Compaction: quick to cause, slow to remedy

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Soil Compaction

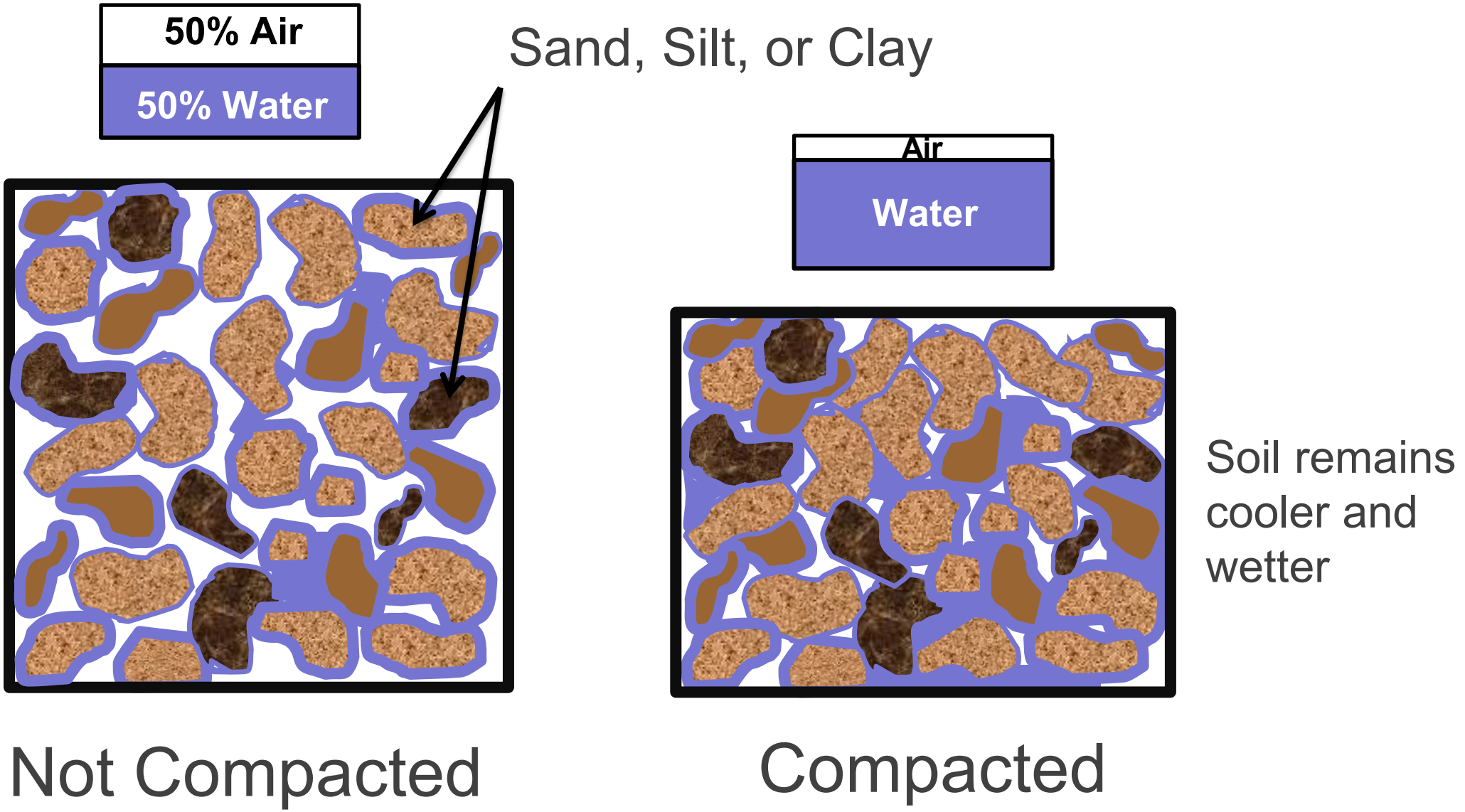
- What is it?
- So What?
  - Effects
  - Longevity
- Now What?
  - Causes
  - Management
  - Alleviation
- Summary

What is Soil Compaction?

Simply Stated:

A reduction of pore space

Photo of long-term chisel plowed vs long-term no-till fields

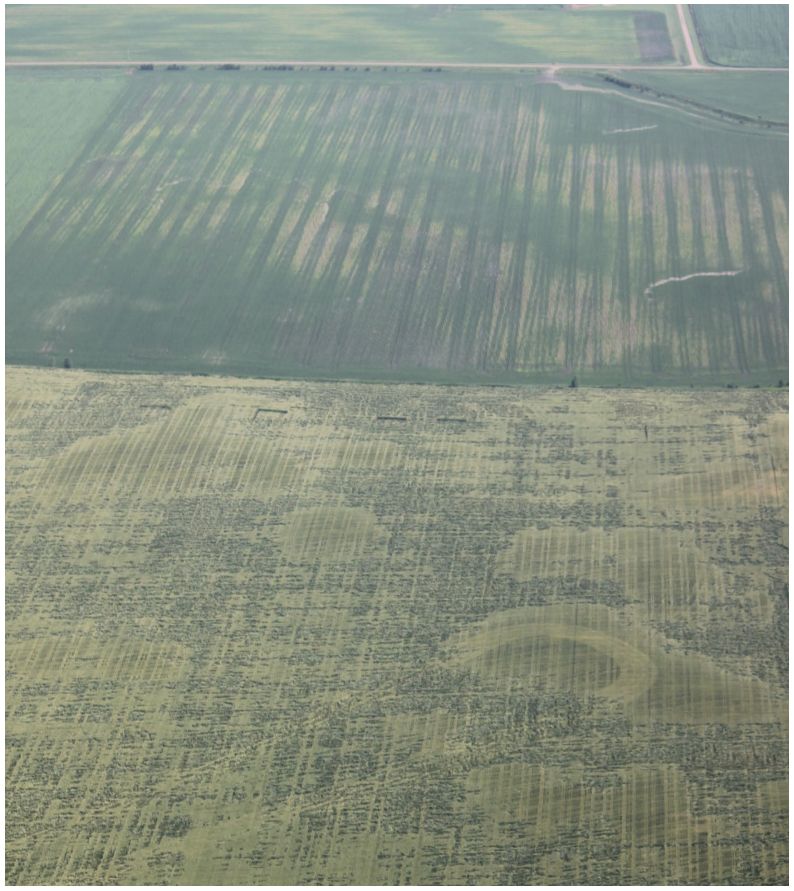

50% Air
50% Water
Sand, Silt, or Clay
Air
Water
Soil remains cooler and wetter
Not Compacted
Compacted

Types of Compaction

Surface Crusting

Tillage Pan

Wheel Tracks



#1 Myth

- Northern soils have high freeze/thaw potential which will break up compaction
- Truth
  - Need 10-12 freeze/thaw cycles
  - Only in the top 2-5”
  - Wetting and drying cycles have a much larger and deeper effect

Clay Minerals

- The type of clay mineral can indicate the ability of a soil to recover from compaction
- If your soil cracks in the summer, then your soil is self-alleviating

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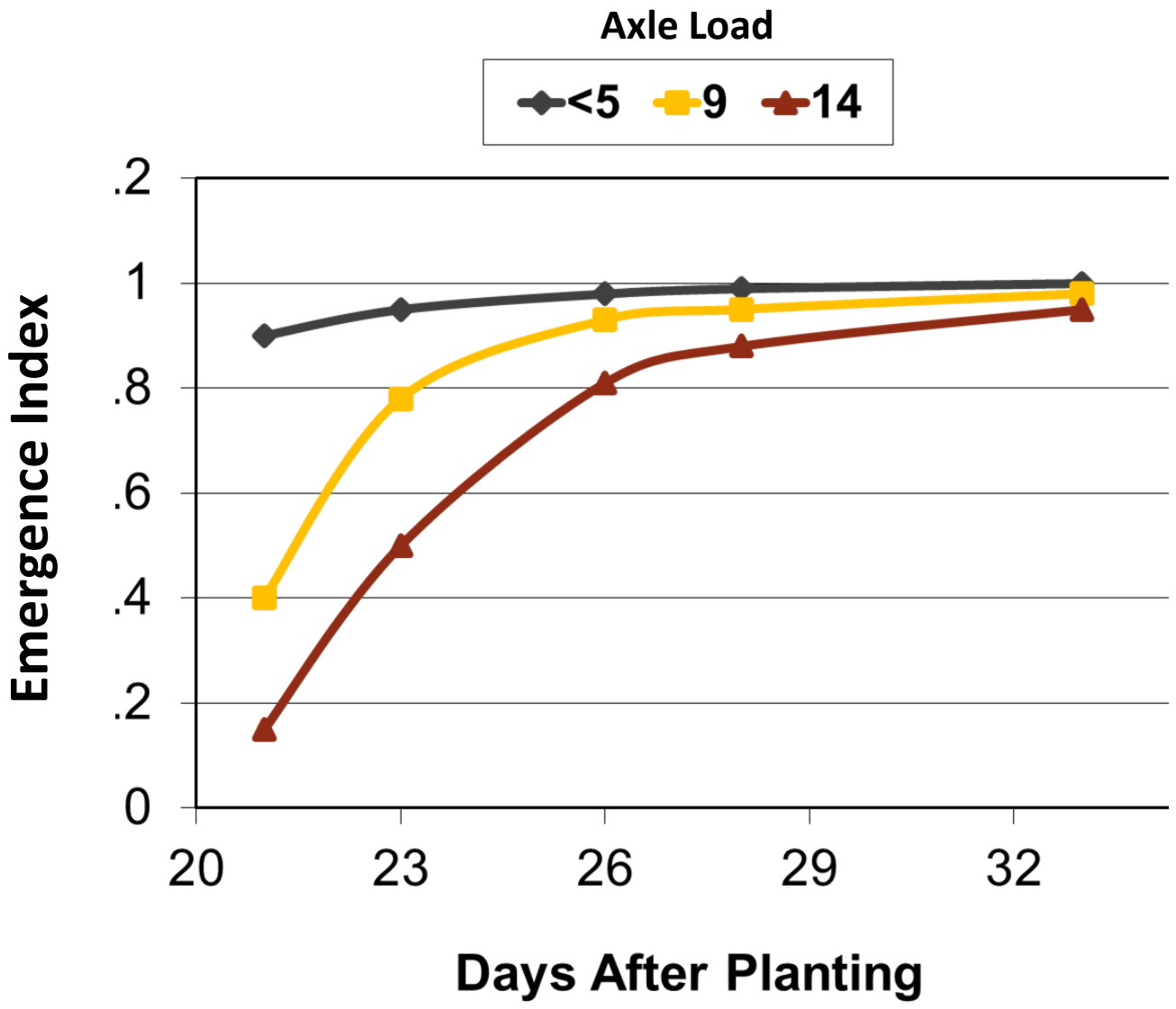
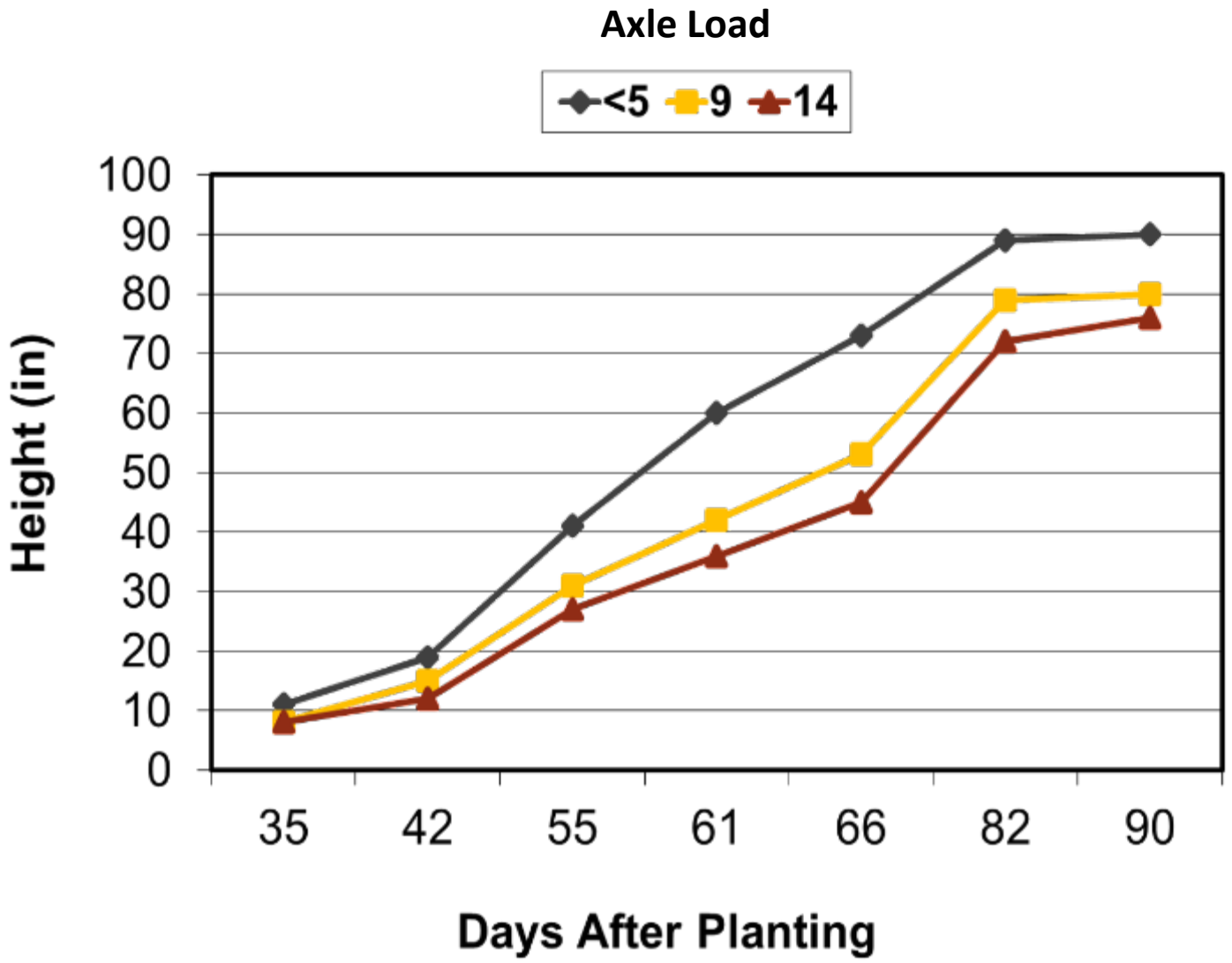
Corn Emergence vs Axle Load

Corn struggles to emerge through compacted soil



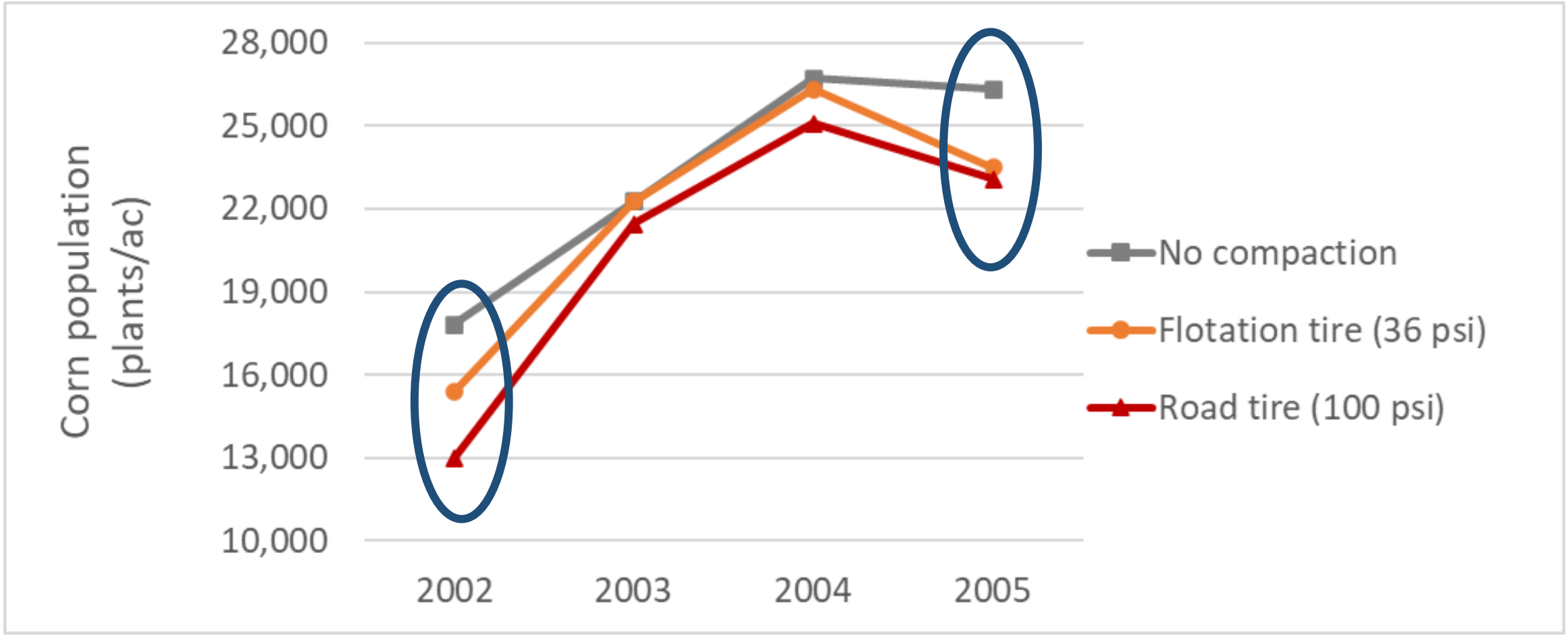
Wolkowski and Lowery, UW, 2008

Corn Height vs Axle Load

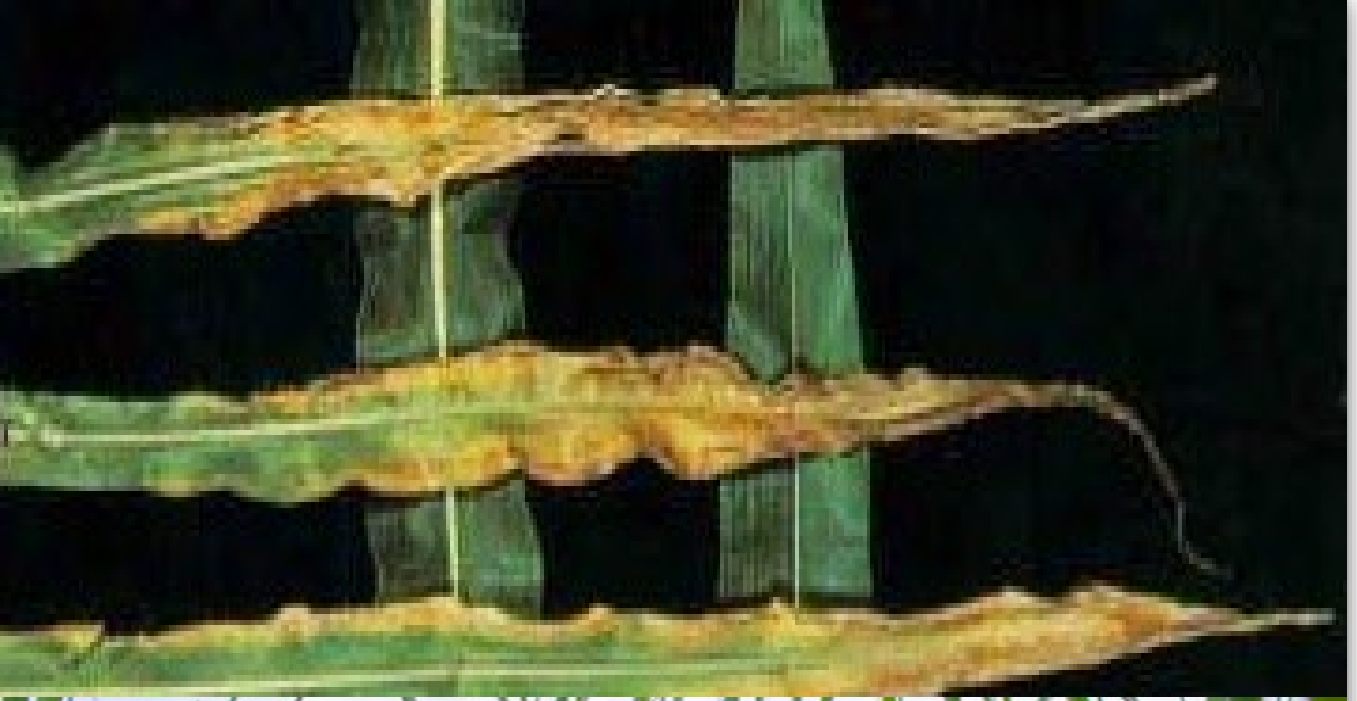


Wolkowski and Lowery, UW, 2008

Corn Population vs Tire Pressure



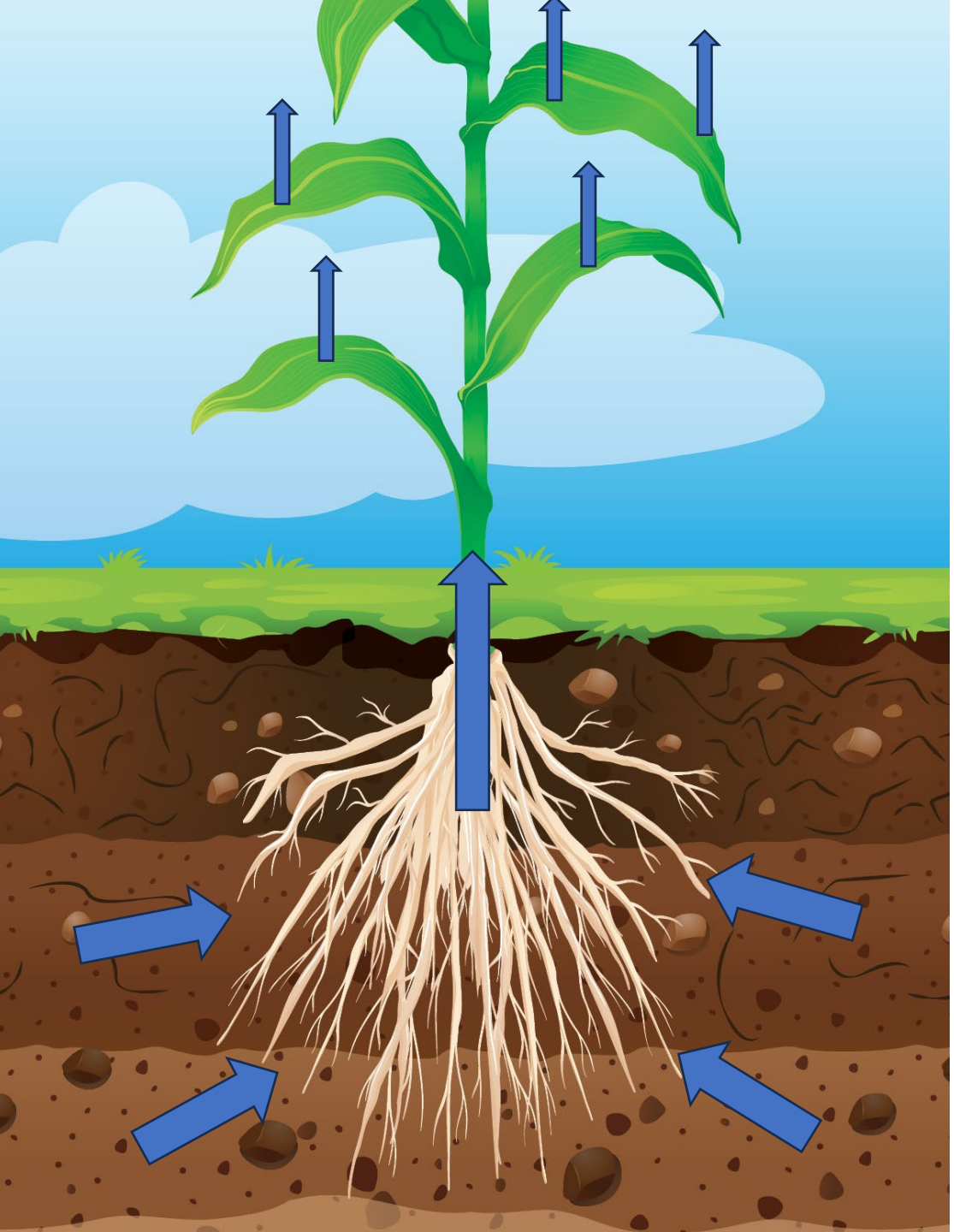
Krmenec, 2000



Nutrient Deficiencies

Plants get nutrients by

- Mass flow (water)
- Diffusion
- Interception
  - Including mycorrhizae



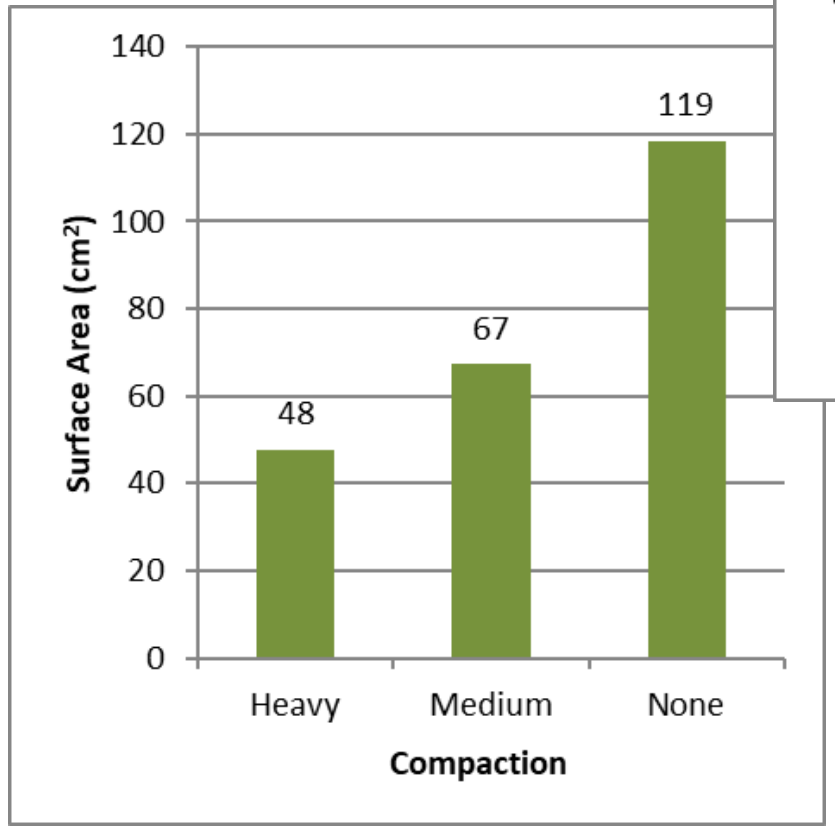
Mass Flow

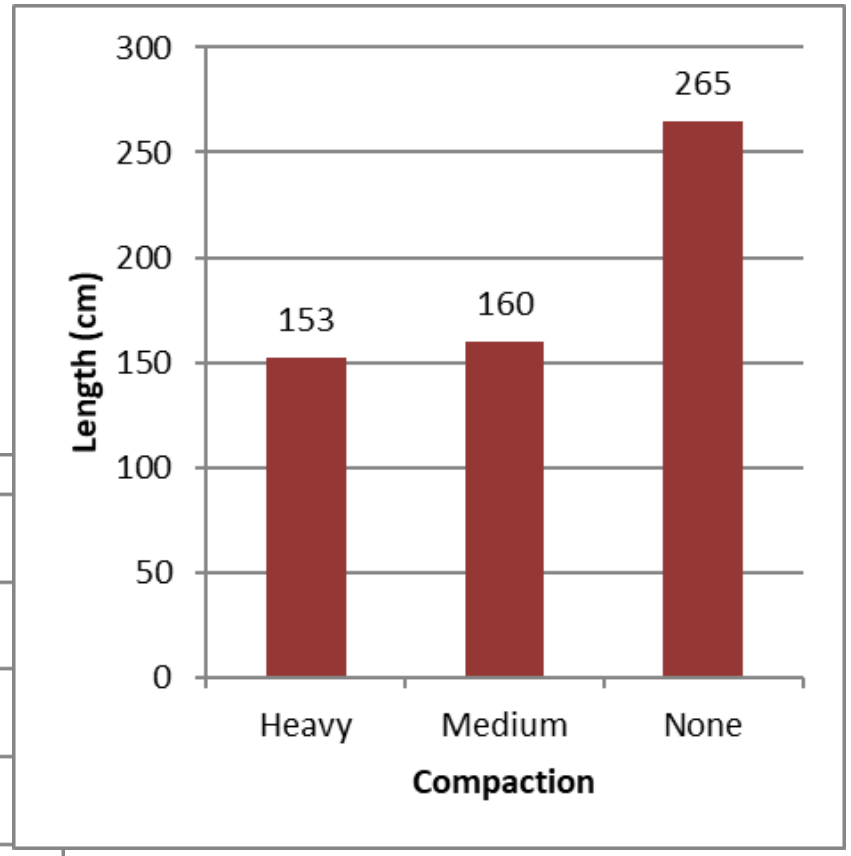
- Mobile nutrients
  - Nitrogen
  - Sulfur
- Crop transpiration pulls in soil water
- Compaction can slow or stop the movement


Compacted
Well Structured

Compaction and Root Growth

- Compaction reduces:
  - number of roots
  - total root length
  - rate of root growth

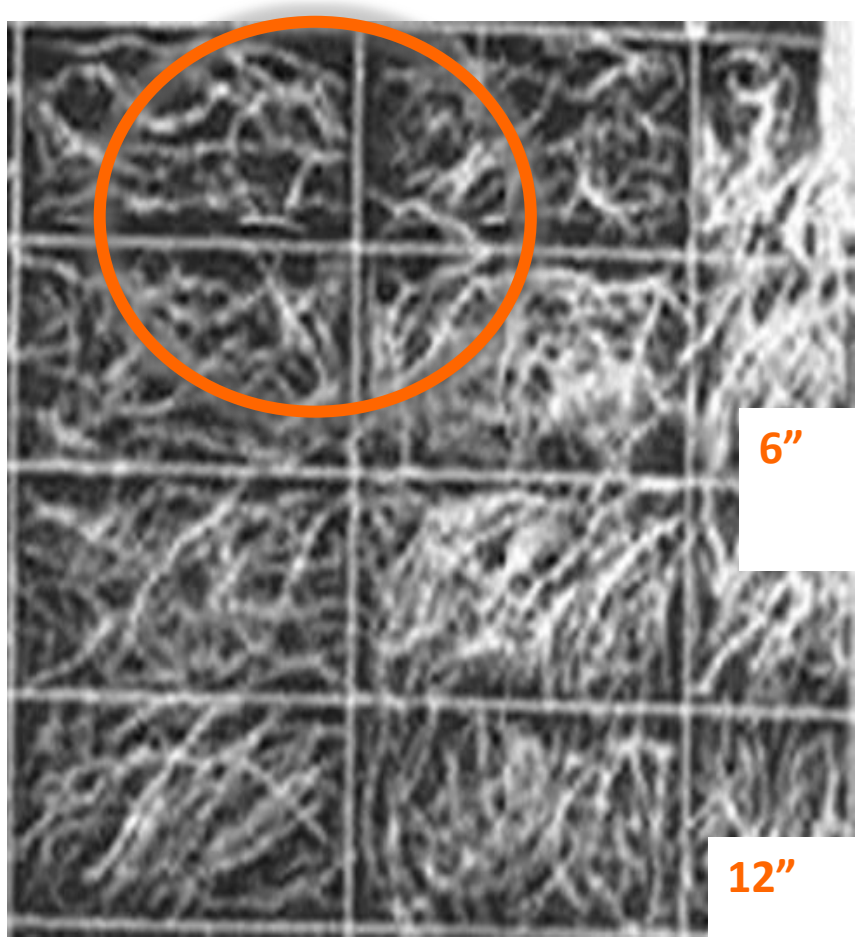




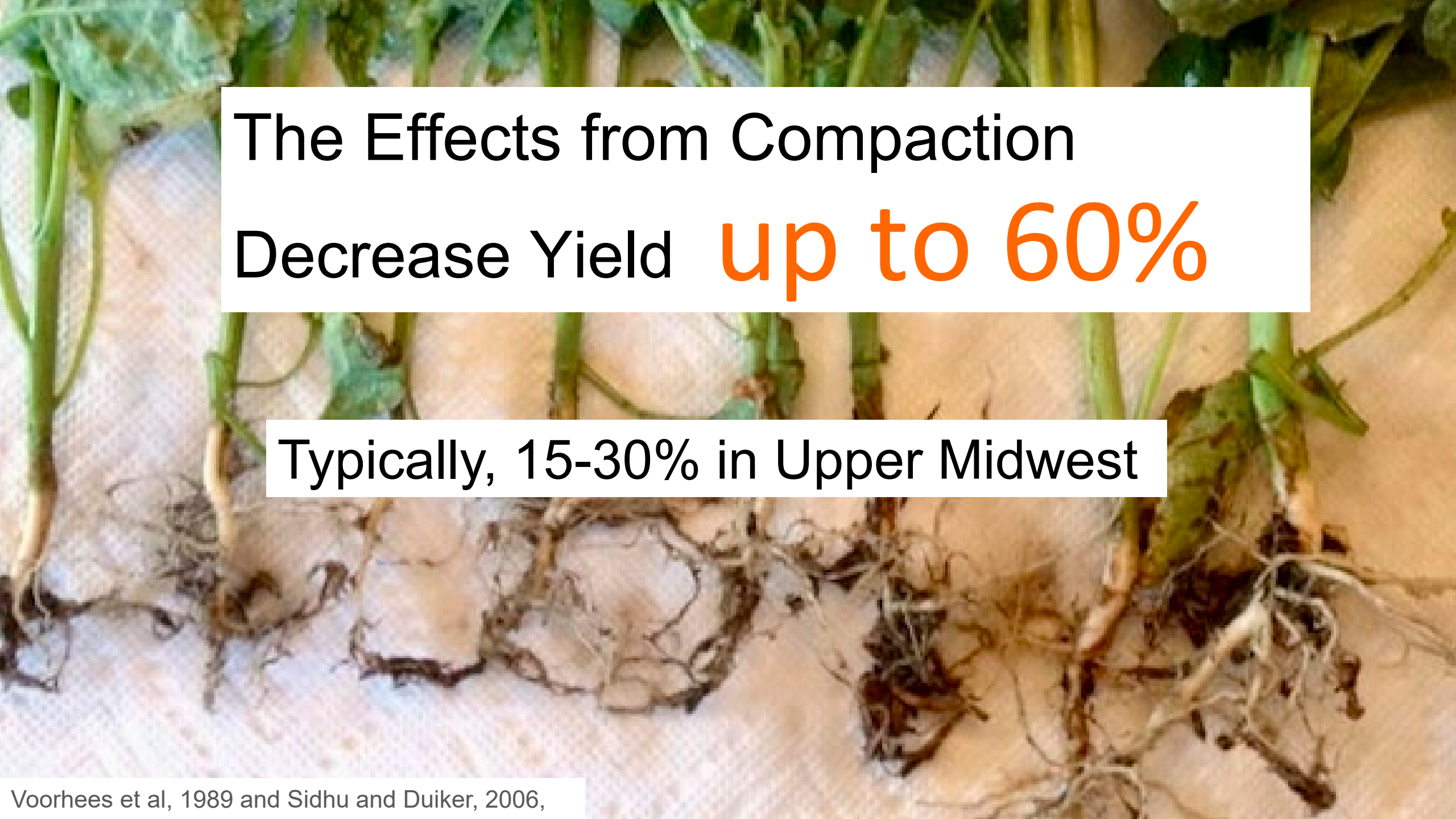
Data from UMN soybean compaction demo

Diffusion

- 1/10th of an inch
- P, K, Zn, Fe
- Compaction can stop root growth



Foth, 1962



The Effects from Compaction

Decrease Yield up to 60%

Typically, 15-30% in Upper Midwest

Voorhees et al, 1989 and Sidhu and Duiker, 2006,

Extensive Wheel Traffic

Wheel Traffic	45 bu/ac
No Traffic	59 bu/ac

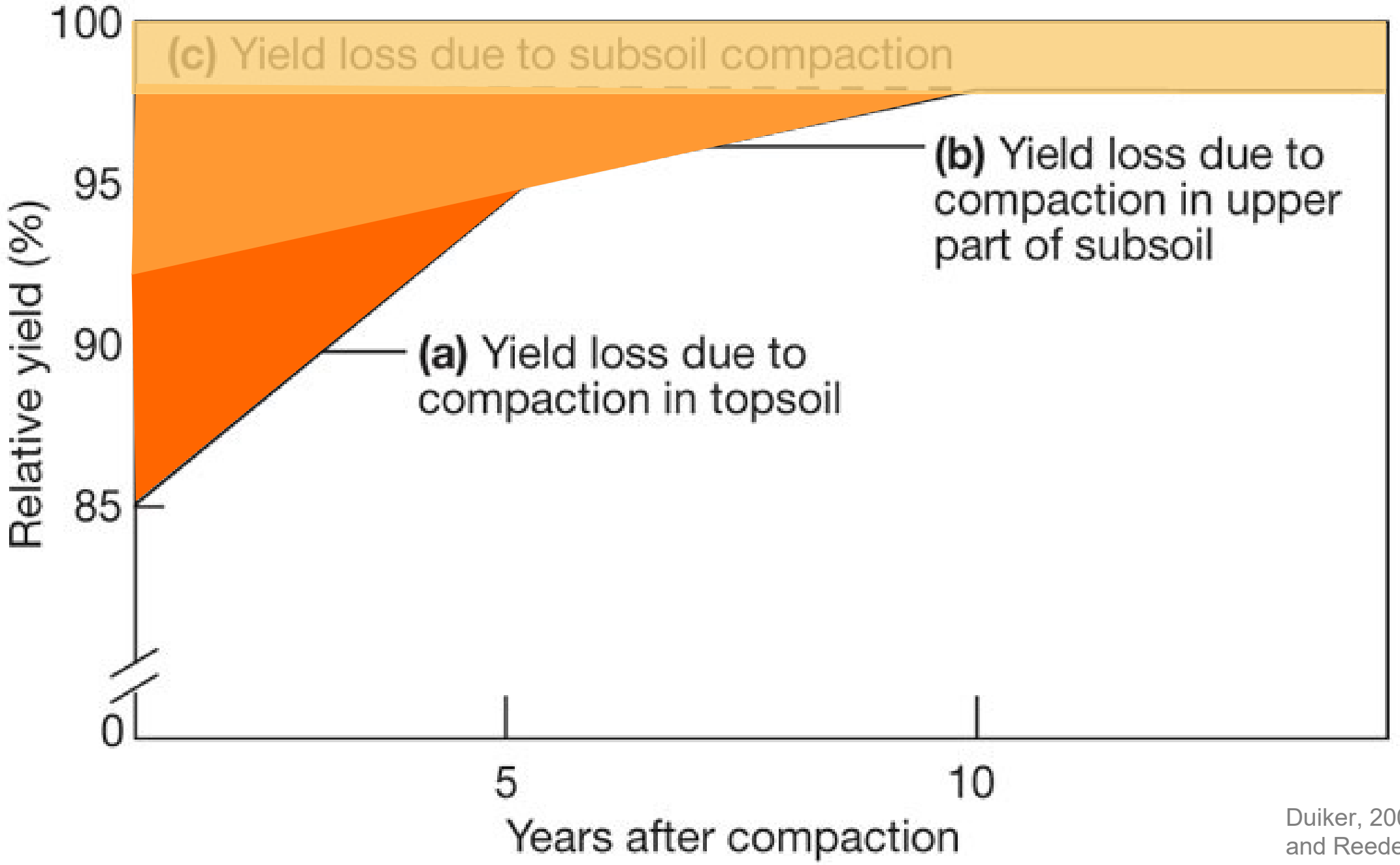
-14 bu/ac

Yield reduced 24%

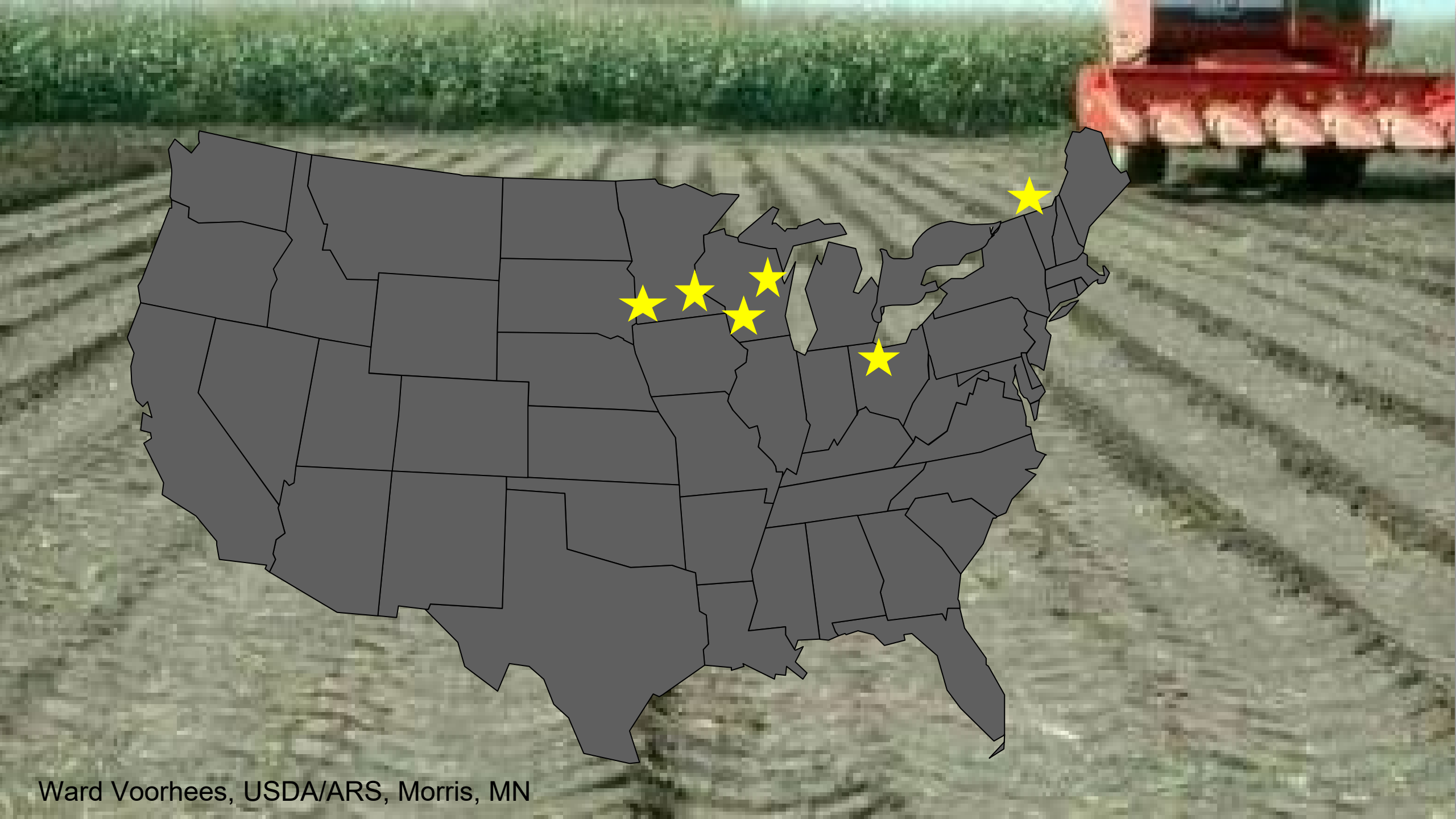
Courtesy of Dan Smith, Asgrow/DeKalb

How Long Does Soil Compaction Last?

Depends on depth



Duiker, 2004; Hakansson, and Reeder. 1994

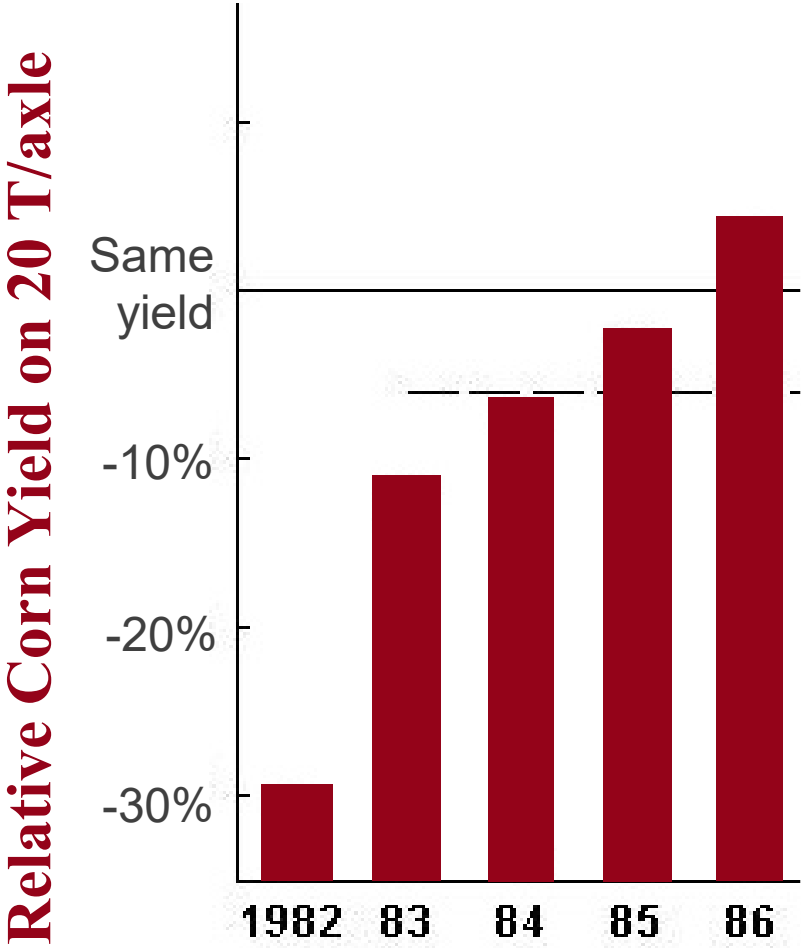

Ward Voorhees, USDA/ARS, Morris, MN

Multi State Compaction Research

- Corn at 6 locations
- Annual precip 25 to 38”
- Lower rate (8-10 T/axle)
- Higher rate (12 or 20 T/axle)
- 1 time compaction event
- Yield reduction 1-55%

Ward Voorhees, USDA/ARS, Morris, MN

Waseca, MN Corn Yield Response to a **1-time** 20 T/axle Compaction Pass



Ward Voorhees, USDA/ARS, Morris, MN

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Factors of Compaction

- Soil moisture
- Axle loads
- Ground pressure (PSI)
- Traffic passes
- Soil structure (soil health)

1 Working soil when it’s too wet

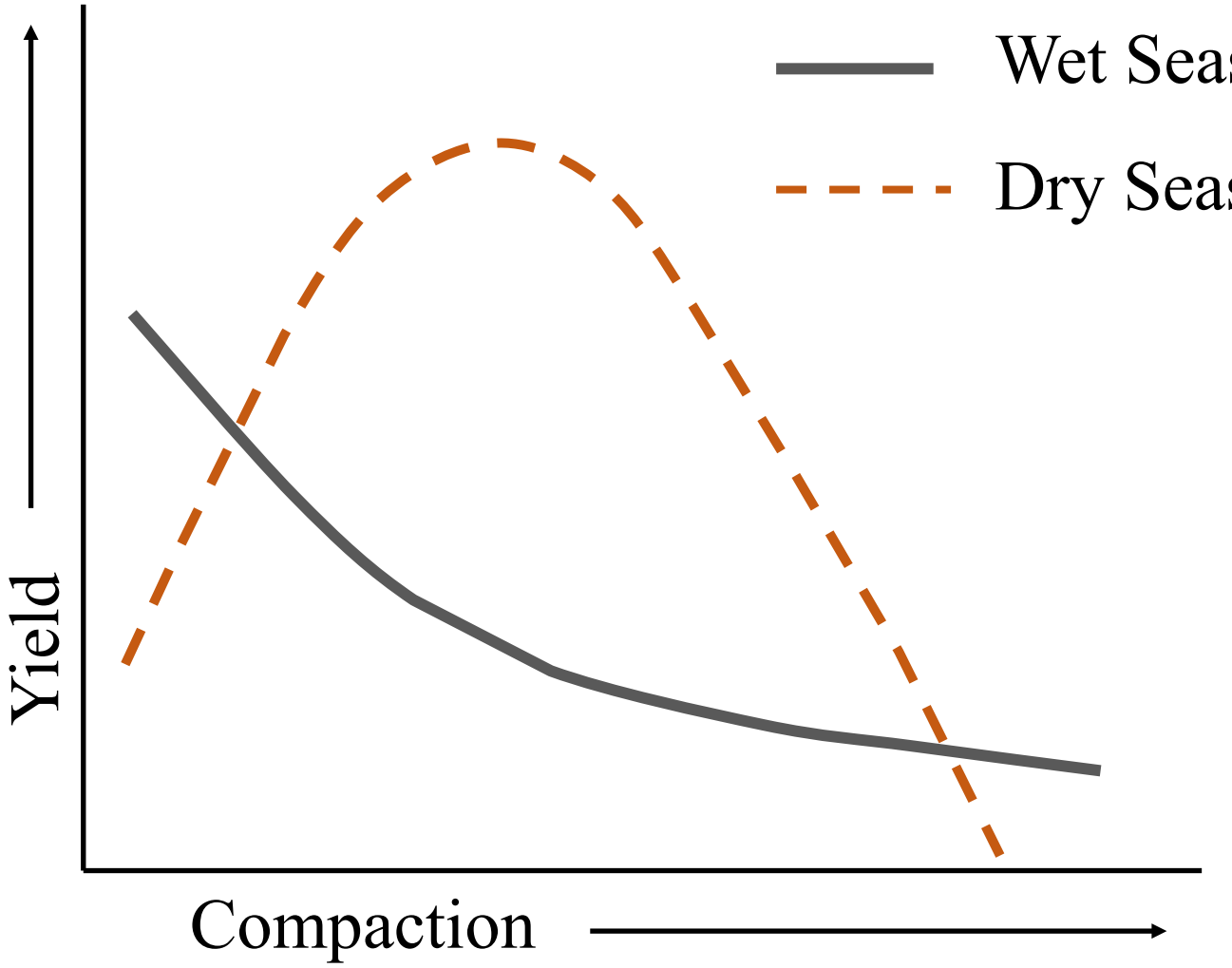
Photo found on social media

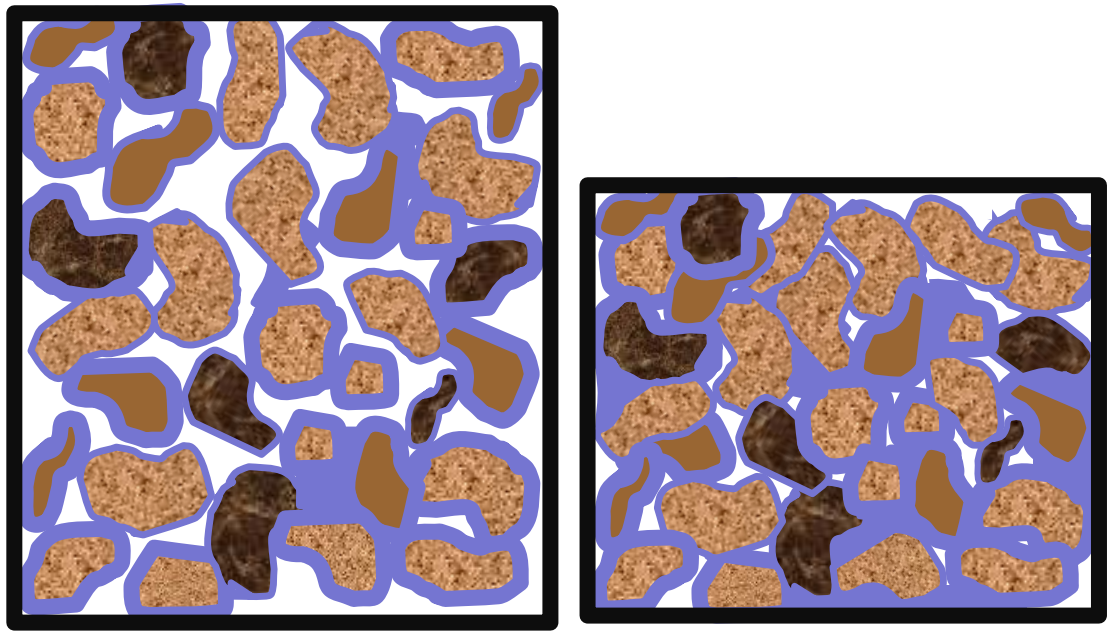
Soil Moisture

- Water acts as a lubricant
- Greatest compaction occurs at moistures near field capacity (22% water content)

Photo found on social media

Wet Versus Dry Years





Adapted from Soane et al. 1994

Flat, Heavy Soil - Drained vs Undrained

2

Heavy Axle Loads

(determines the depth of compaction)

Photo JohnDeere.com

Weight vs Depth

Weight (tons/axle)	Depth (inches)
4.4	12”
6.5	16”
11	20”
16.5	24”

Hakaansson and Reeder, 1994

Equipment (full weight)	Axle Load (Tons/axle)
Gravity wagon, 385 bu, 2 axles	6-7
Gravity wagon, 560 bu, 2 axles	10
Terra-gator, rear axle	12-18

Stay around 5 tons/axle on poor soil and 10 tons/axle on well structured soil

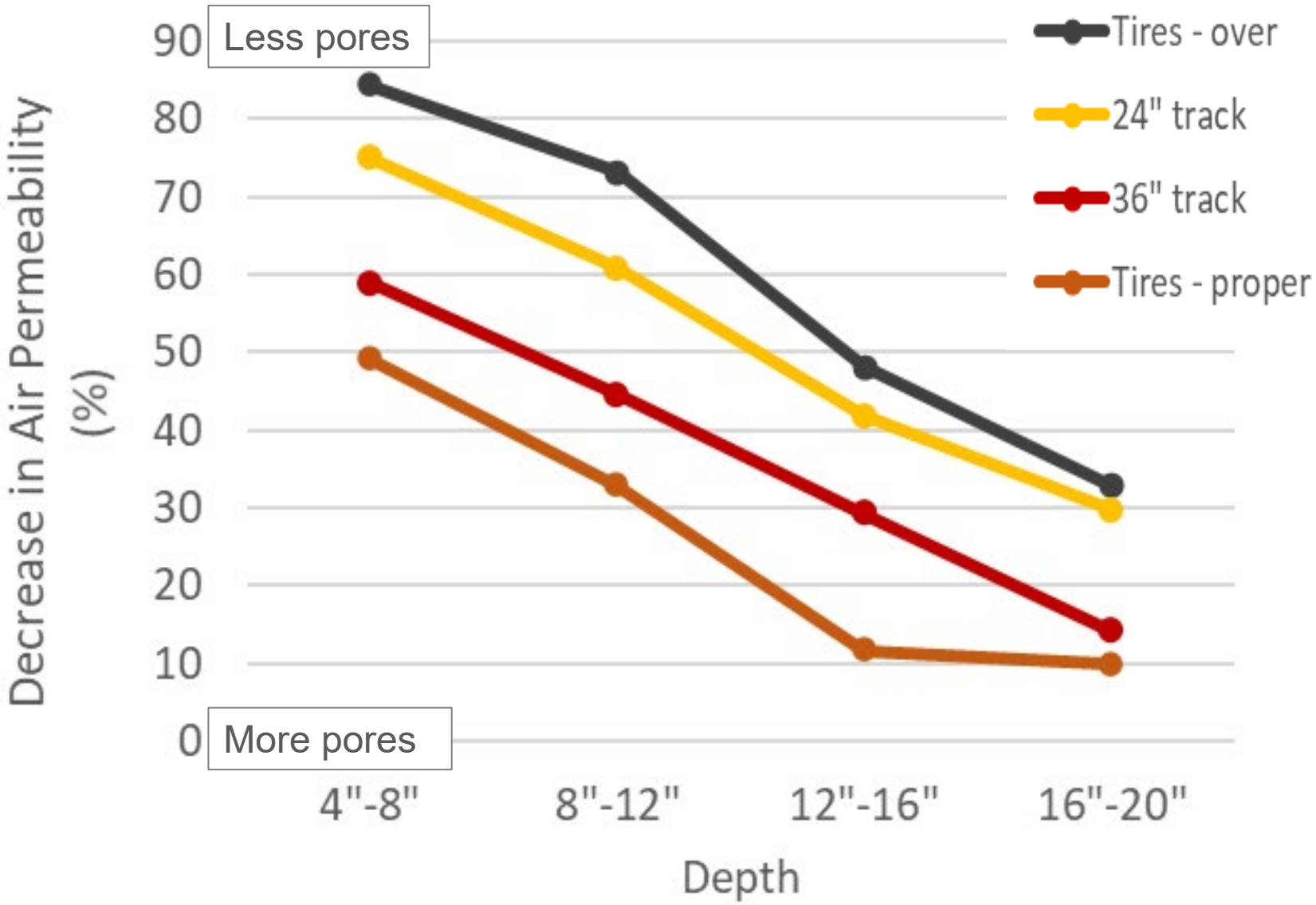
Equipment (full weight)	Axle Load (Tons/axle)
4,200 gal slurry tank, 2 axles	10-12
8,500 gal slurry tank, 3 axles	15
8,500 gal slurry tank, 4 axles	11

Stay around 5 tons/axle on poor soil and 10 tons/axle on well structured soil

3

Ground Pressure

- Tractors, sprayers, tankers, grain carts, trucks, combines …
- Bigger sidewall on tires = lower pressures
- Ideally 10 psi



Abu-Hamdeh et al. 1995

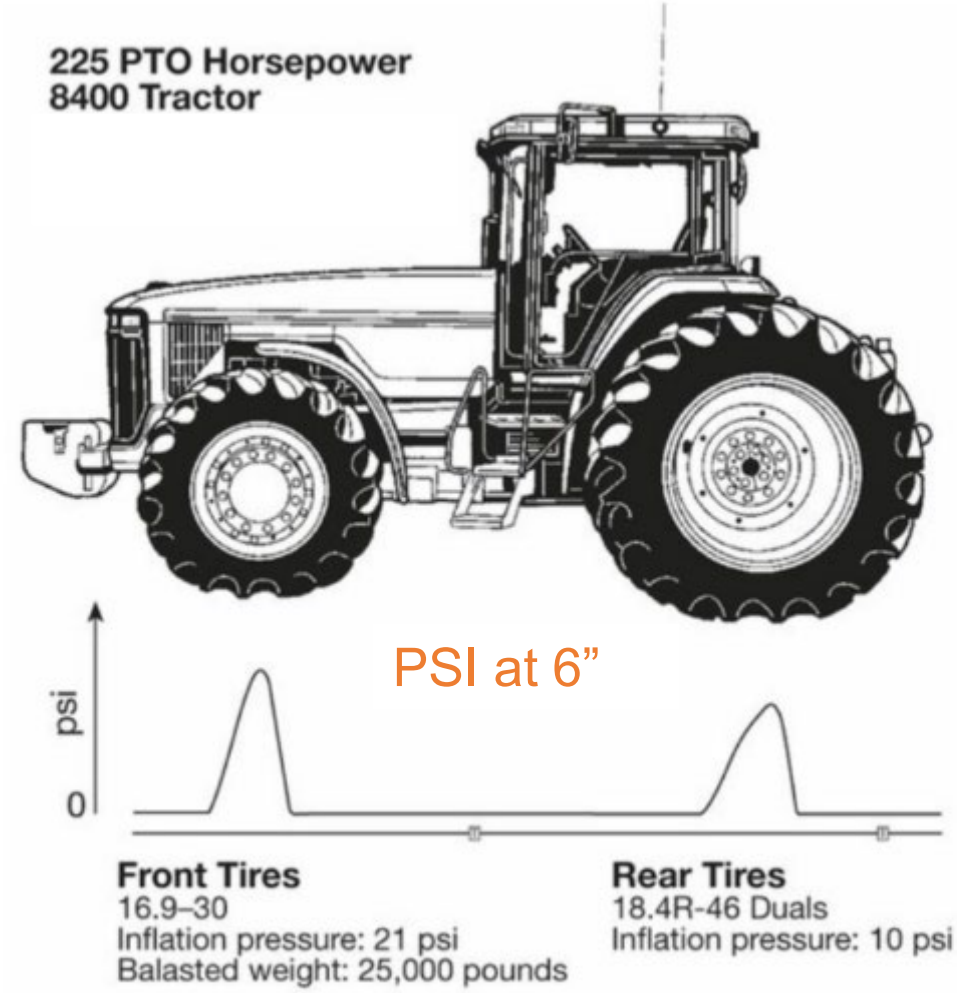
OSU Study

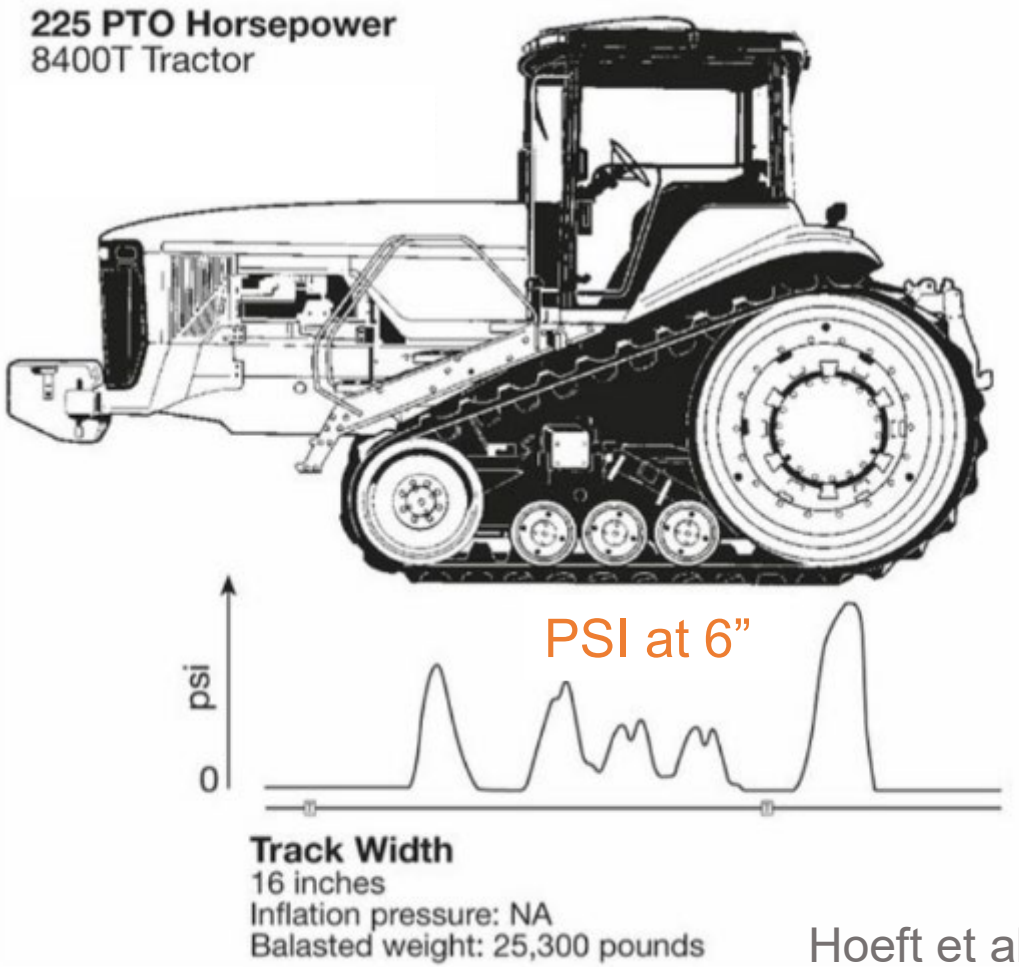
- JD 8870 4WD with 710/70R38 at 6 and 24 psi
- Cat Challenger with 2’ and 3’ tracks
- Towing had similar results
- 4 reps

Ground Pressure Factors for Tracks

Average psi changes with:

- positioning of mid-wheel rollers
- spring stiffness at attachment points
- track stiffness
- track width vs carriage width
- dynamic weight transfer when under drawbar load





Hoeft et al. 2000

Average contact pressure under rubber tracks is low, however, there are pressure points under guide wheels (Compaction Energy)

Properly Inflate all Tires

bigger sidewall on tire = lower pressures

Central Tire Inflation Systems (CTIS)

- Road inflations are much higher than field inflations
- Center fill planters have very high psi (85 to 120 psi)
- Installs quickly
- Can move to different tractors

www.PrecisionInflation.com

Can lower psi on tractor and planter in 30-90 seconds

CTIS Advantages

- Better fuel economy
- Less greenhouse gas released
- Less wear and tear on tires
- Better trafficability in the field
- Quick return on investment
- Yield?

Tractor Performance

Tire Pressure	Fuel Use
psi	gal/ac
13/11 – properly inflated	1.43
24 – over inflated	1.75

Lancas et al, 1996

4

Unchecked Traffic Patterns

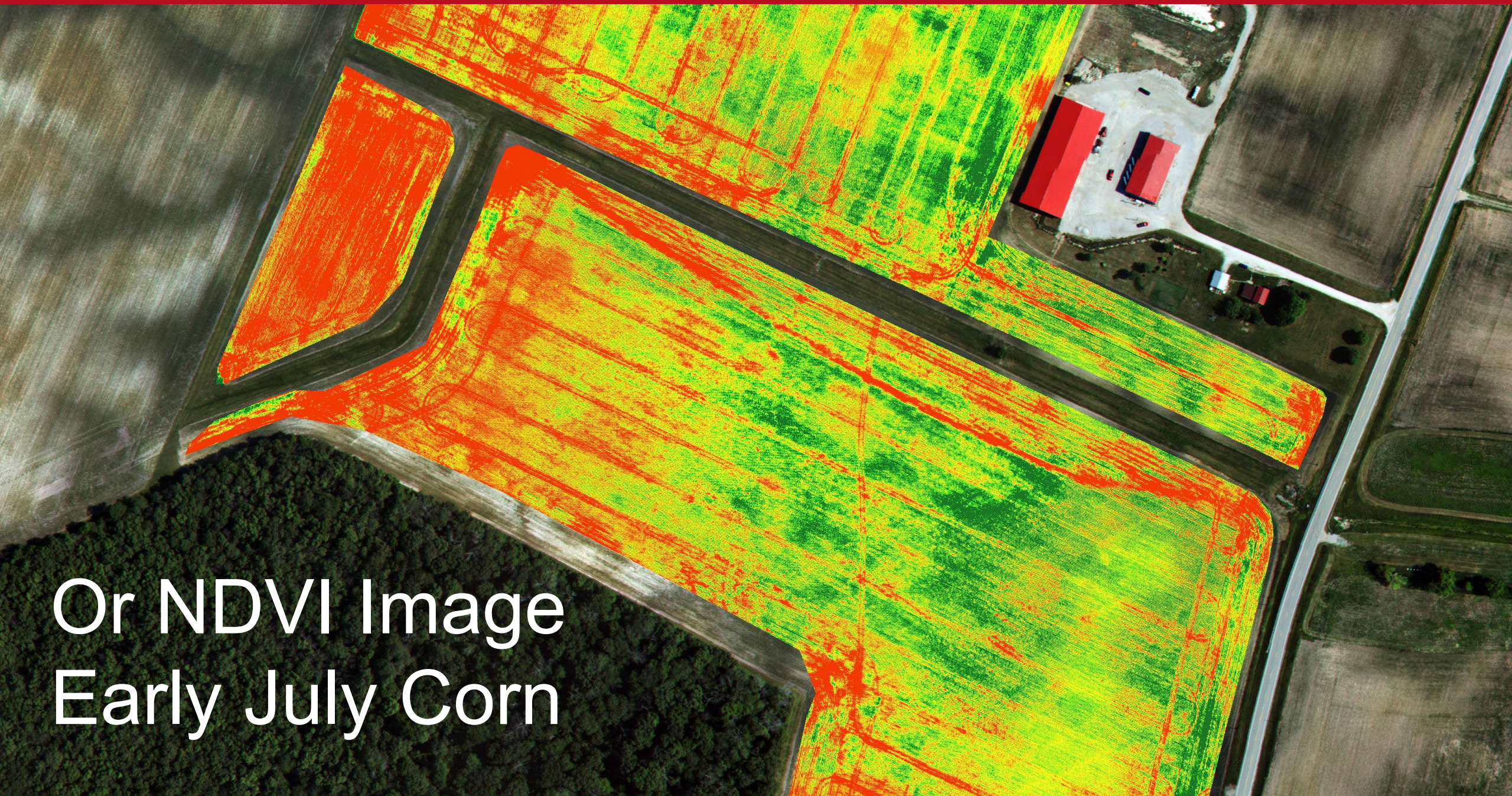
One vs Multiple Passes

Up to 80% of the compaction happens on the first pass

Control Field Traffic

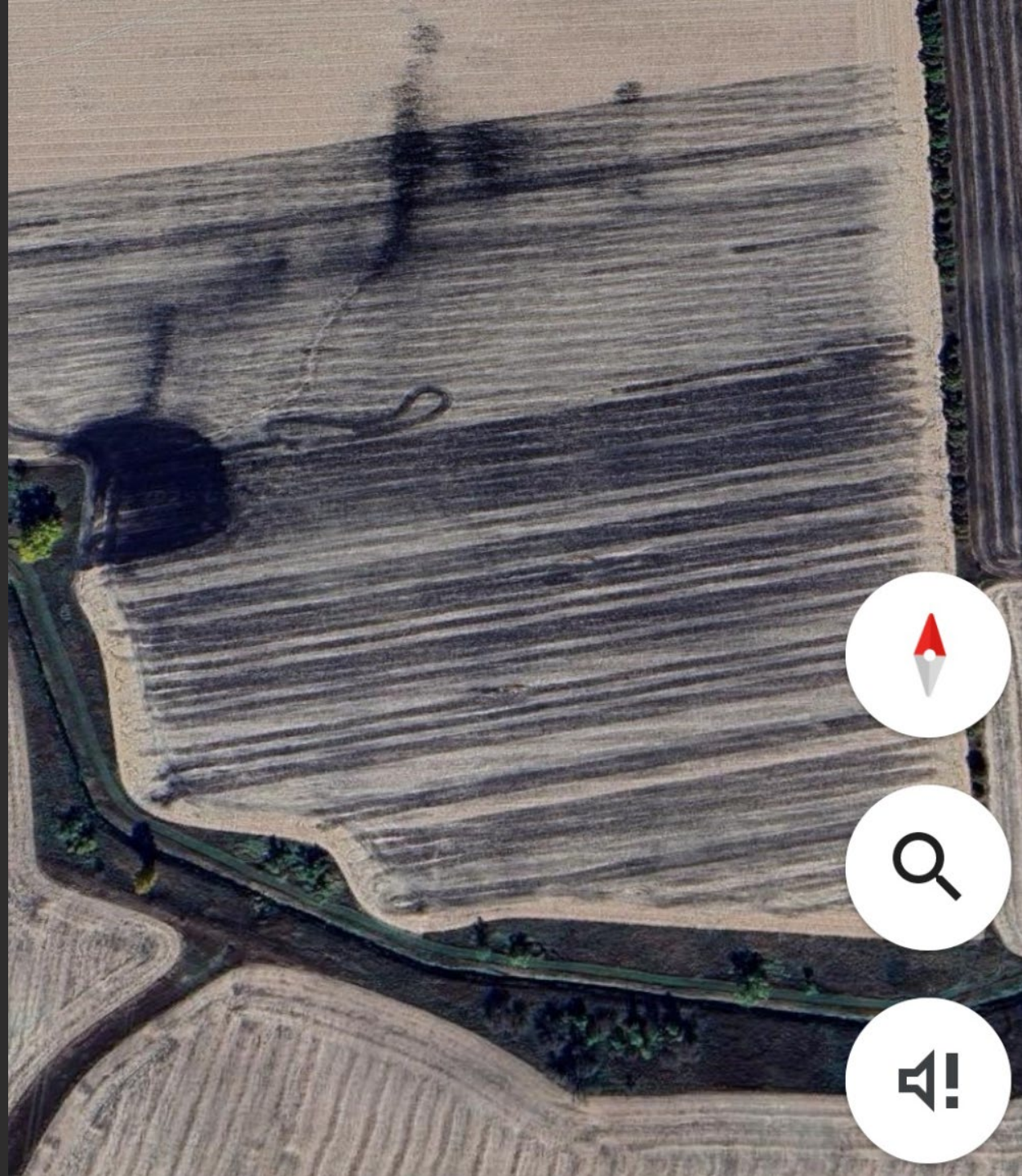
Look at your applied down pressure maps after planting

Image: Brian Luck, UW



Or NDVI Image Early July Corn

Or look at Google Earth or Satellite Maps



Line up the Grain Cart Tracks in the Previous Combine Tracks

Photo courtesy of MN Ag Services

Auger or Grain Cart Extensions

CaseIH.com

FaceBook.com

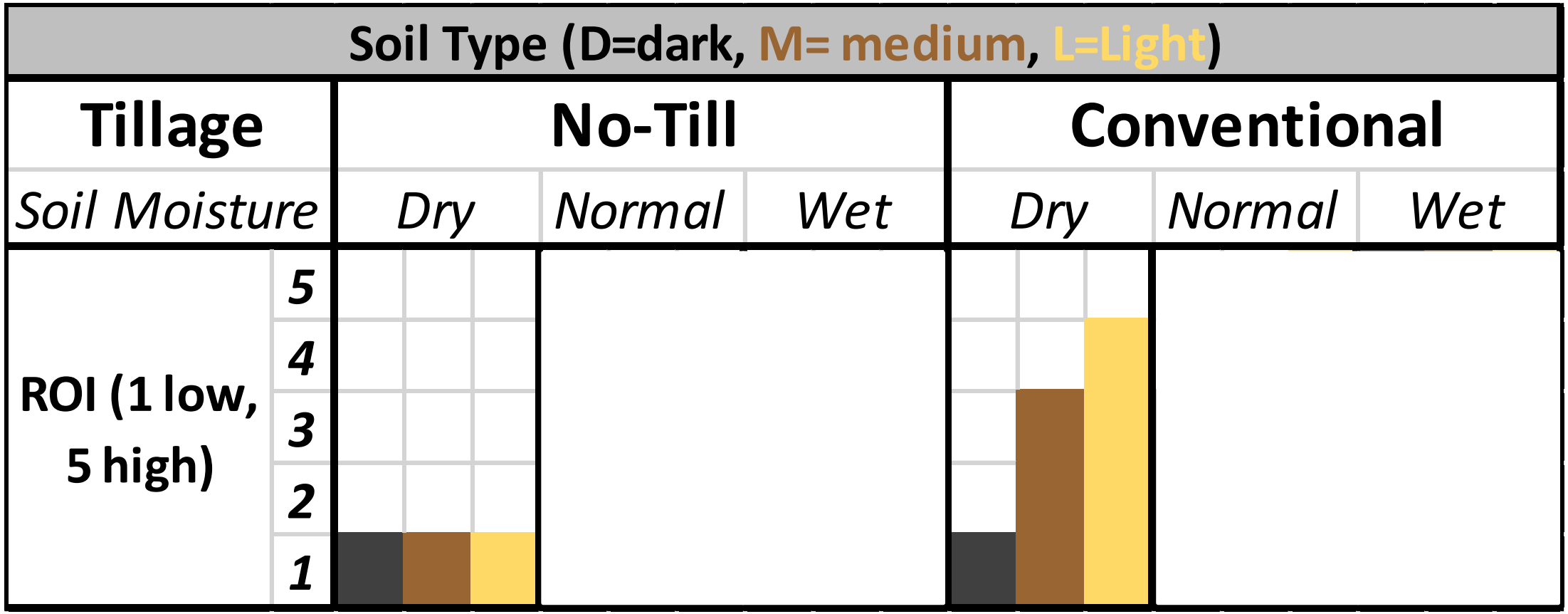
Yields in Different Systems

- Controlled traffic using fixed tramlines will drive on 20% - 40% of the field
- Traditionally farmed fields will drive on approximately 85% of the field

Scenario	Average Yield (bu/ac)
20% Wheel Traffic	56
40% Wheel Traffic	53
85% Wheel Traffic	47

Center Fill Planter, Tracks vs Tires

OSU Study (2016-2019)



5

Lack of Soil Structure

Aggregates!

#1 natural defense against soil compaction

Is Structure Important?

- Macropores are less than **1%** of all soil pores
- But they contribute **up to 70%** of the water infiltration

Schjønning et al. 2016 Soil Research;
Hirmas et al. 2018 Nature

Tillage

Destroys Aggregates

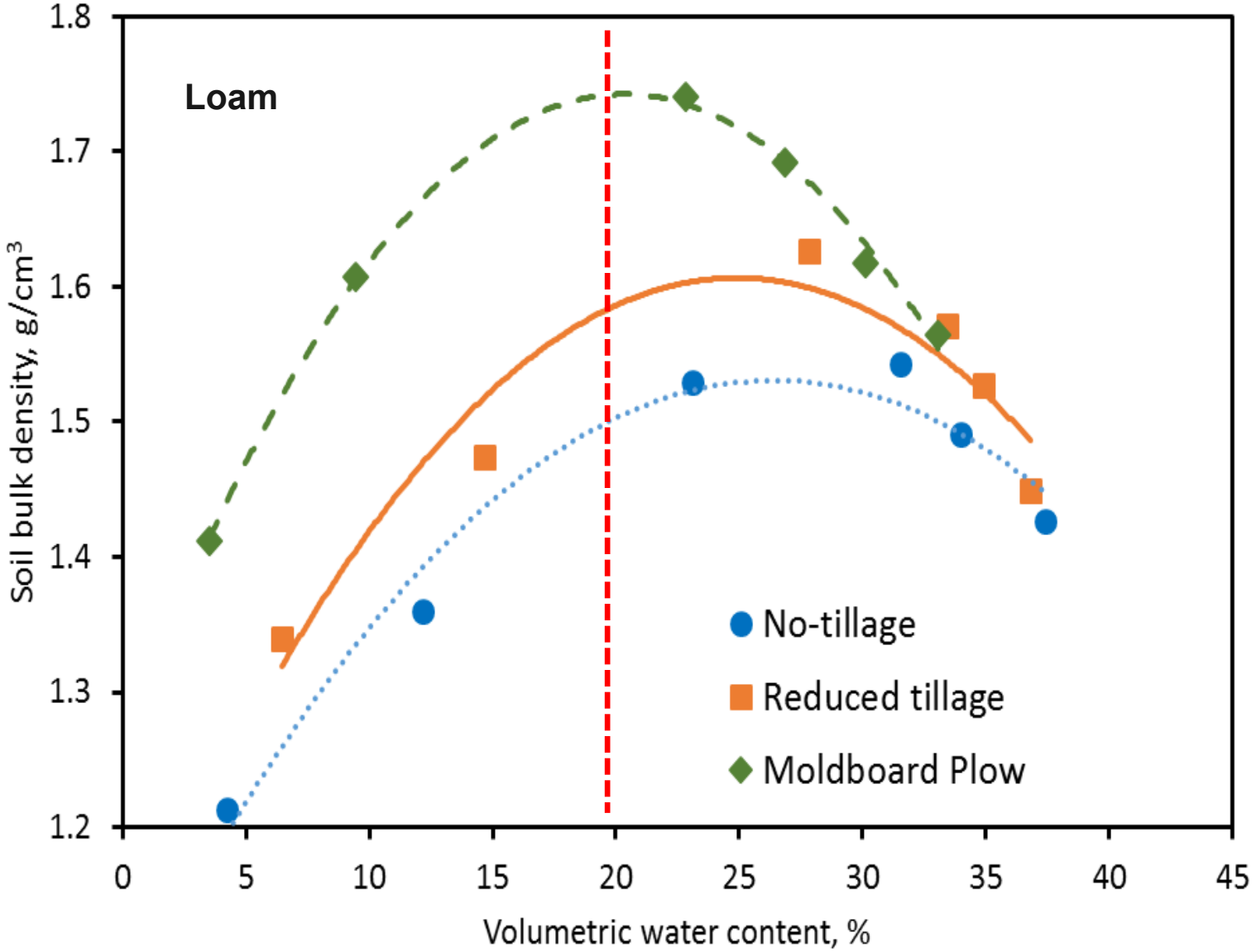
So how do we minimize the damage?


8THS
LINEAR METRIC UNITS AND SYMBOLS
1000 millimeters (mm) = 1 meter(m)
CONVERSIONS
inches x 25.4 = millimeters
inches x 2.54 = centimeters
feet x 30.48 = centimeters
feet x 0.3048 = meters
yards x 0.9144 = meters
miles x 1.609344 = kilo

Reduce or No Tillage

- Less aggressive implements
- Less passes across the field
- Shallow up equipment
- Choose shanks over disks
- Try strip till, rotational tillage, or no-till

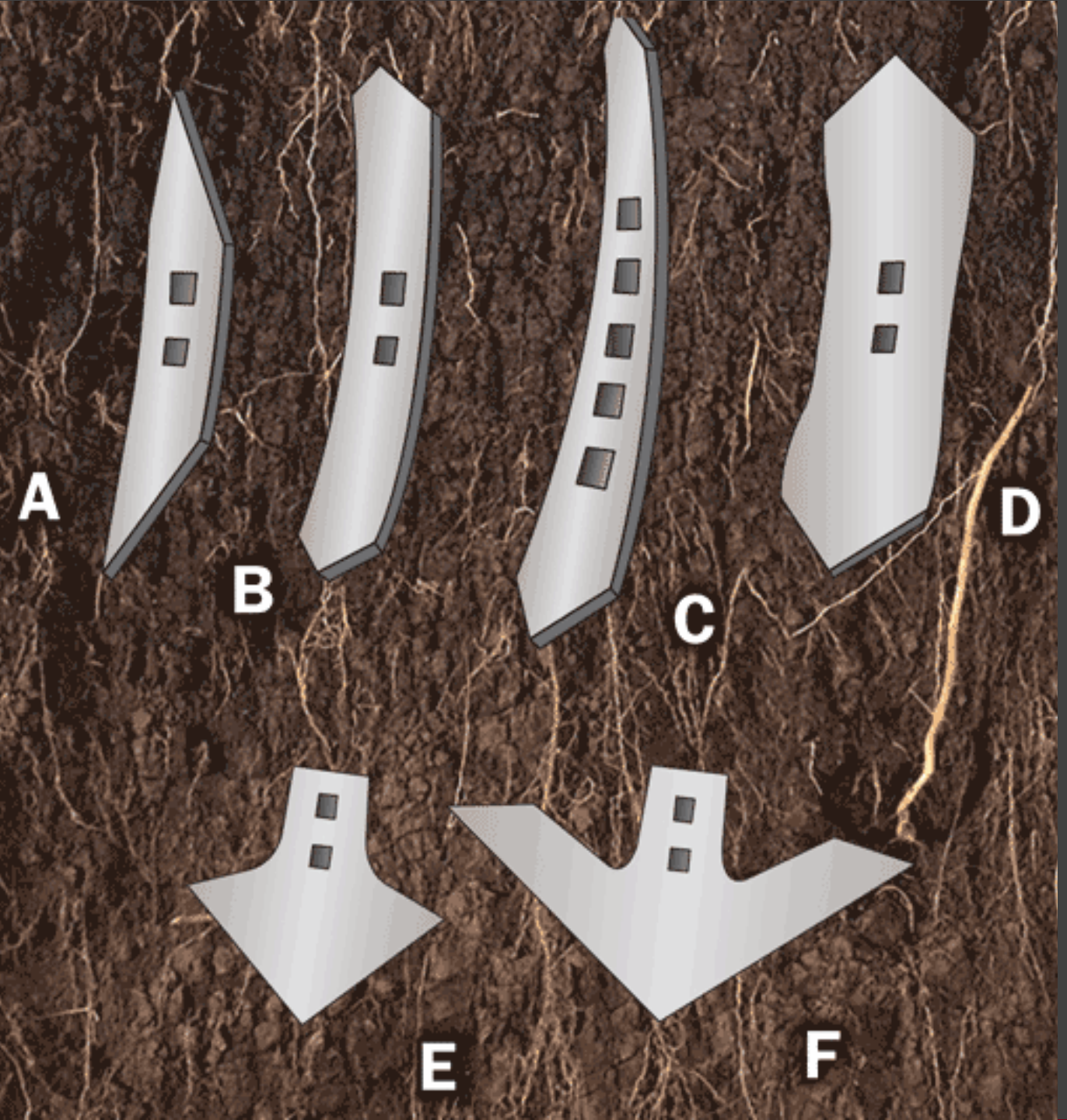
3-4” Field Cultivation Compaction



Soil Compactability

Soil with better aggregation has lower soil compaction risk

Adapted from: Blanco-Canqui, 2009 and F. Arriaga



Points, Shanks, Sweeps

- Lifts and separates the soil
- Less destruction of soil structure

Image Farm-Equipment.com

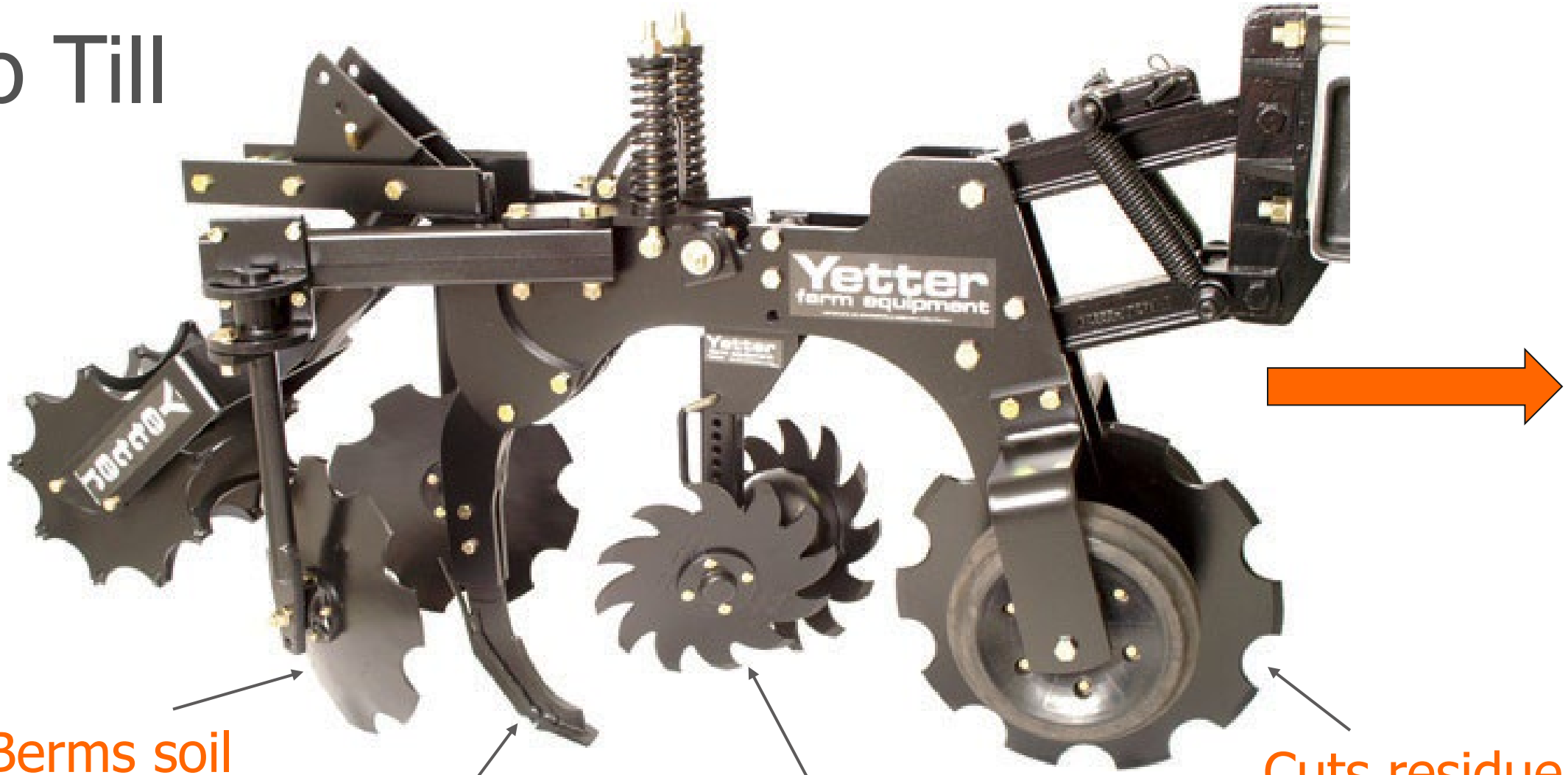
Twisted Shovel vs. Sweep

Photos: Dick Wolkowski, UW

Disks

- More destructive forces (very aggressive)
- Shears and presses soil
- If you have to use it, keep it shallow. However, rain gets in the soil from the surface

Strip Till



Berms soil

Tills and injects fertilizer (6-8”)

Moves residue

Cuts residue

Disturbs only 1/3 of the soil

Benefit:

Get into the fields quickly after a rain event

IRF – Irrigation Research Foundation – Yuma, CO

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What to do if you have compacted soil

Natural or Bio Alleviation

In dry years, there is natural deep “tillage”

- Only for soils that crack open when dry
- Works for all depths of compaction

Cover Crops

- Improves trafficability
- Builds soil aggregates
- Breaks through plow pans (with time)
- Protects the soil

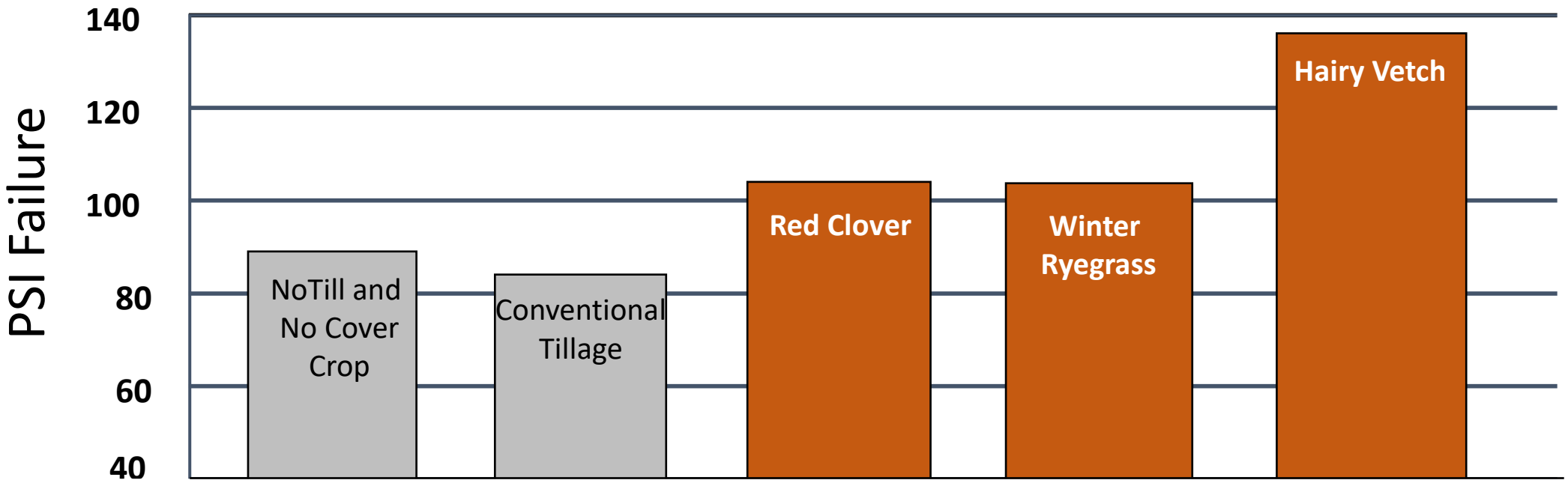
Soil Strength and Trafficability

A measure of the capacity of a soil to withstand stresses without giving way to those stresses by collapsing or becoming deformed.

Photos: Shannon Osborne, ARS

Cover Crops Improve Trafficability

Due to either reduced moisture and/or better soil structure



Cover Crops and Plow Pans

- Montana ARS study
- 3 cycles of a 2-year rotation
- Plow pan at 4-6”

Jabro et al, 2021

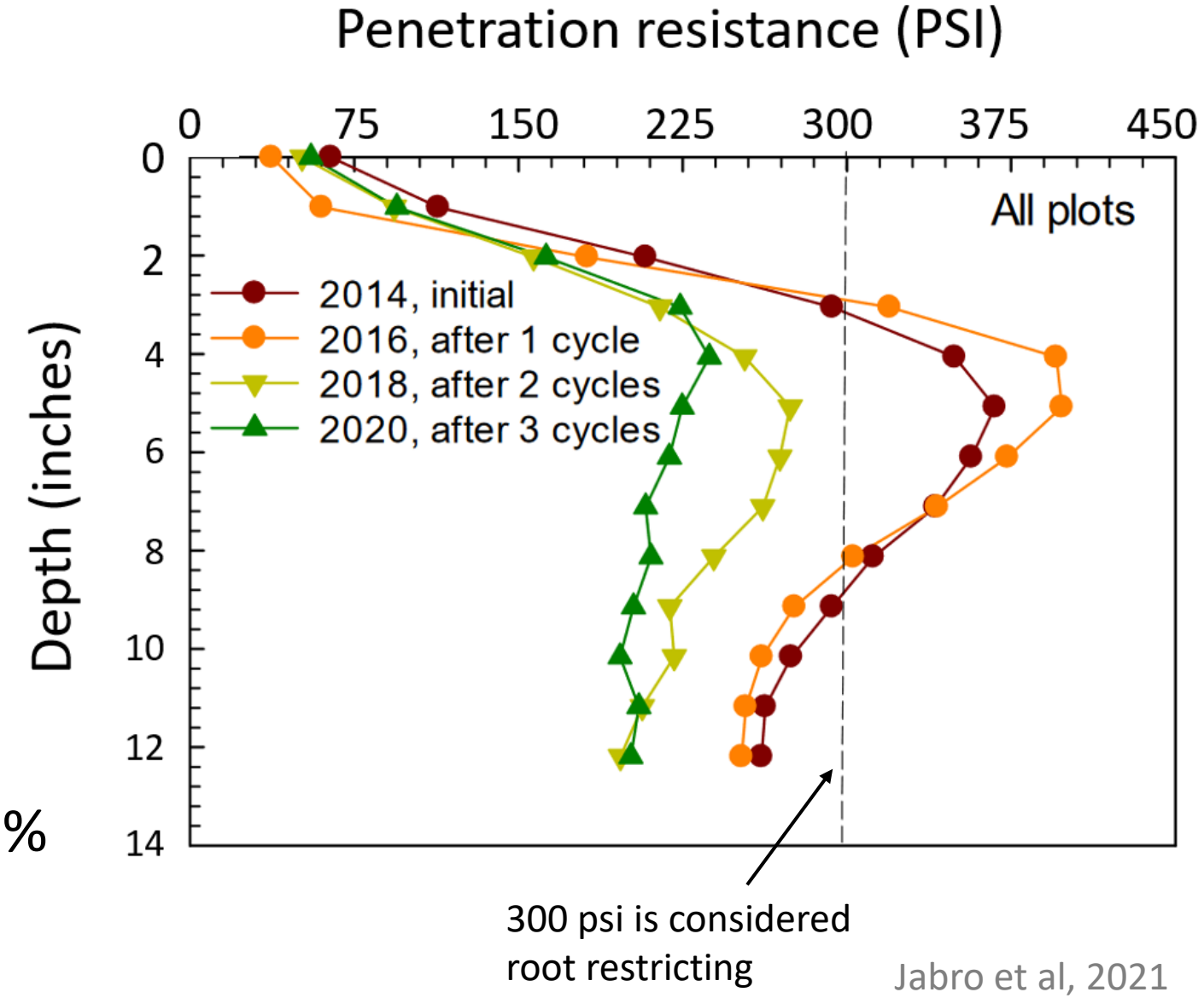
Cover Crops and Plow Pans

After 2 cycles (4 years)

- bd in plow pan ↓ 25%

After 3 cycles (6 years)

- bd in plow pan ↓ again by 32%



Jabro et al, 2021

Which handles the elements and field traffic better?

Mechanical Remediation

Find the Compacted Layer

- What is the soil moisture?
- How deep is he layer?
- Where is it located?

More info at
z.umn.edu/UWpenetrometer

Or dig a pit

Use the most non-invasive, straight shank

Photos by Dick Wolkowski, UW

Set points 1-2 inches below compacted layer

- Work soil when dry
- Rip only where needed (precision tillage)

- Do not drive on ripped soil again
- Use controlled traffic practices. Especially important in no-till fields

Zone Tillage

(subsoiler)

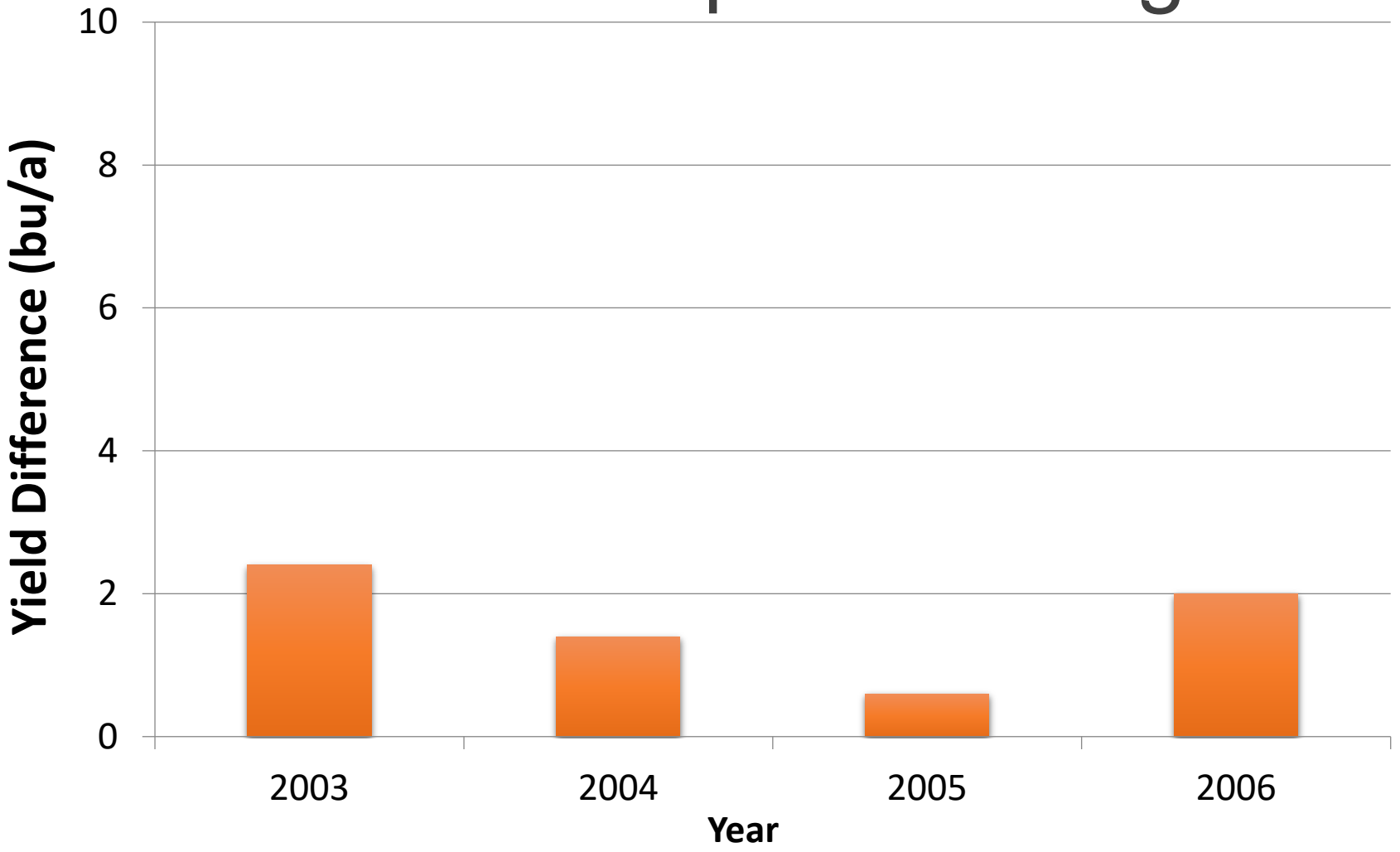
- A very aggressive tillage operation to cut through deep compaction (15-20”)
- Requires 30-50 hp per shank

Iowa Soybean Assoc Study

- Central and NE Iowa
  - 34-70 fields per year
- Replicated 4 times, field length plots
- John Deere in-line ripper, 16” deep

Iowa Average Yield Difference

Due to Deep Zone Tilling



Iowa Summary

Producers said:

- Not enough increase in yield to pay for ZT and no 2nd year benefit
- Rocks became a major issue
  - Rock picking expenses
  - Potential equipment damage
  - Ground rolling to push rocks back down
- Multiple states have similar results

Midwest Deep Zone Tillage Lit Review

		No Restrictive Layer	Restrictive Layer
		% Yield Change	
Corn		**0**	**+16**
	# of site years	42	11

Smeared soil from shank being pulled in soil that was too wet.

Knife slot in soil that was too wet to be deep ripping.

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Managing Compaction

- Saves fuel
- Saves wear and tear on implements
- Saves time in the field
- More consistent yields
- Better water infiltration
- More nutrients available to plant

Take Home Message

- Wet soils have less strength
- Heavy loads move soil compaction deeper
- Higher ground/tire pressures increase the intensity of the compaction
- Increased tillage reduces soil structure and promotes compaction

z.umn.edu/TillageGuide

z.umn.edu/CompGuide

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Virtual Event!

Northern Soil Compaction Conf

NDSU.AG/NSCC2026

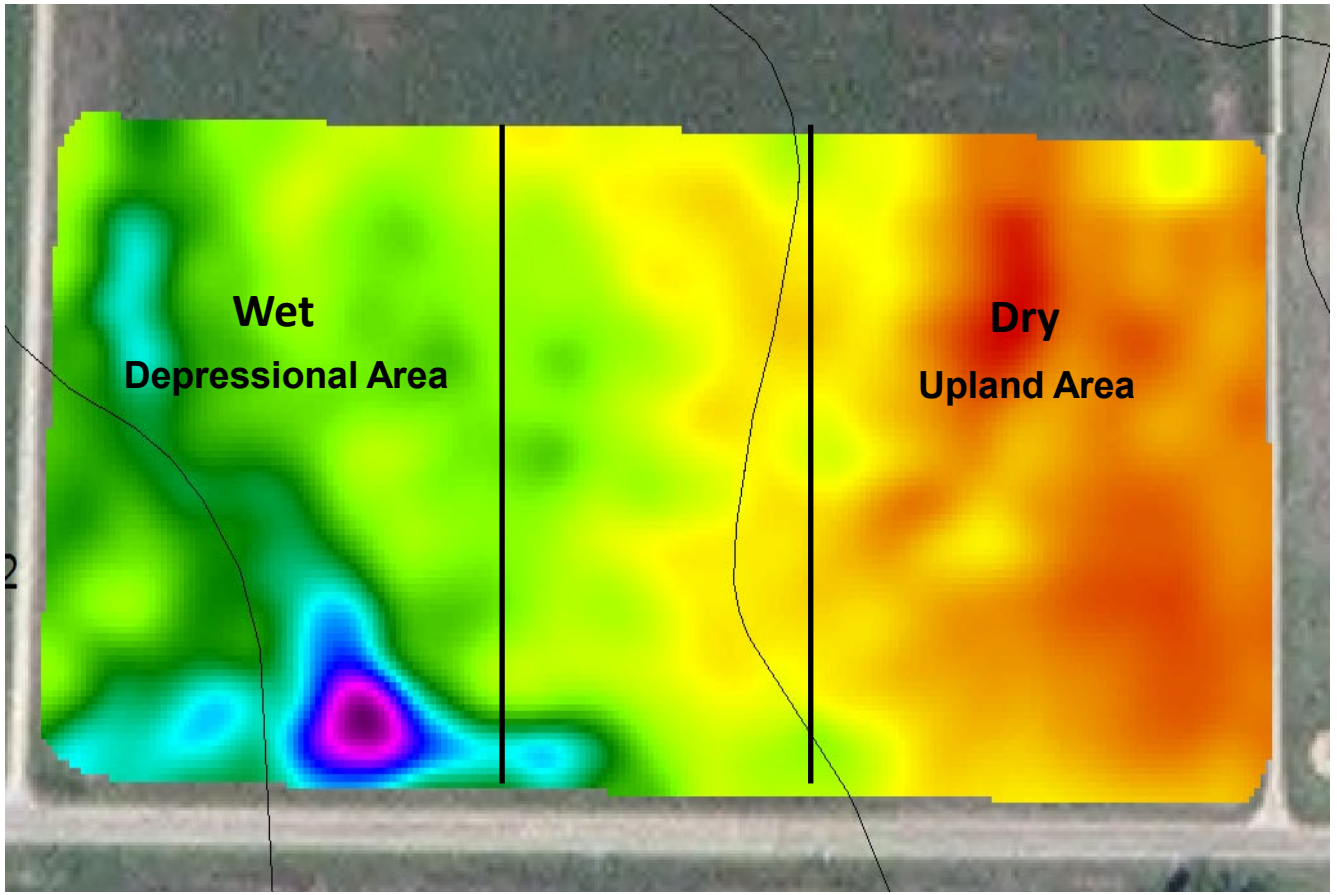
Feb 3, 10, 17, 24

9:00 – 12:00 CST

Presentations will be recorded!

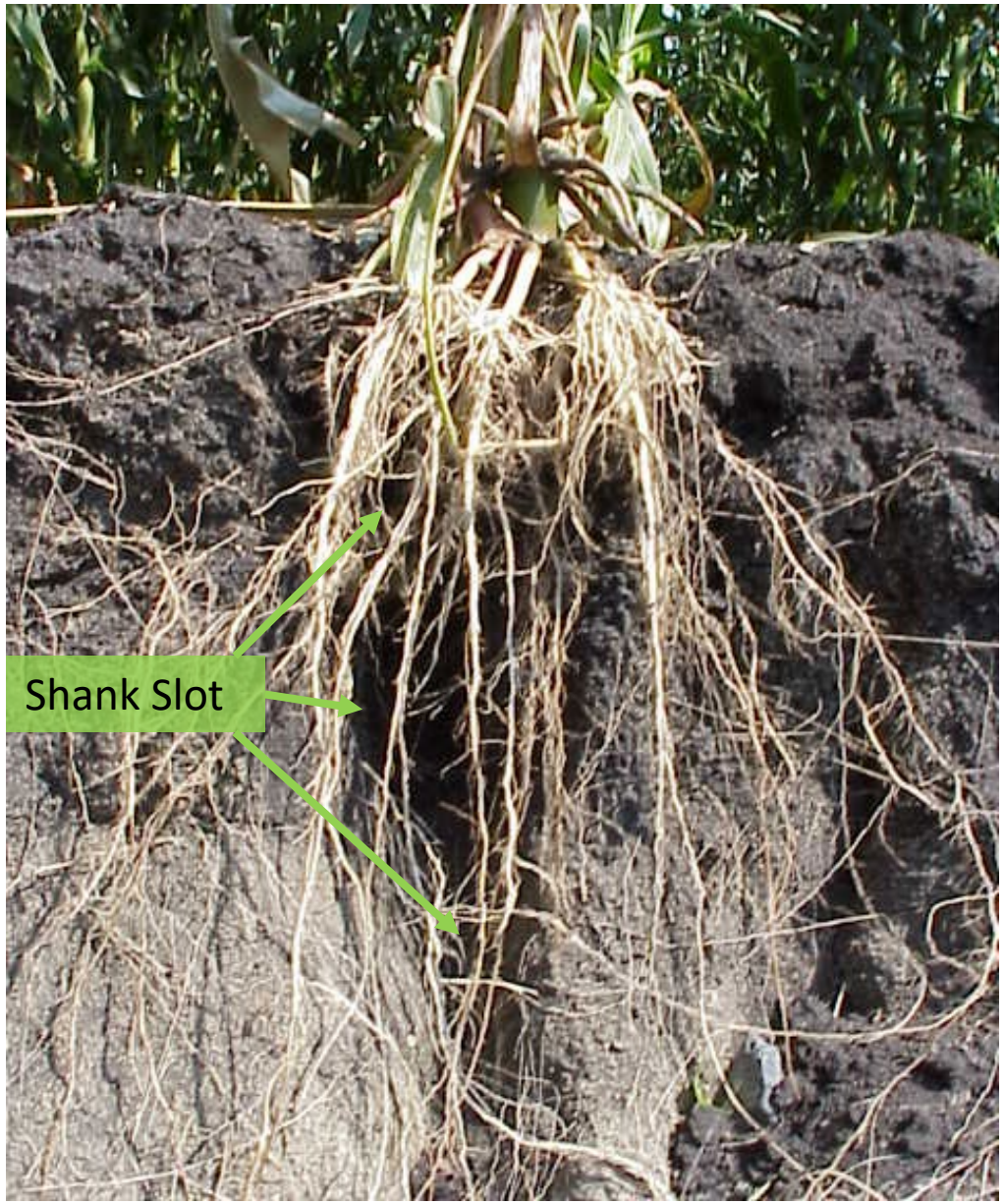
Elrosa Study, MN – Field Stats

- Clay loam soil
- pH 7.2
- Organic matter 4.8%
- Ridge-till system
- 4.5 T/ac poultry manure
- Replicated 8 times across the field

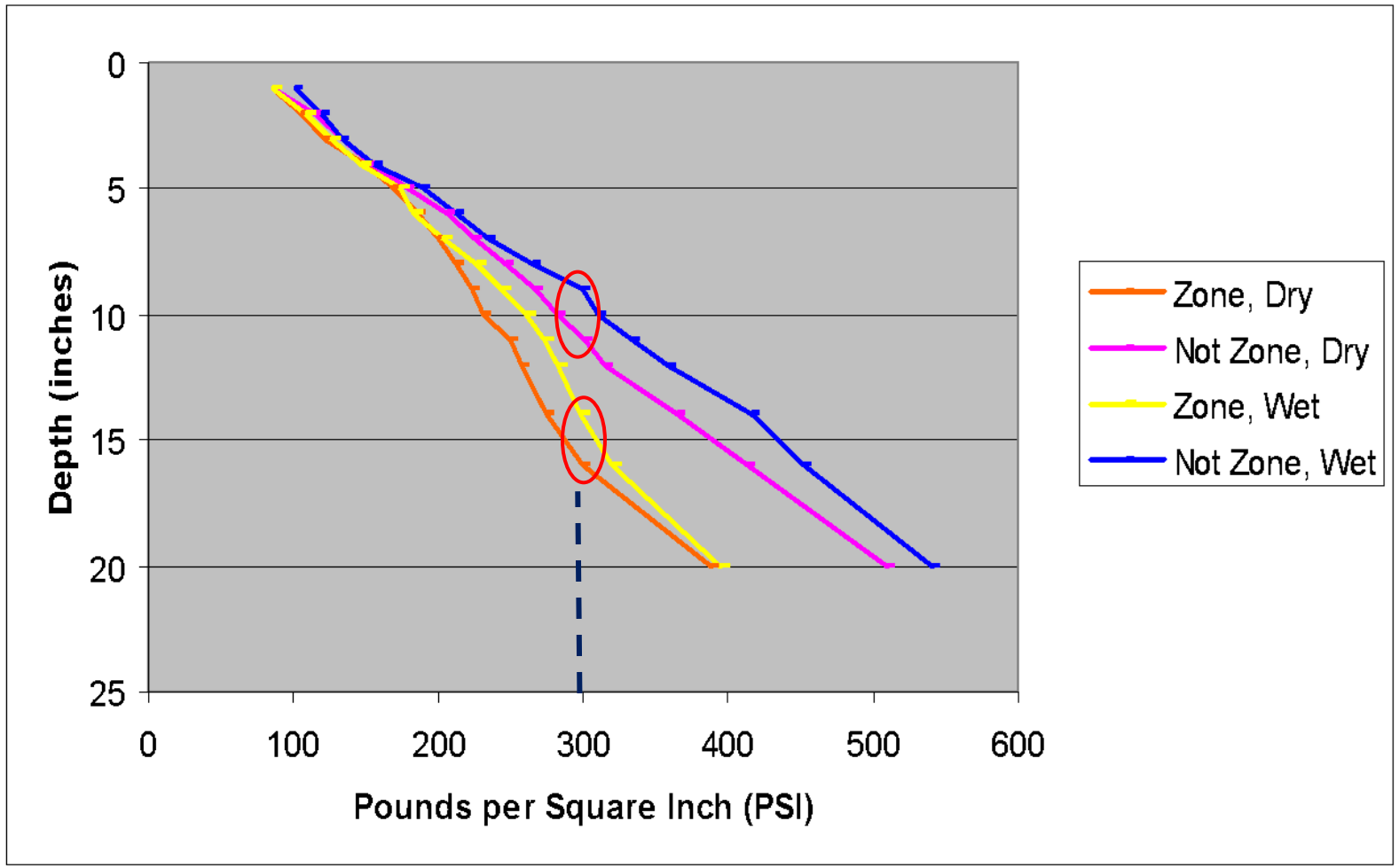


Not Zone-tilled in drier soil conditions

Zone-tilled in drier soil conditions

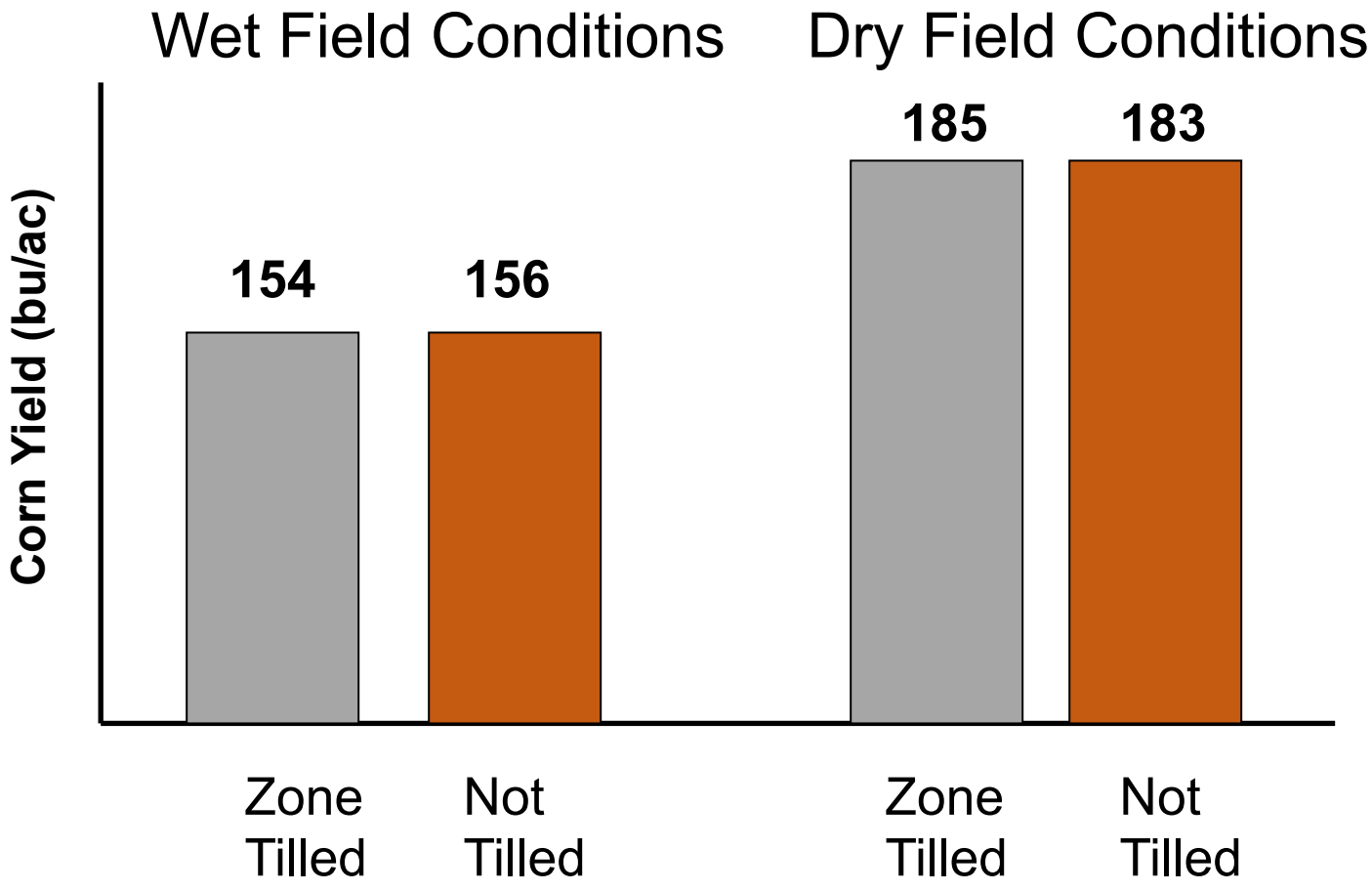


Soil Penetrometer Readings



- Moisture, Tillage and Depth were all significantly different.
- Lowest penetrometer readings were in the Zone tilled plots.
- 2 years later, we could no longer detect the tilled zone

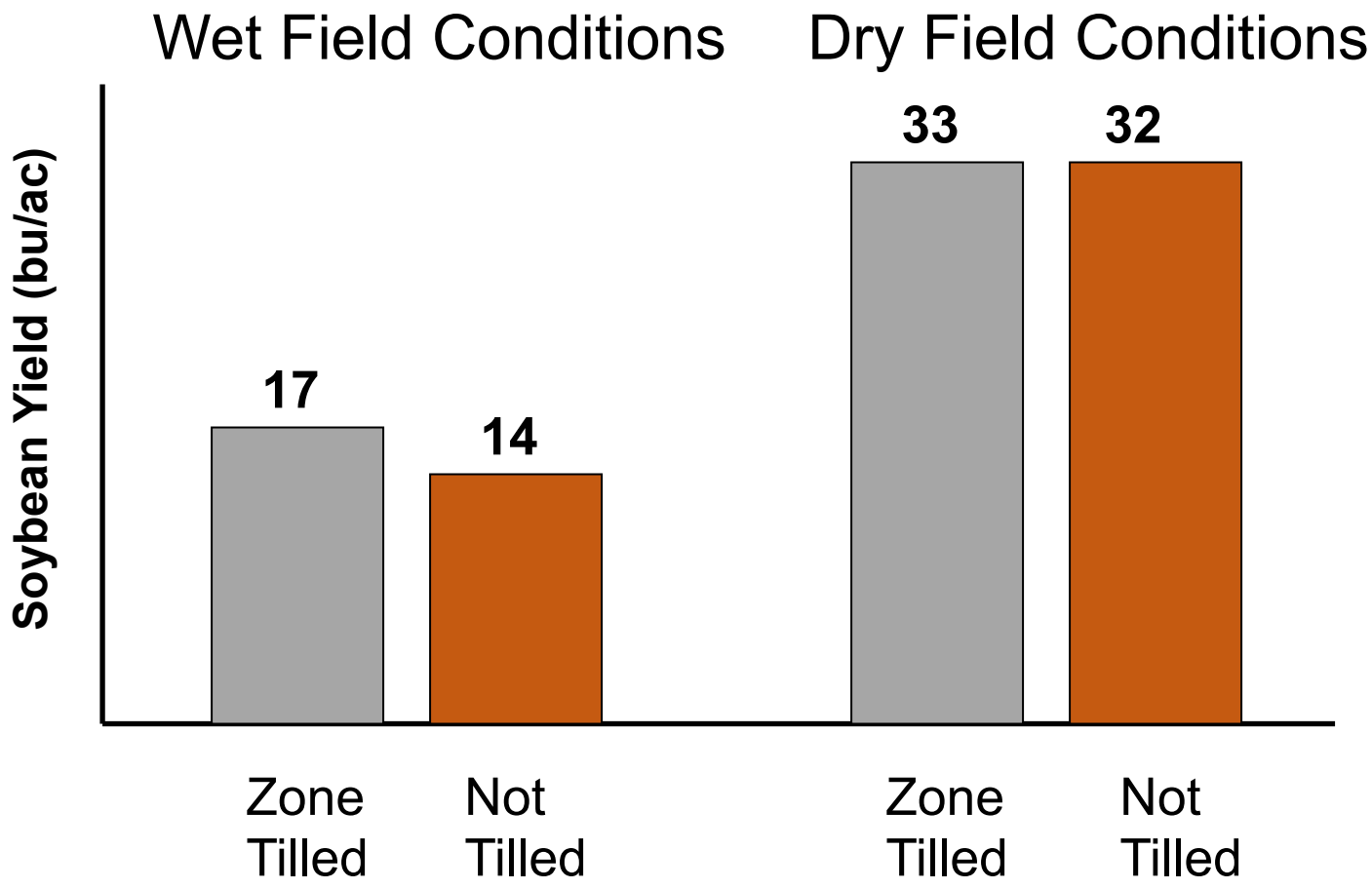
Elrosa 2003 Corn Yield



Yield differences were only significant due to soil moisture

There were no significant yield differences due to zone tilling

Elrosa 2004 Soybean Yield



Yield differences were only significant due to soil moisture

There were no significant yield differences due to zone tilling

Elrosa Summary

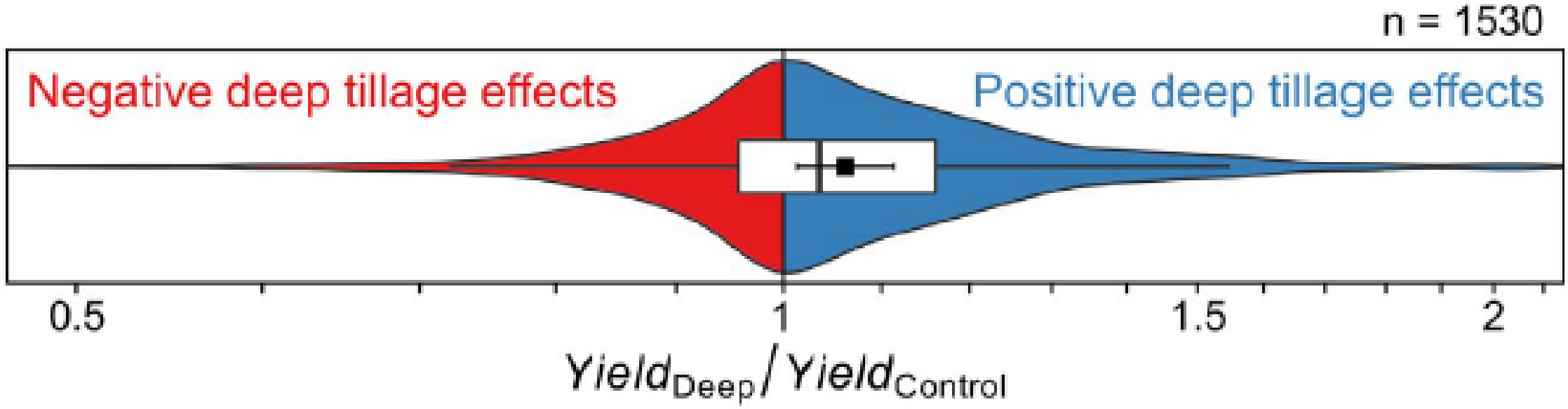
- Only penetrometer readings were significantly different in the zone-tilled plots
- Within 2 years after zone tilling, macropores collapsed into smaller pore spaces = reconsolidation
- Poor drainage had a larger effect on plant growth and soil parameters than tillage

Wisconsin Study (1997-2000)

- Compared a straight shank to a V-ripper
- Clay loam soil

Dick Wolkowski, University of Wisconsin, Manitowoc

Global Literature Review



Aaron Daigh, UNL, Schneider et al., 2017

Overall distribution (violin plot, box plot and mean ± 95% confidence interval).

Effects of Subsoiling

In the US Midwest

Research results have shown

- few positive yield responses
- responses are variable and relatively small

Why No Yield Response to Subsoiling?

- Unfavorable soil moisture conditions while subsoiling
- Wheel traffic recompacted the loosened soil
- Climatic effects were no longer limiting

All Tillage Destroys Aggregates

So how do we minimize the damage?

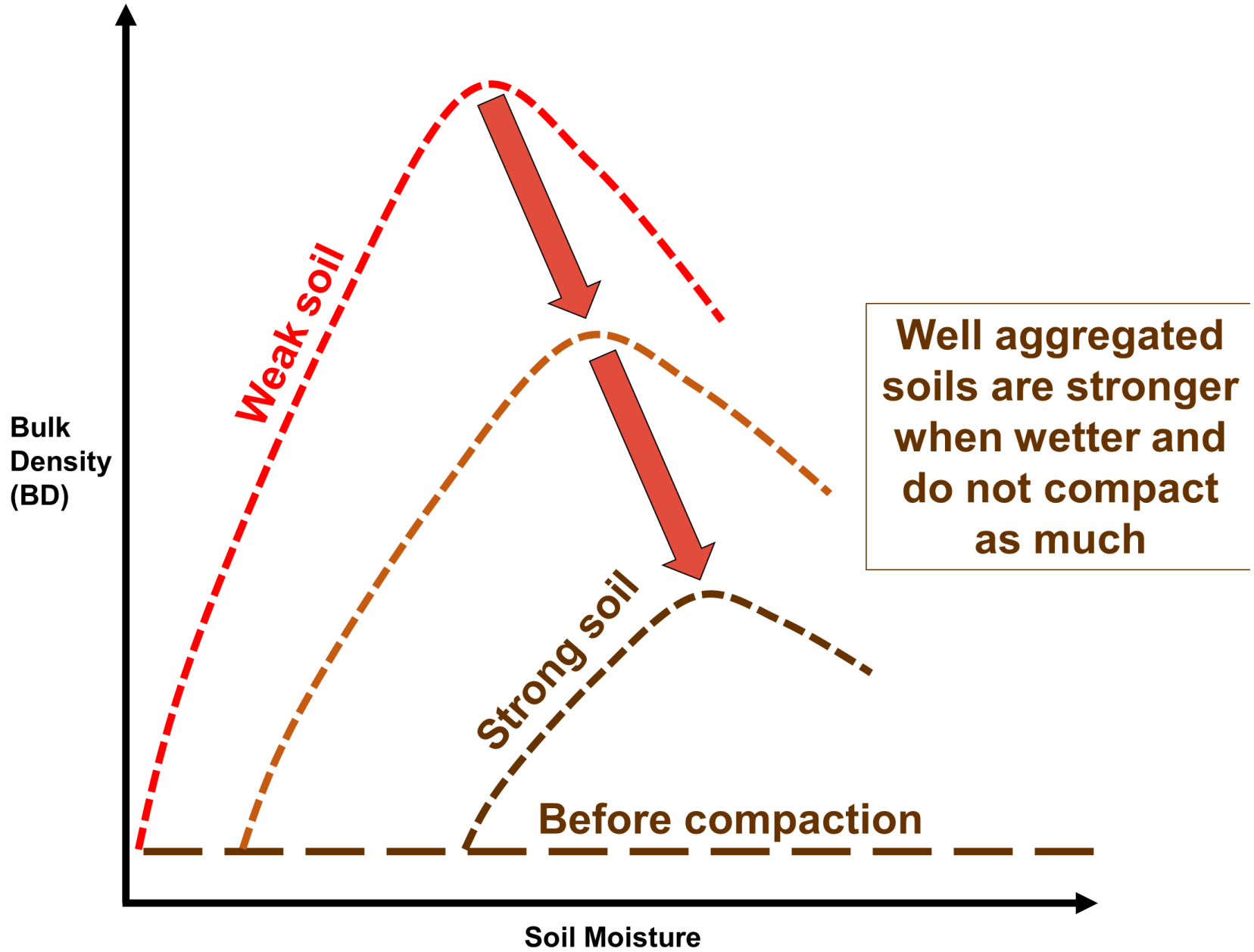


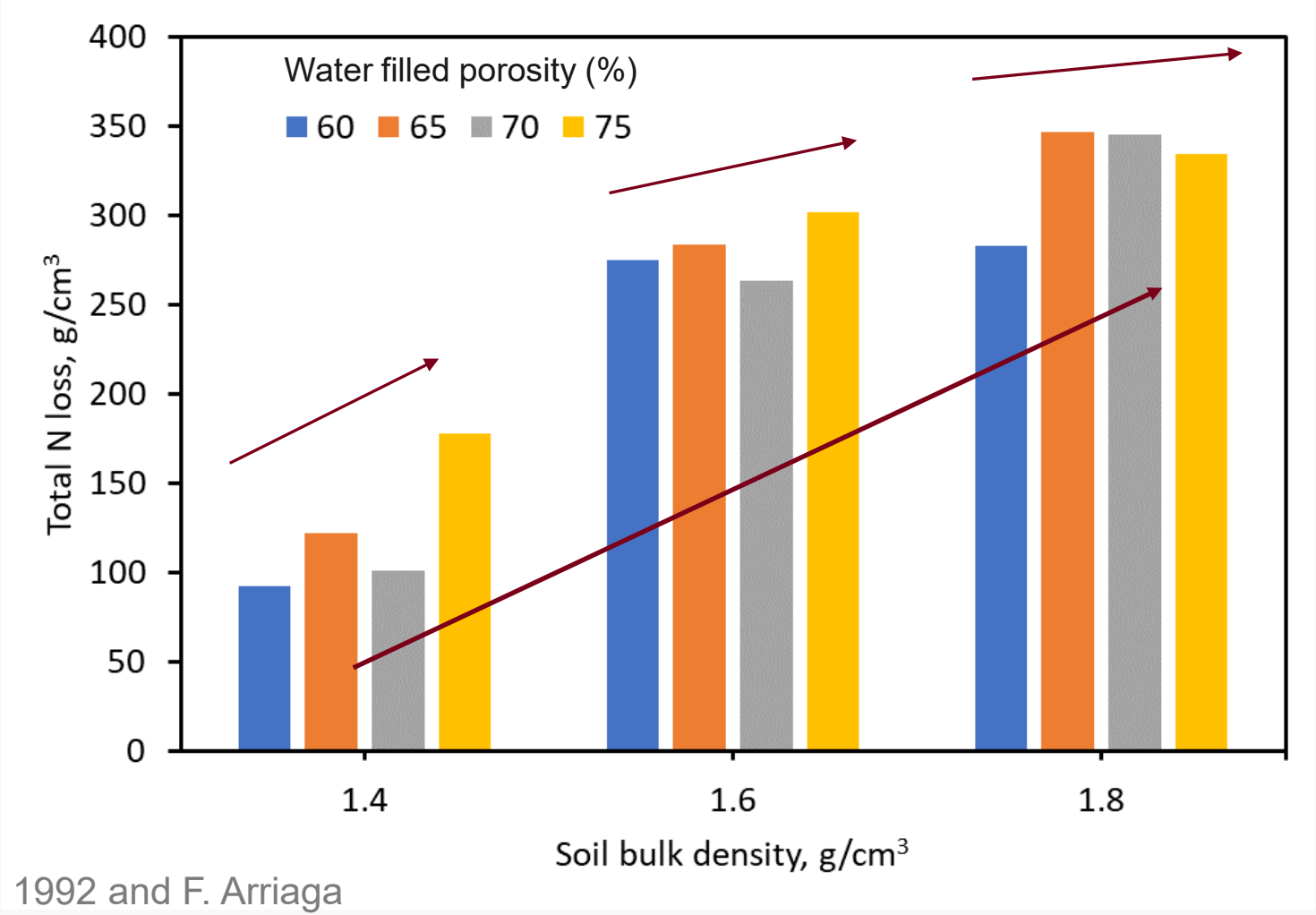
Image by Daigh 2021

Newton's 3rd Law

When two objects (soil and tillage) interact, they exert equal and opposite forces on each other

Soil Compactability

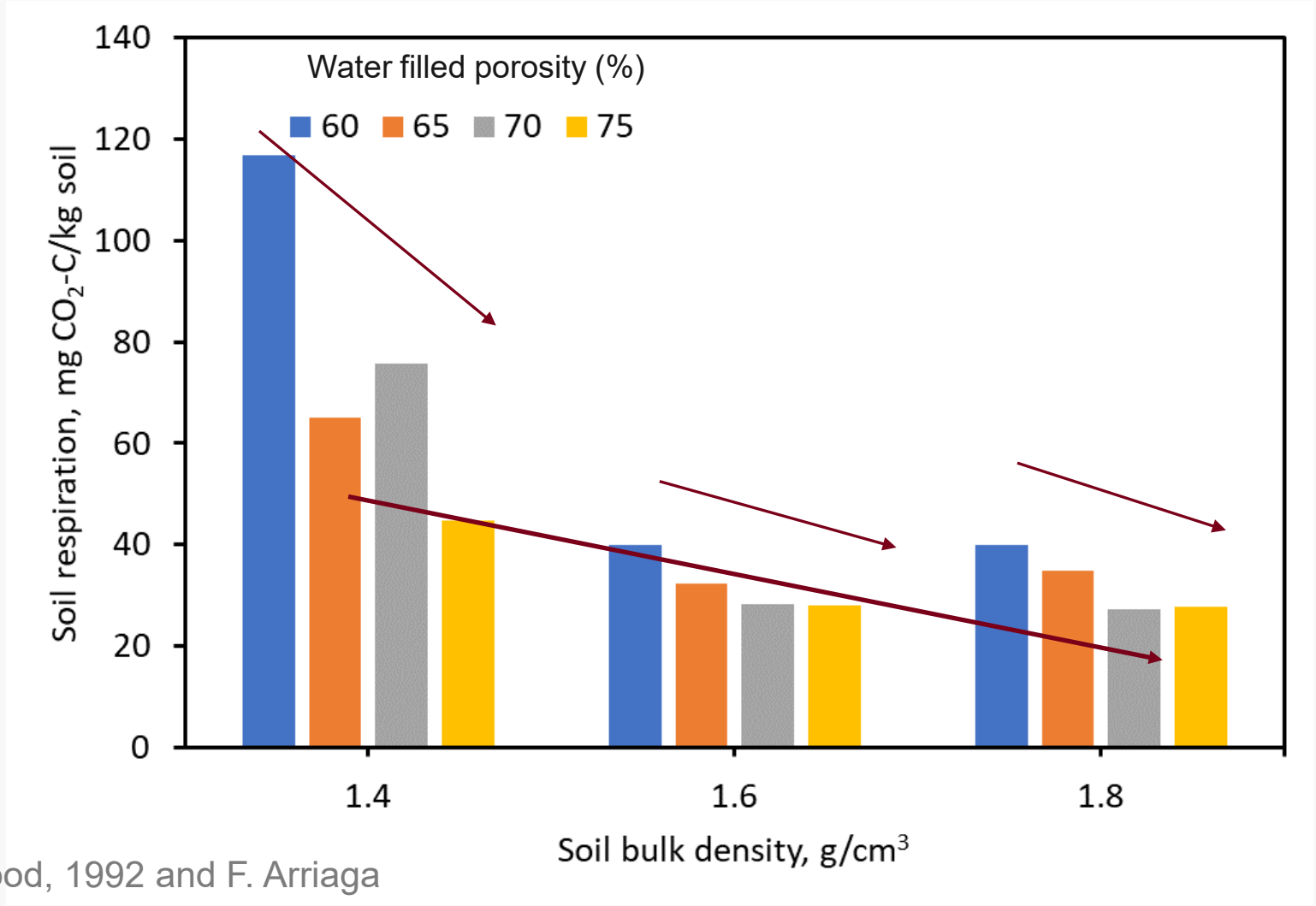
Increasing soil bulk density increase gas N losses



Source: Torbert and Wood, 1992 and F. Arriaga

Soil Compactability

Increasing soil bulk density reduces microbial activity



Source: Torbert and Wood, 1992 and F. Arriaga