Total P	N	P
Moldboard plow	5.2	15.0	0.6	0.4	2.2	0.1	53.4	20.9	55.6	21.0
Typical tillage	4.8	7.8	1.0	1.0	3.0	0.4	32.8	12.7	35.8	13.1
No till	4.2	1.0	1.5	1.7	3.6	0.7	6.1	2.4	9.7	3.1
Contour farming	4.4	3.9	0.8	1.3	3.5	0.5	12.5	4.8	15.9	5.3
Strip cropping	4.4	2.9	0.8	1.3	3.5	0.5	9.5	3.7	12.9	4.2
Terraces surface-drained	4.4	2.3	0.8	1.3	3.5	0.5	7.4	2.9	11.0	3.4
Water and sediment control basins	3.9	0.4	1.5	1.7	4.0	0.6	2.5	1.0	6.5	1.6

*Nutrient enrichment ratios, relative to the typical tillage practice, were calculated based on concentrations taken from Baker and Laflen (1983), and on soil erosion and sediment yields.

Research Findings:

- The addition of as little as 4” of topsoil to severely eroded hill tops increased yields by 10% to 33% in wet years and 39% to 133% in dry years.

- The addition of topsoil improves water retention, soil nutrient status, and organic matter concentrations.

- The cost of rehabilitation can be recovered in 3 to 5 years.

Wind Erosion Factors

E = f(IKCLV)

E average annual soil loss in tons per acre.

f indicates the equation includes functional relationships that are not straight-line mathematical calculations.

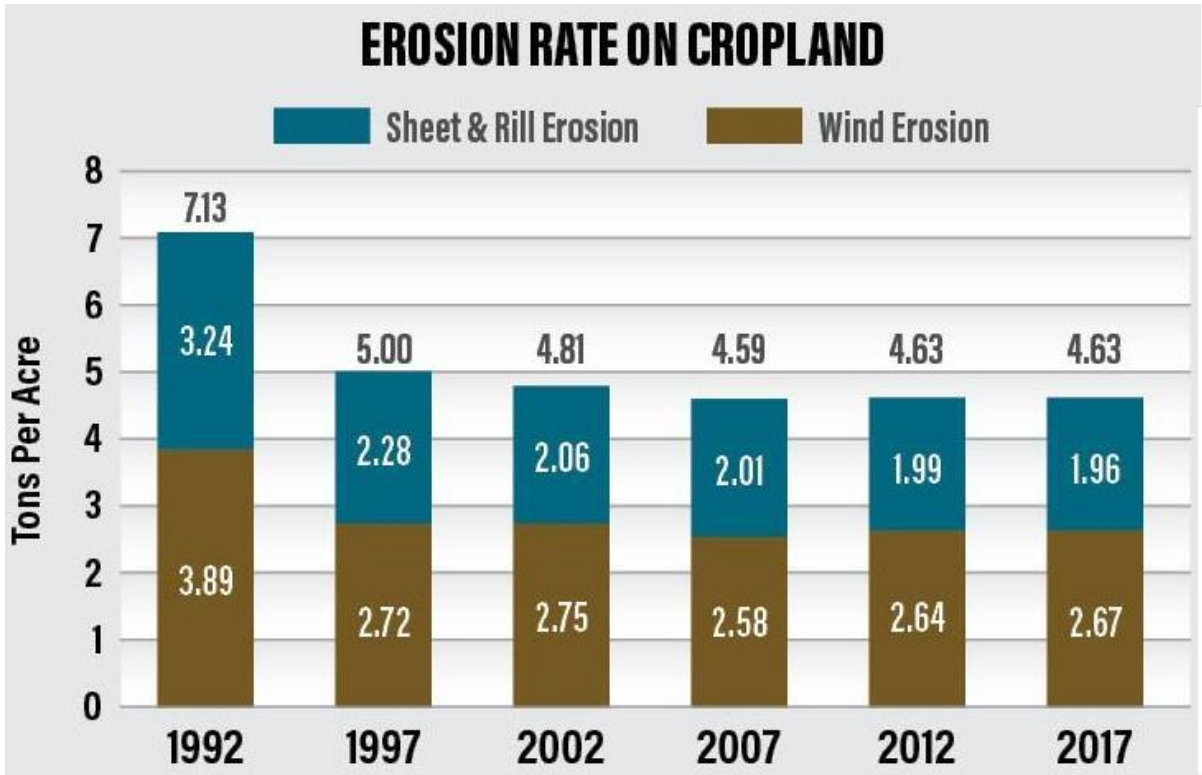
I soil erodibility index (soil surface texture, calcium carbonate content, % clay)

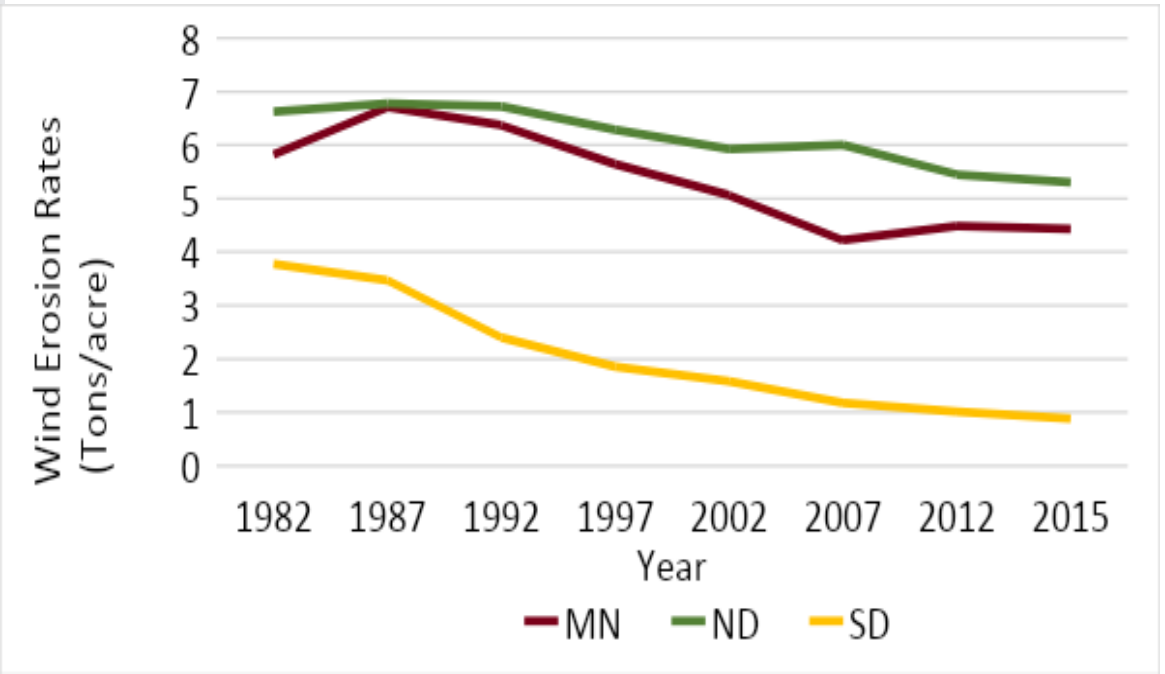
K ridge roughness factor (tillage and planting implements)

C climatic factor (wind speed, surface moisture compared to Garden City, KS)

L unsheltered distance

V vegetative cover factor (kind, amount, and orientation of growing plants)

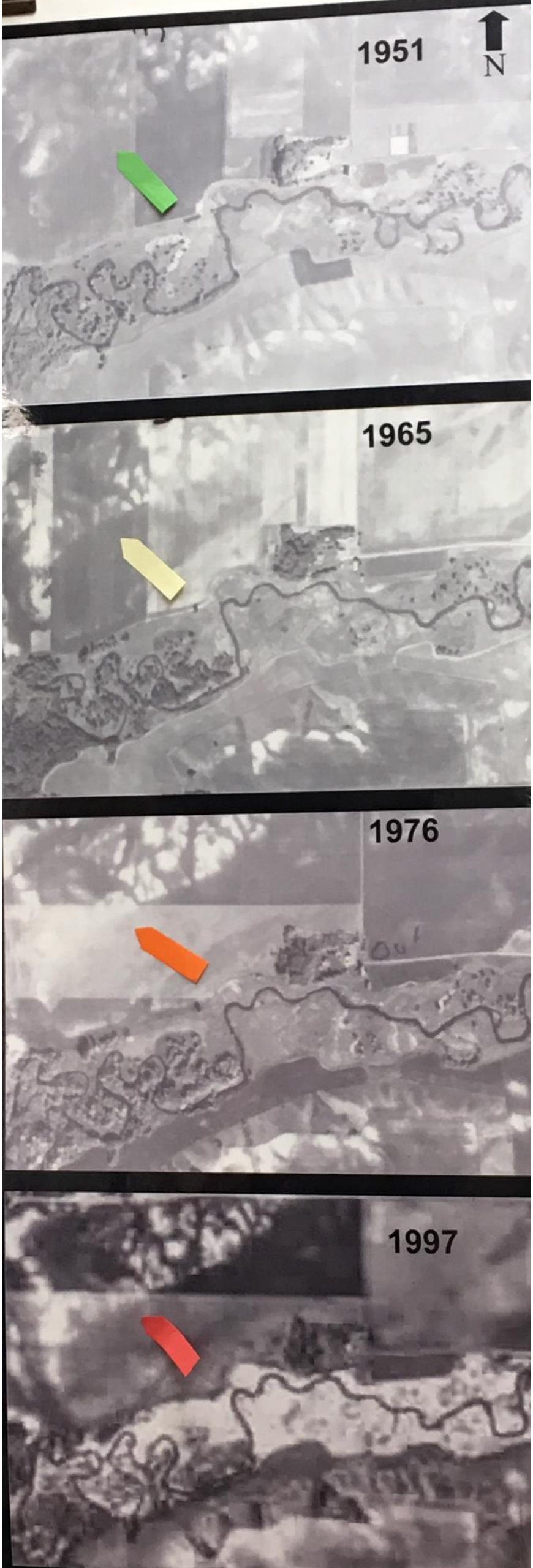

EROSION RATE ON CROPLAND
Sheet & Rill Erosion
Wind Erosion
Tons Per Acre
0
1
2
3
4
5
6
7
8
7.13
3.24
3.89
5.00
2.28
2.72
4.81
2.06
2.75
4.59
2.01
2.58
4.63
1.99
2.64
4.63
1.96
2.67
1992
1997
2002
2007
2012
2017


Wind Erosion Rates
(Tons/acre)
0
1
2
3
4
5
6
7
8
1982
1987
1992
1997
2002
2007
2012
2015
Year
MN
ND
SD

Discovery Farms – 2015-2018

- Primarily caused by heavy rain (storms, high-intensity rainfall events)
- 10% of events generate 85% of soil loss
- Highest rates of runoff in May and June – just after planting (least soil cover)
- Soil loss equals 3 five-gallon buckets per acre each year
- Nutrient loss follows water loss
- Average TN and TP losses
  - TN (8 ppm, 3 lb/ac)
  - TP (1 ppm, 0.6 lb/ac)
- Average NO3 and Dissolved P (DRP) Losses with surface runoff
  - NO3 (4 ppm) – 5.4 ppm NO3 in groundwater is conc limit for MN's DWSMA designation
  - DRP (0.6 ppm) – 0.05 ppm DRP is associated with algal blooms in freshwater

Lindsay Pease –
Data from MN Discovery Farms


1951
N
1965
1976
1997

5 T of soil = 1 dime’s width

The rich, soft soil has all run away,
leaving the land nothing but
skin and bones

~Plato

Denitrification in a Saturated Soil

Can Lose **2-4** lbs of Nitrogen/acre/day

Photo: Dave Franzen, NDSU

10 ac of drown out corn at

180 bu/ac at $6/bu = $1,080

Photo: Dave Franzen, NDSU

THE WAY FORWARD

Research Findings:

- The addition of as little as 10 cm of topsoil to severely eroded hill tops increased yields by 10% to 33% in wet years and 39% to 133% in dry years.
- Although, there was a significant reduction in removal plots at one of the three sites there was still a NET increase in crop production.
- Landscape restoration provides continued yield response on hilltops for several years after the initial restoration.
- The addition of topsoil improves water retention, soil nutrient status, and organic matter concentrations.
- The cost of rehabilitation can be recovered in 3 to 5 years.

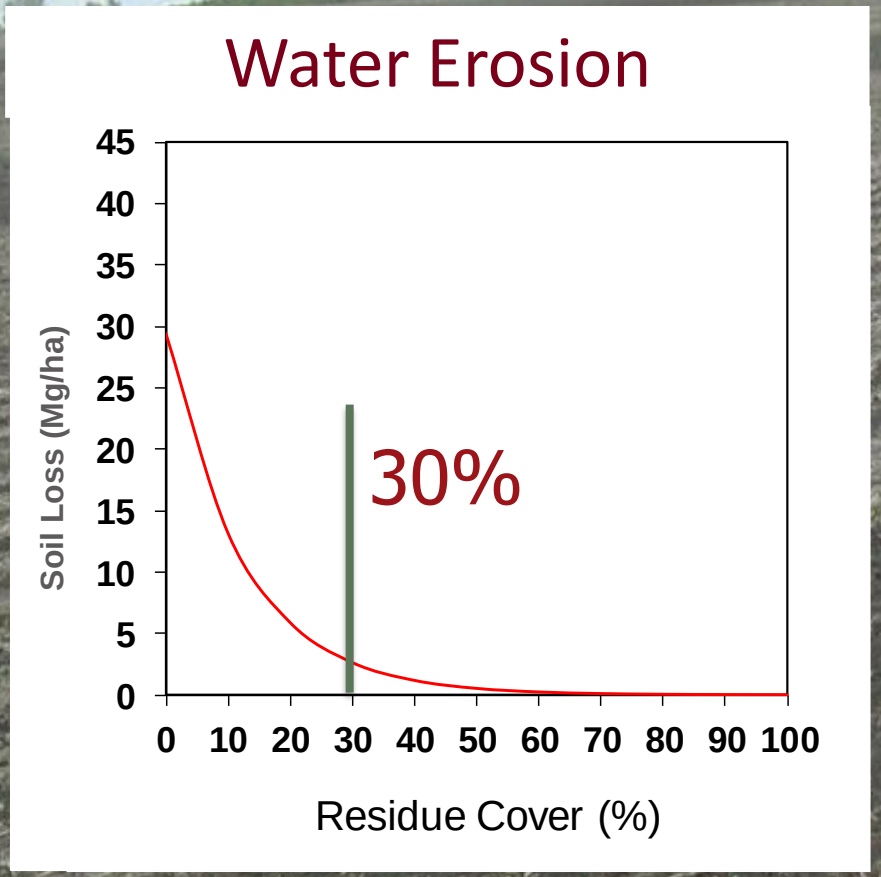
GOAL:

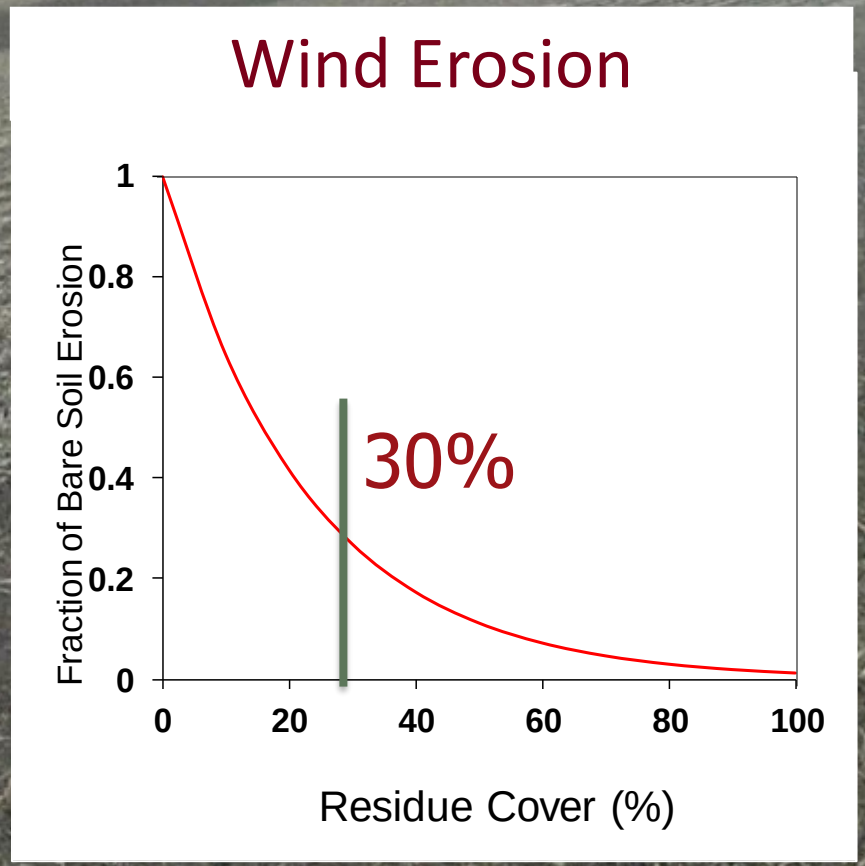
Manage for Better Structure (soil health)

Crop Damage

- Sugarbeets need less than 0.5 T/ac soil loss to save emerging plants

Percent Residue





Notes

- Data was reported by MN Discovery Farms 2015-2018
- Primarily caused by heavy rain (storms, high-intensity rainfall events)
- 10% of events generate 85% of soil loss
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  - DRP (0.6 ppm) – 0.05 ppm DRP is associated with algal blooms in freshwater

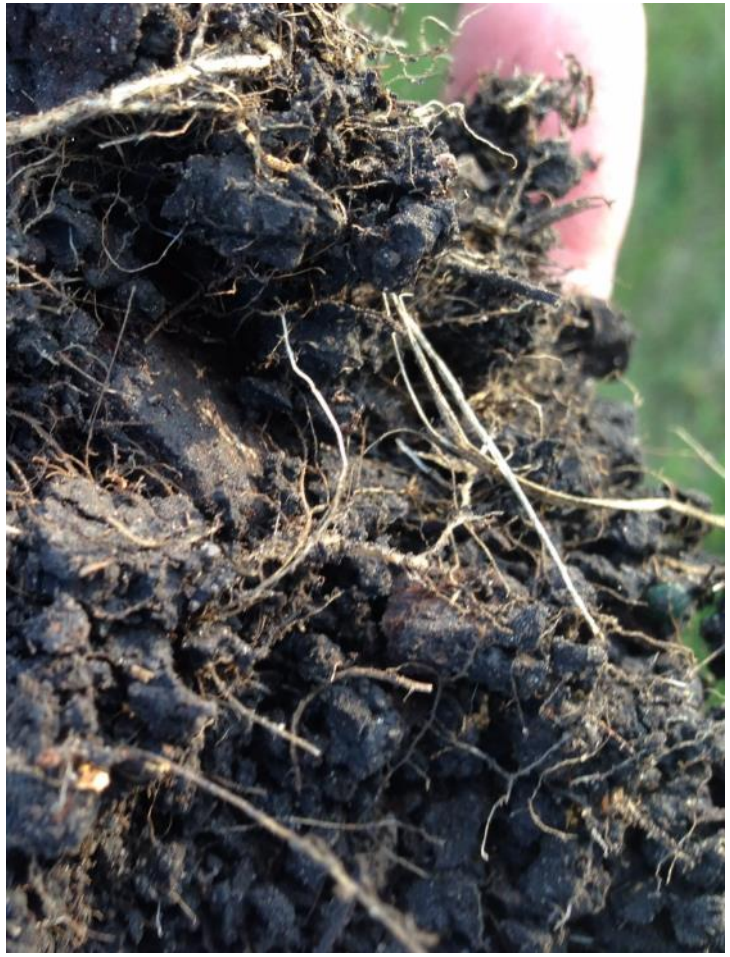
Lindsay Pease –
Data from MN Discovery Farms

What is Tillage Erosion?

- Breaks apart soil aggregates
- Leaves the soil bare
- Tillage erosion exposes subsoil which is highly erodible

Loss of Topsoil with Rain

Benefits of Less Tillage - Aggregation



Aggregates give soil a higher bonding weight and strength.

Soil microbes build aggregates.

Tillage reduces soil biological life.

Vegetation, Residue, Snow Cover

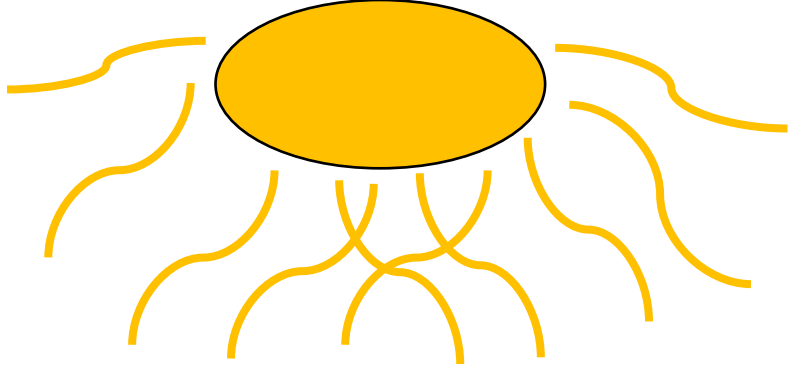
- Distance the wind can blow without encountering a barrier

Soil Properties

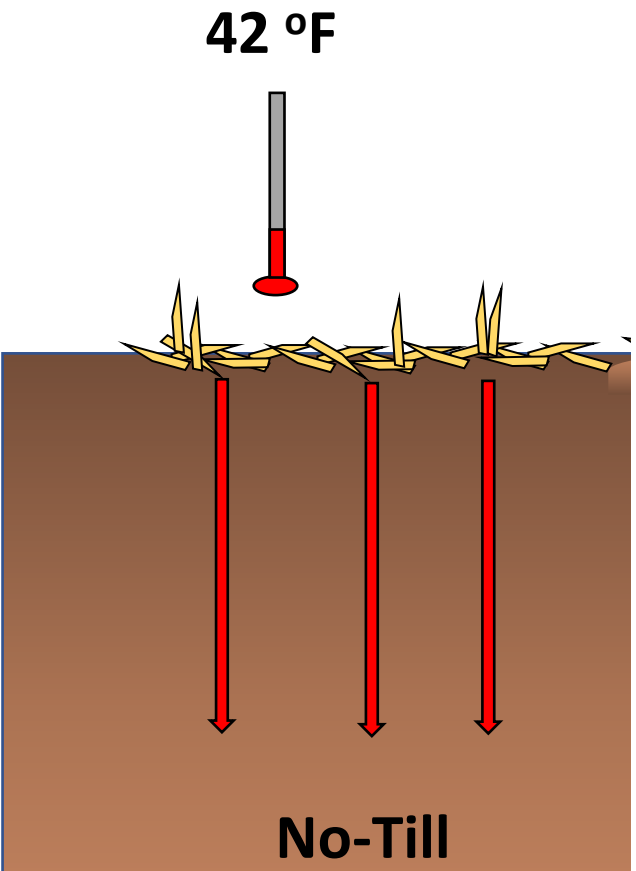
Soil Infiltration Rates

- Sands vs clays
- Dry vs wet soil
- Compacted vs aggregated
- Residue and plants
- Flat vs slope

Which one protects the soil from the elements?

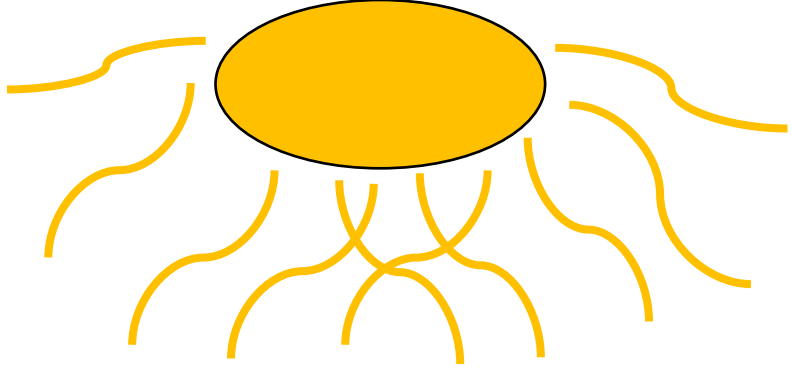


Average temperatures of the three farms



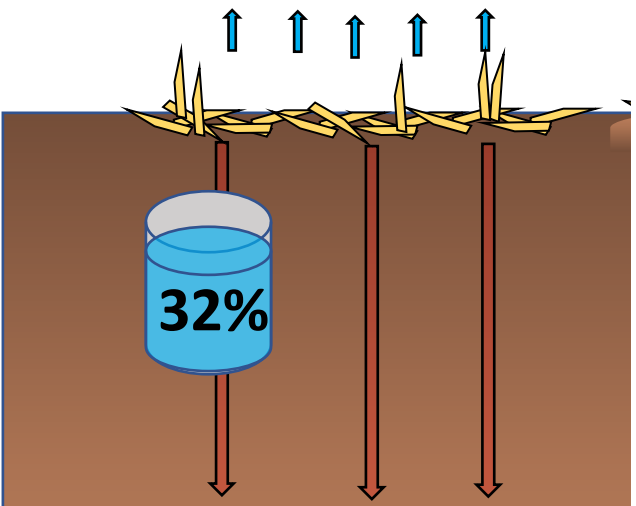
Daigh et al, 2019 NDSU

Saturated Soil



Average water content of the three farms

Water



Daigh et al, 2019 NDSU

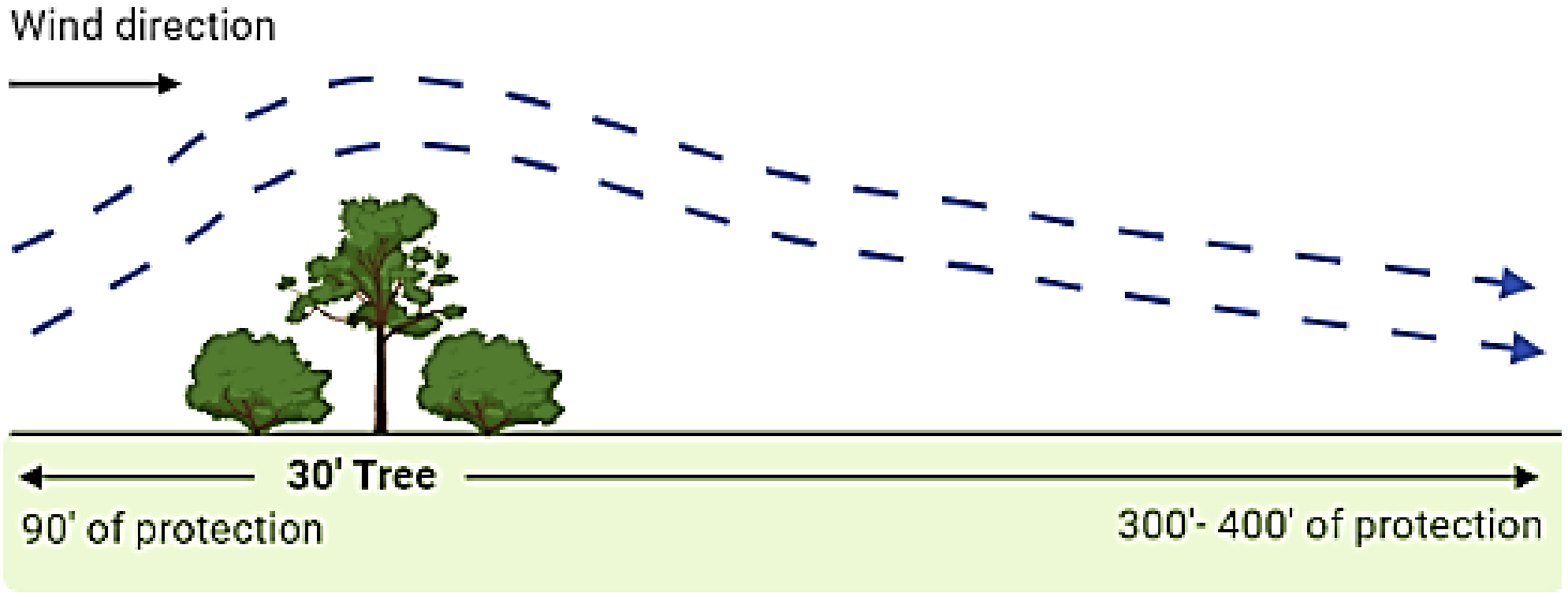
Cleaning out ditches cost $$

Climate

- Change in climate- estimated wind erosion will increase between 10 to 15% across the Corn Belt

Unsheltered Distance (when residue isn't enough)

Wind can pick up speed and intensity along flat landscapes. Shelterbelts protect the leeward soil for a distance of 10x the height of trees.



Soil Roughness

- A bare, smooth surface is easier to erode than a rough surface
- Especially over the winter months
  - Fall land rolling
  - Fall VT or soil finisher

Soil Properties

Carbonates

- Carbonates separate particles from each other
- High soil sodium or salt content often have a layer of dust on the soil surface, which can blow away

Photo - NDSU

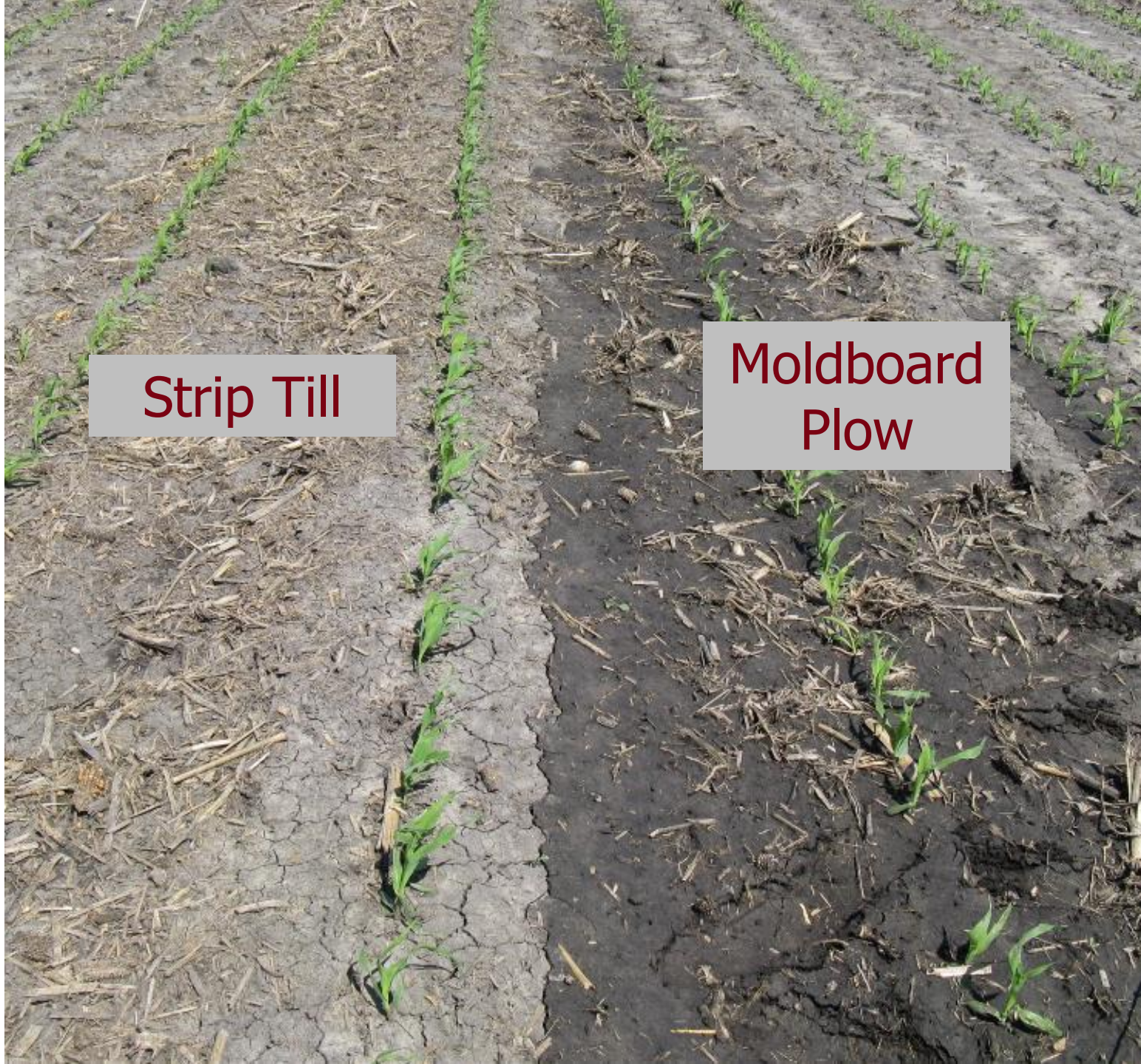
Tillage Depth and Aggressiveness

- Breaks up aggregates
- Leaves the soil unprotected
- Leads to clogged pores and crusts the soil surface

Reduced Tillage Concern #1

Reduced tilled fields won't warm-up or dry
in time for early planting

*See handout for data



What's it cost to replace your topsoil?

- If you lost 5T/ac
- Over 40 acres
- At $25/T to replace
- That's **$5,000**

- **1,000 ac = $125,000**