OHIO STATE UNIVERSITY EXTENSION

The Biology of Soil Compaction

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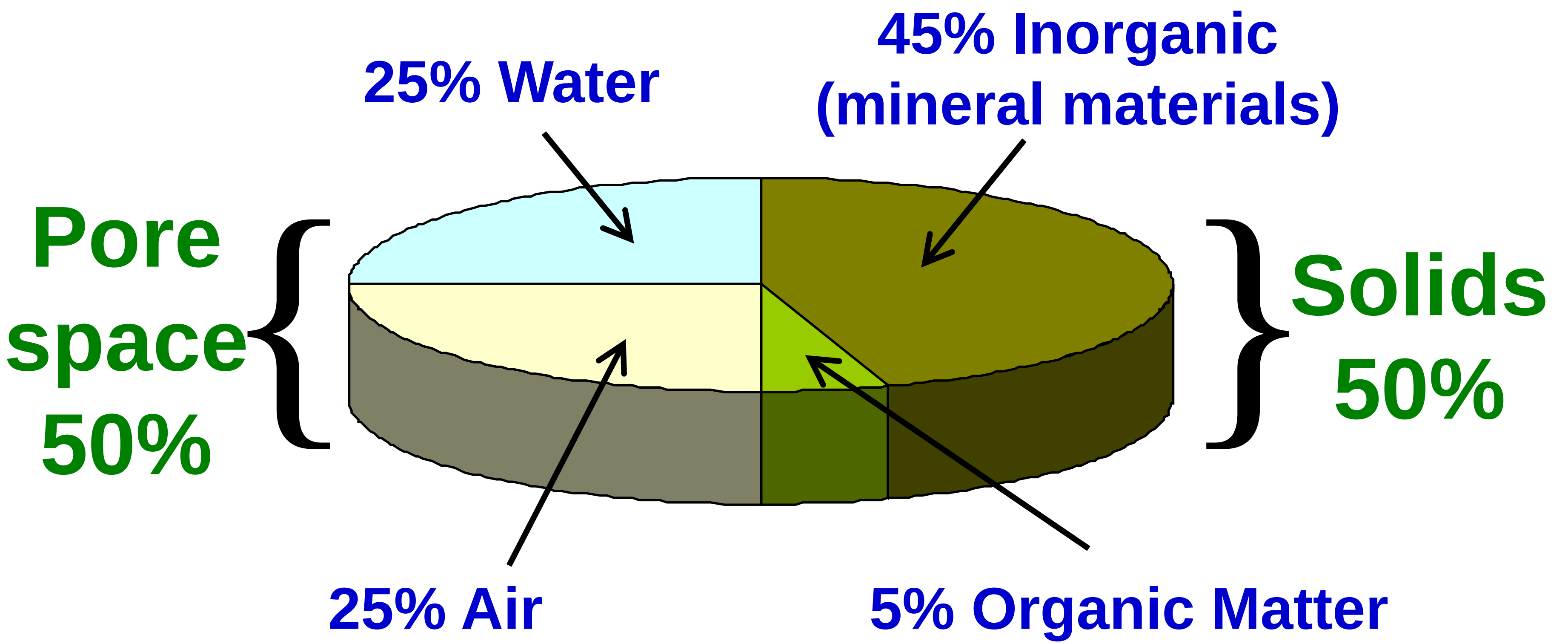
THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

Ideal Soil Composition

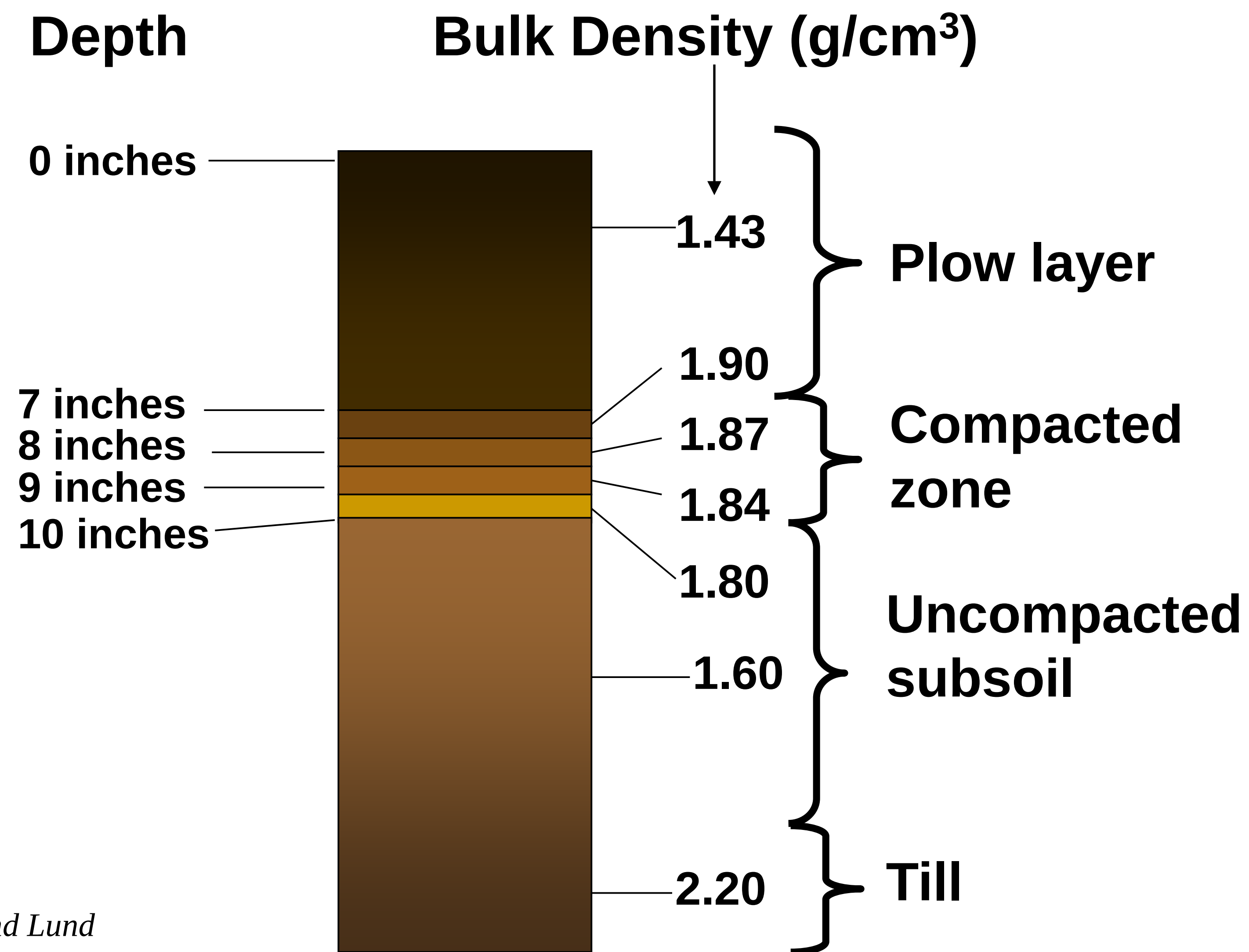


Some Common Bulk Densities

- **Uncultivated/undisturbed woodlots**
  - **1.0 to 1.2 g/cm^3**
- **Cultivated clay and silt loams**
  - **1.5 to 1.7 g/cm^3**
- **Cultivated sandy loams**
  - **1.3 to 1.7 g/cm^3**
- **Compacted glacial till**
  - **1.9 to 2.2 g/cm^3**
- **Concrete**
  - **2.4 g/cm^3**

1.6 g/cm^3 = Root Limiting
1.8 g/cm^3 = Roots Restricted

Bulk Density and Compaction



Data from Camp and Lund

Soil Organic Matter Characteristics

*Density of SOM: .6 g/cm^3 vs 1.45 g/cm^3 soil

Bulk density =Mass (grams)/Volume (cm^3)

SOM has less density than soil so it has more space for air and water storage.

*Every Pound SOM holds 18-20# of Water!

*SOM acts like a Sponge!

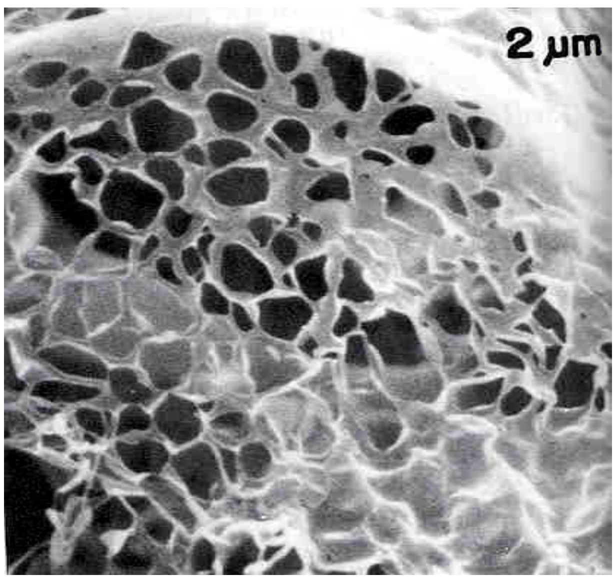
Physical properties and nature of SOM

Color and shape ~ light to dark brown and amorphous

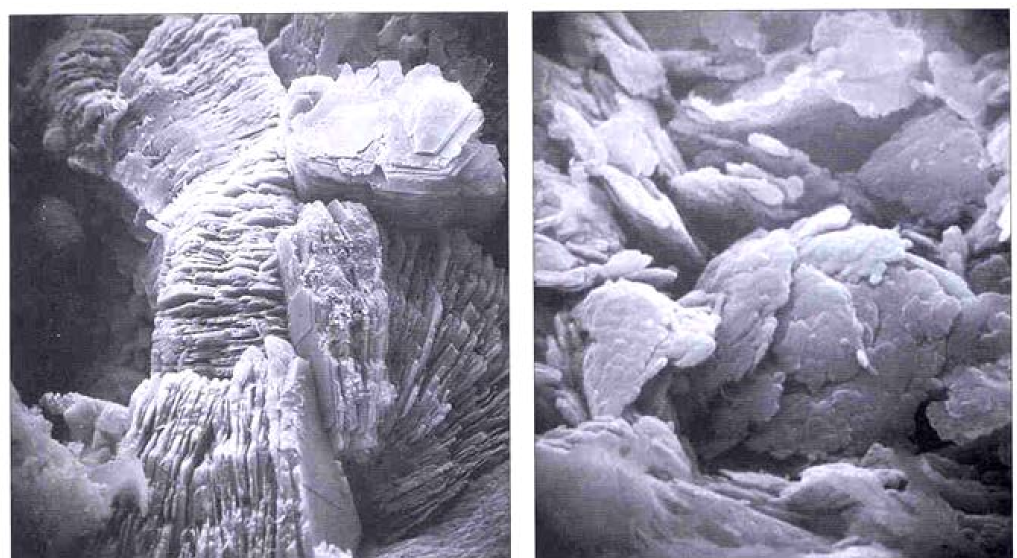
Size ~ Large to colloidal (0.1 - 2 μm)

Surface area ~ Variable (20 – 800 m2 g-1)

Adsorption ~ like sieve to hold cations, anions & water



Soil Organic Matter
From Brady & Weil



Electron Microscope of Clay Particles

Compacted Soil Characteristics

*Density 1.6 to 1.8 g/cm^3 vs 1.45 g/cm^3 regular soil.

*Compacted soil has higher density than regular soil so it has less space for air and water storage.

*Dense soils acts like a road or pavement!

Result in Flash floods!

*Dense soils have less microbes/biological life.

Three Soil Compaction Factors

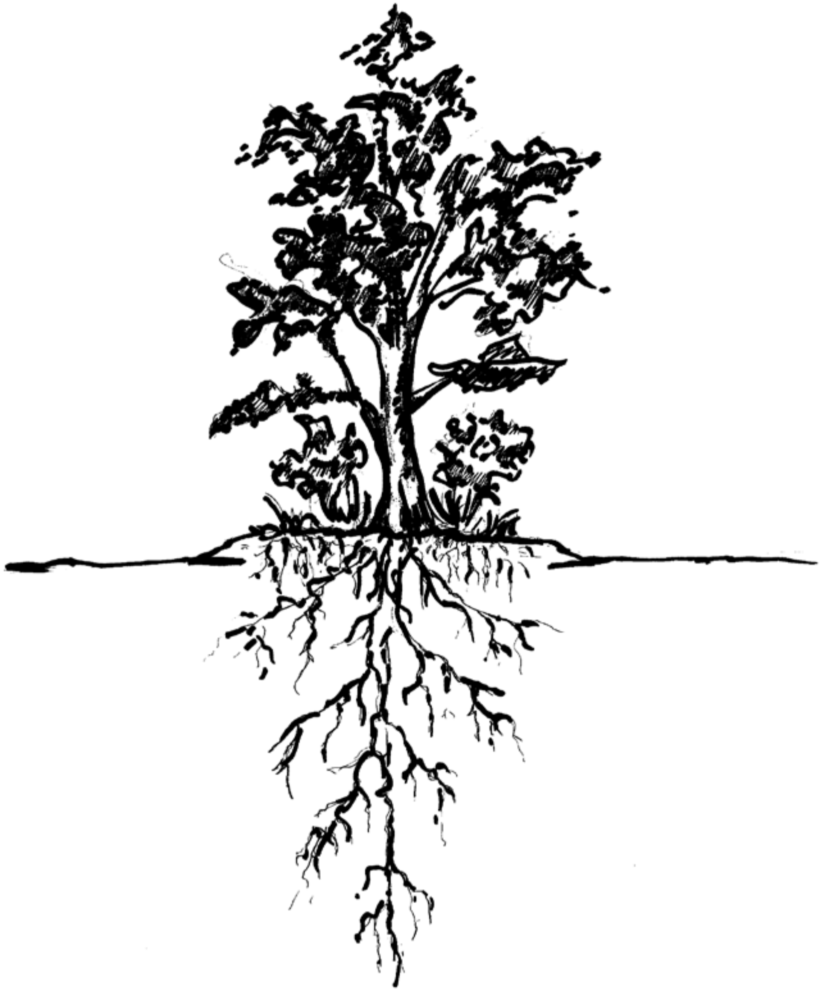
1) Heavy Equipment (Weight)

2) Rain (Precipitation)

3) Gravity

What is a visual way to measure soil compaction?

Increased Water Storage Capacity Equals less Flooding



1) 6-9 inch Elevation Difference

2) 50% Void Space Equals 3-4.5 inches of additional water storage capacity.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Soil Function- Provide Water to Plants

- Observations
  - Wilting & Stressed plants
- Weather?

- 200 bu Corn crop will need 22 inches of plant available water
  - Ohio receives 19 to 23 inches of water from April to September

Efficient Water Use Crucial!

Soil Inherent Properties

- Inherent Plant Available Water
  - Texture
  - Depth of Soil
  - Soil Layering
  - Presence of Rocks

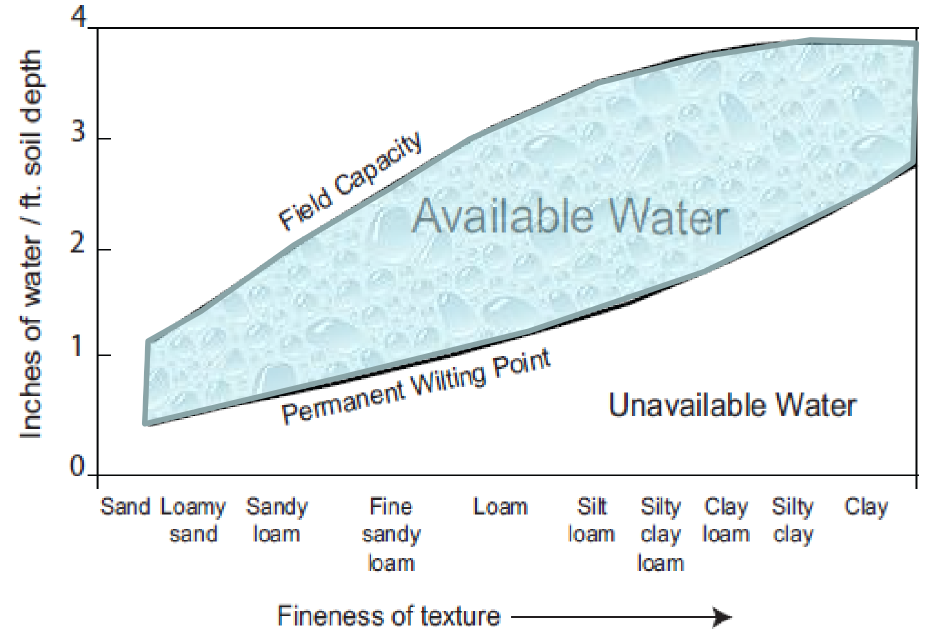


Figure 1. General relationship between soil moisture and texture. Ohio Agronomy Guide, 14th edition, Bulletin 472-05

<u>Available water is largely an inherent soil property….</u>

<u>So what can we do?</u>

SOM and Available Water Capacity
Inches of Water/Per one foot of Soil

Berman Hudson Journal of Soil & Water Conservation 49(2) 189-194 March-April 1994

Percent SOM	Sand	Silt Loam	Silt Clay Loam
1	1.0	1.9	1.4
2	1.4	2.4	1.8
3	1.7	2.9	2.2
4	2.1	3.5	2.6
5	2.5	4.0	3.0

Dynamic Properties: Infiltration

- If rainwater runs off field…. It is not available to the crop
  – Dynamic Soil Property greatly influenced by management

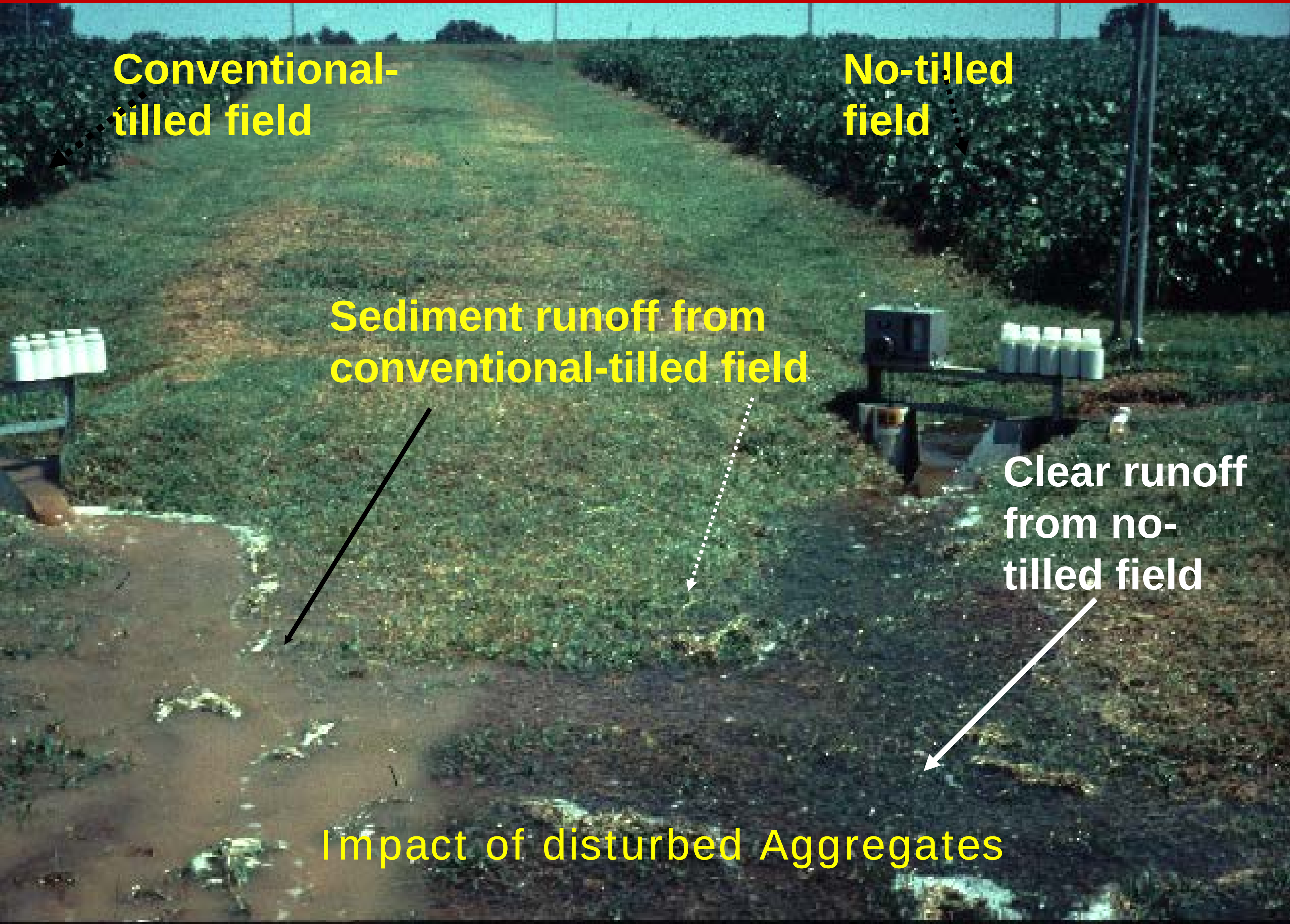
Tillage System	Water Infiltration Rate after 1 Hour (in/hour)
Plowed, disked, cultivated, bare surface	.26
No-tillage, bare surface	.11
No-tillage, 40% cover	.46
No-tillage, 80% cover	1.04

Bare Soil

Low Residue Cover

High Residue Cover

- Residue cover prevents soil crusts


Conventional-
tilled field
No-tilled
field
Sediment runoff from
conventional-tilled field
Clear runoff
from no-
tilled field
Impact of disturbed Aggregates

Let's look at some common practices that have a negative impact on soil health and water quality

Long Term No-Till vs. Rotational Tillage

Both Fields are a Corn/Soybean Rotation

These pictures are of a newly emerging corn crop

NoTill soybeans then StripTill Corn

NoTill Soybeans then Tilled corn

Saving Nutrients in the Soil

…is related to the speed of Water!

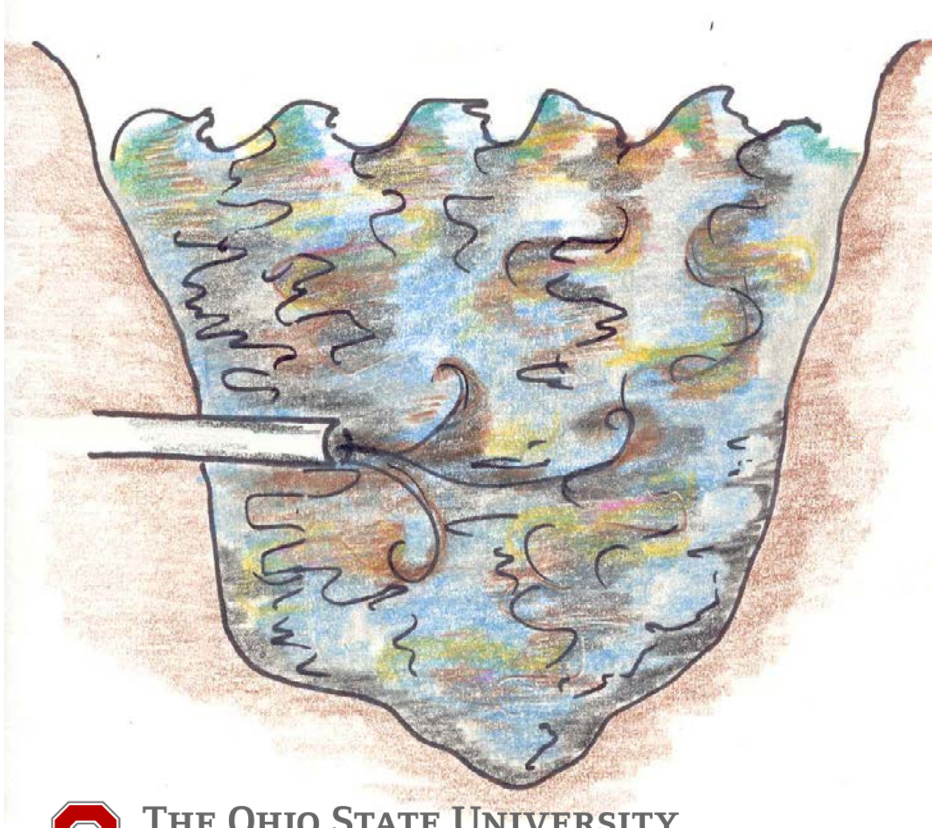
If the velocity of water is doubled how many more nutrients travel in a stream with the water?

2^6 = 64 times more nutrients lost!

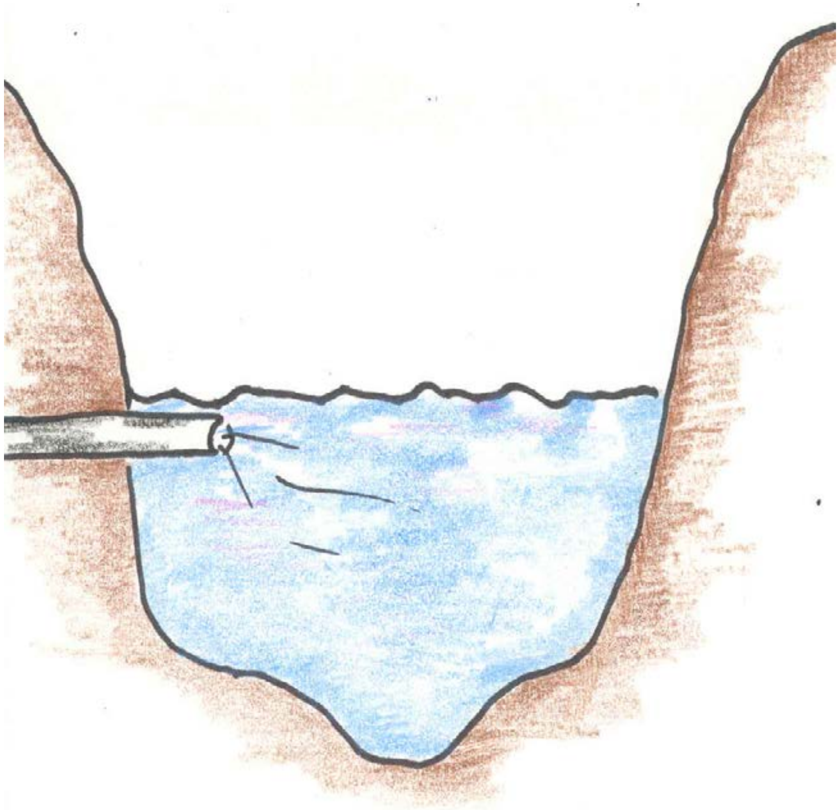
1	to	2 mph		64x
2	to	4 mph		128x
4	to	8 mph		256x
8	to	16 mph		512x
16	to	32 mph		1,024x

Agricultural Flooding

Conventional Tillage

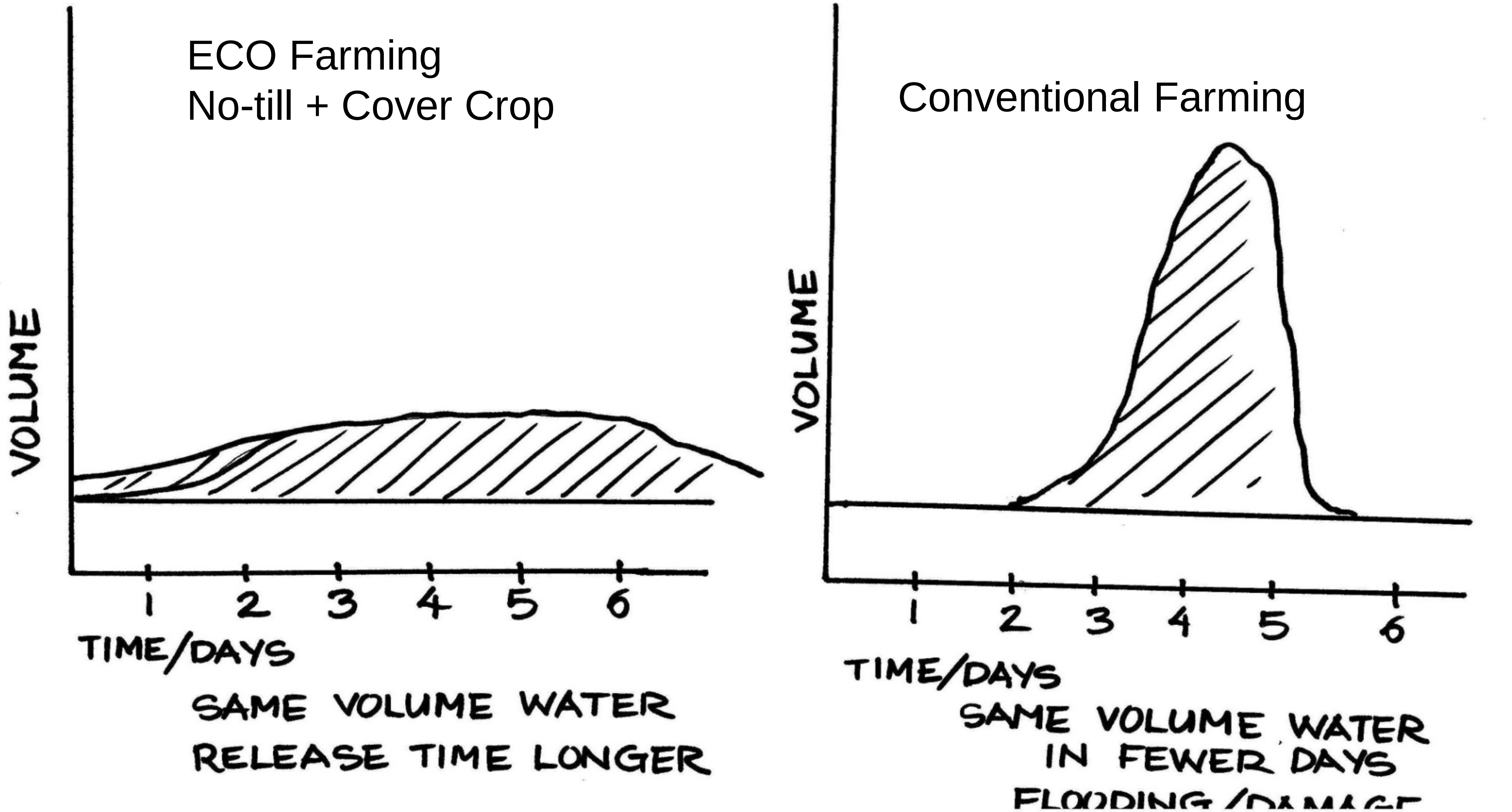


ECO Farming



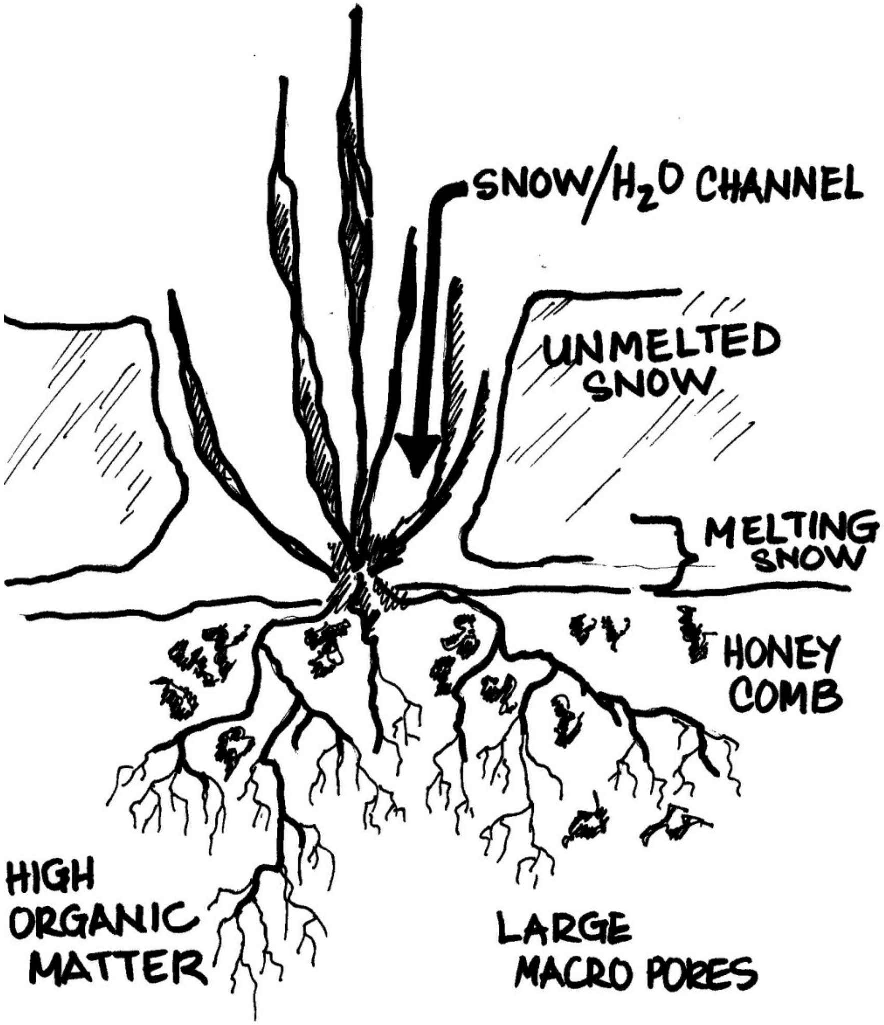
Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

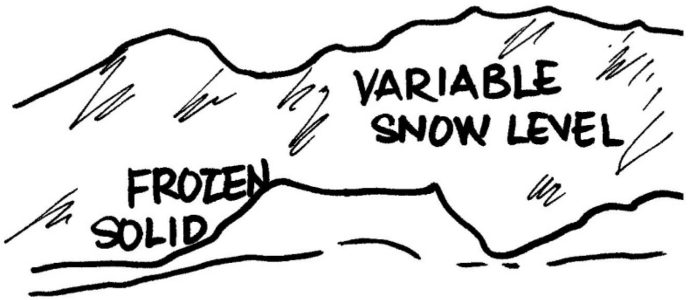
Flooding Hydrographs



Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

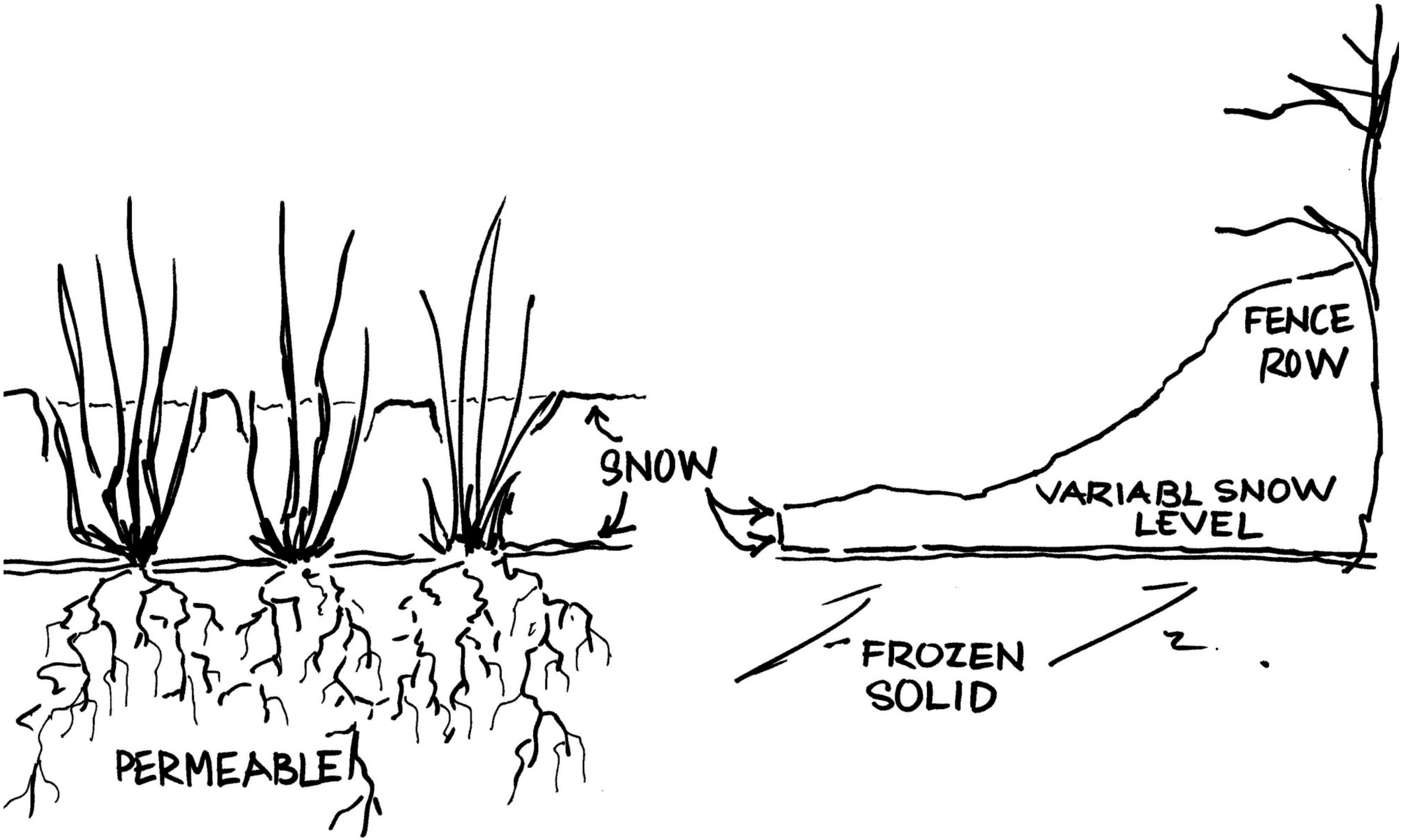
Impact of Crops on Frozen Soil





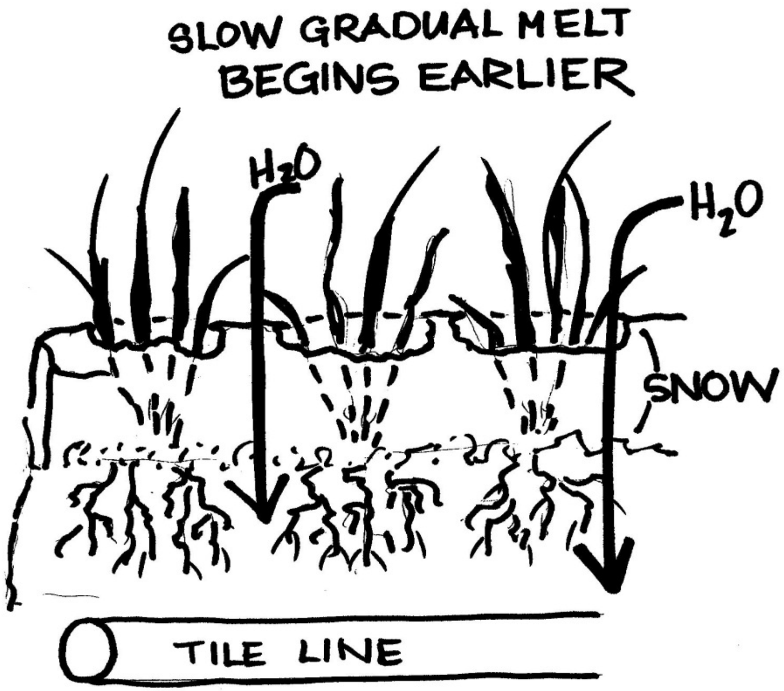
Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

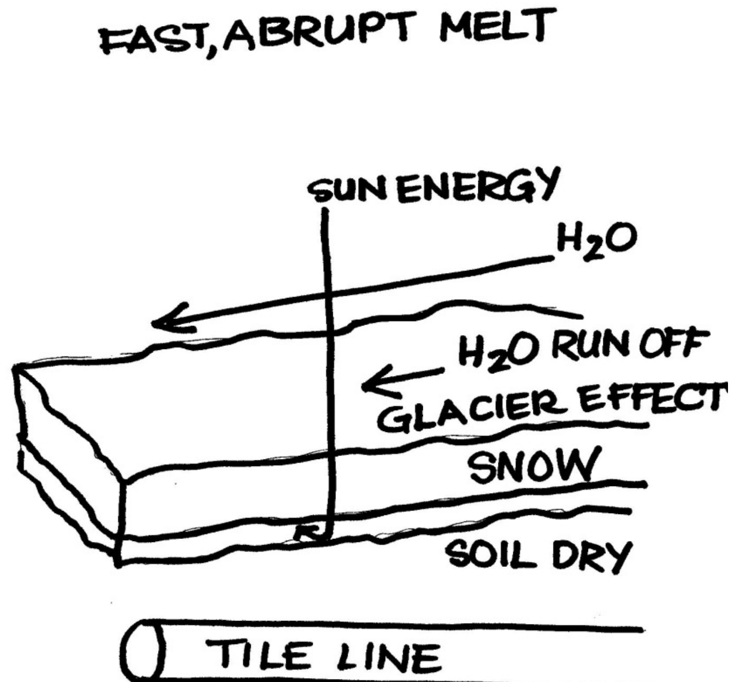
Snow accumulation



Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

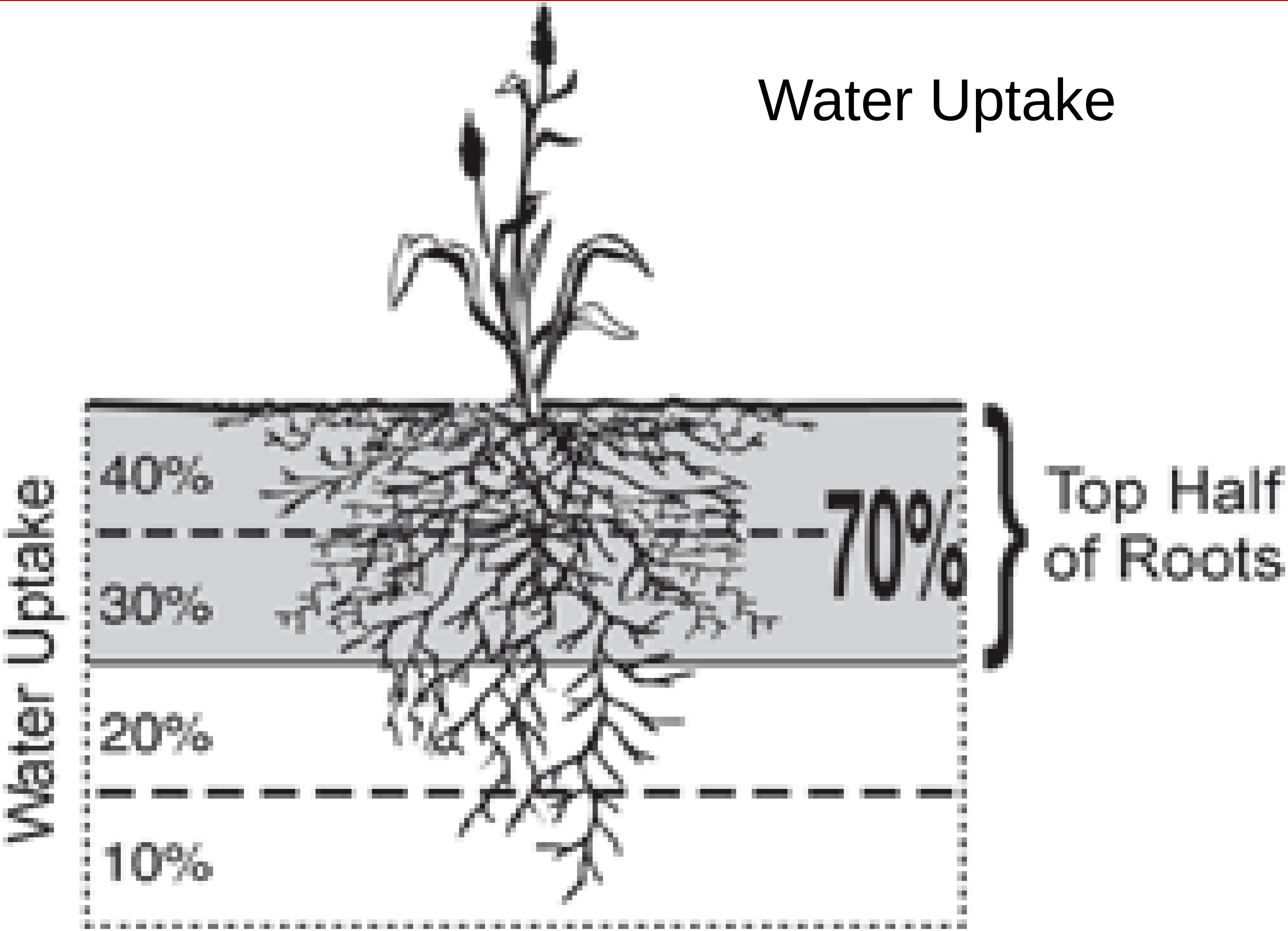
How snow melts



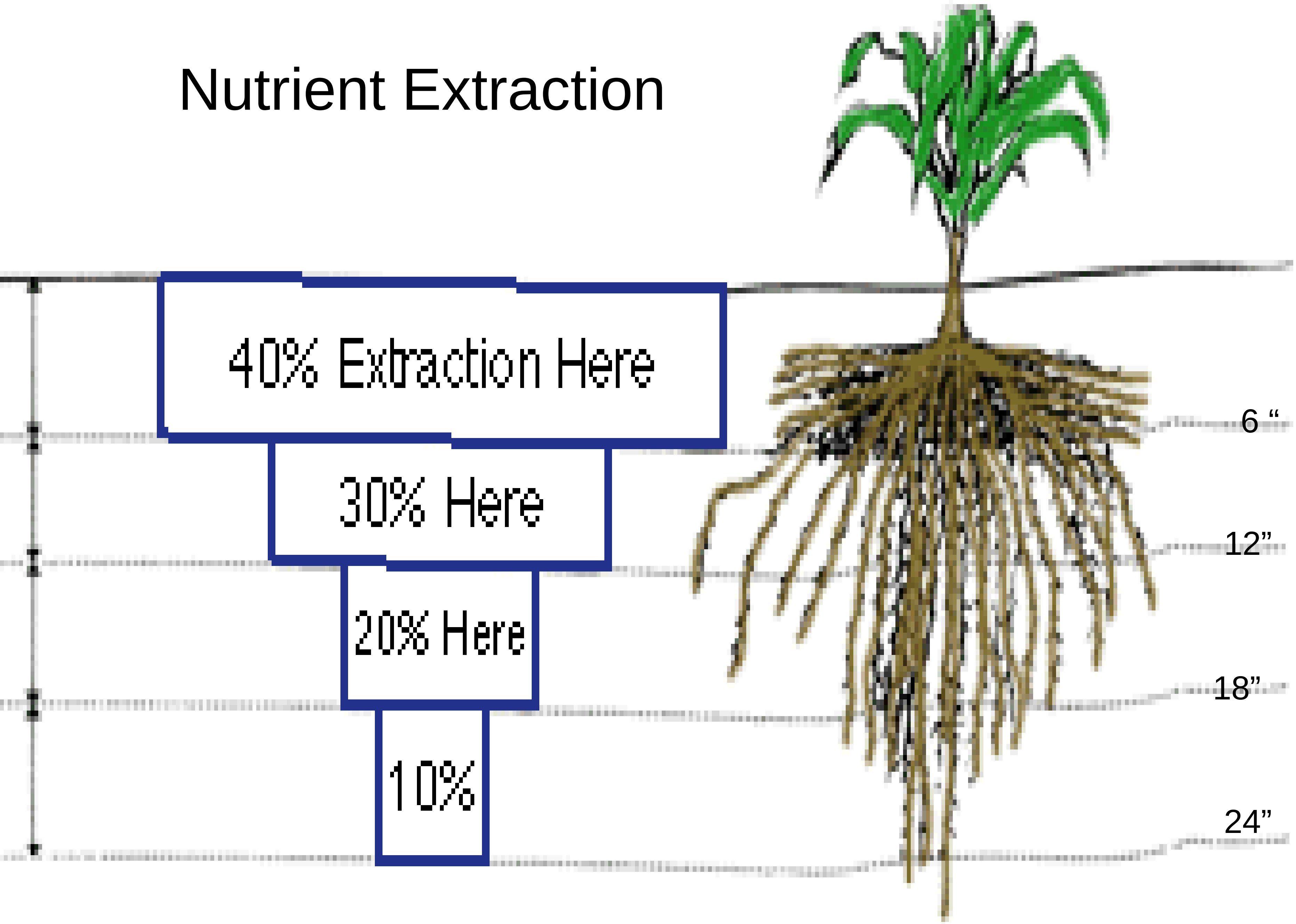


Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Water Uptake



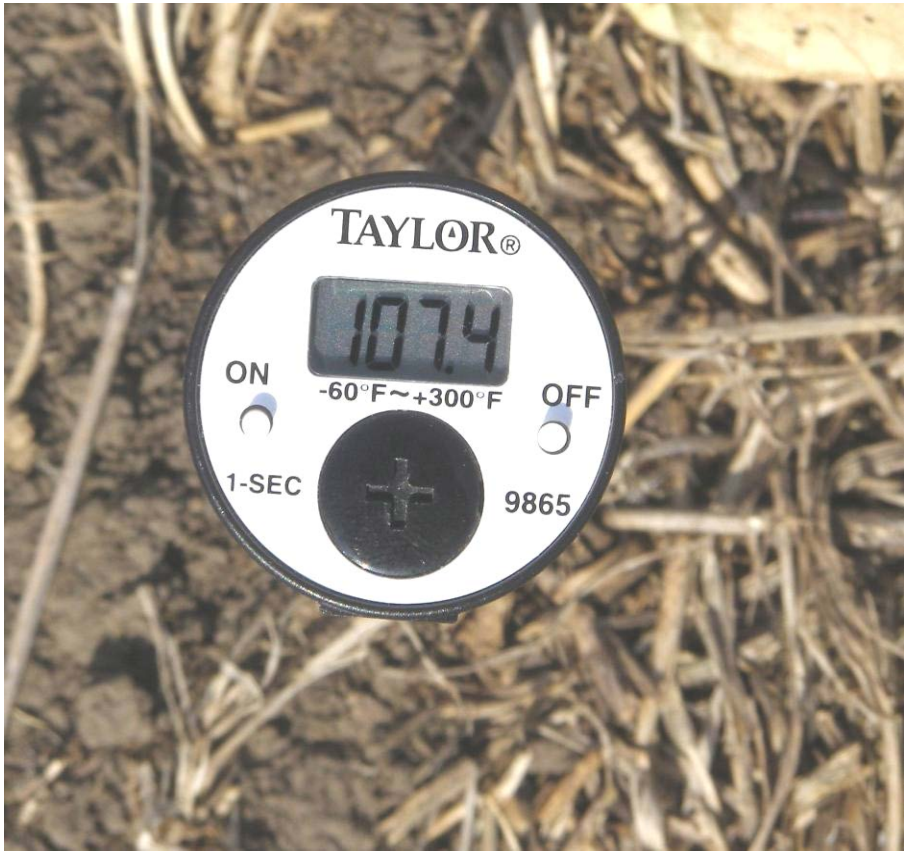
Nutrient Extraction



Soil Temperature Differences

Conventional /No-till??

No-till + Cover Crops & Live Plants



For Hot Dry Summers

For Corn Production:

75 degrees Fahrenheit – 1 Inch water/week

85 degrees Fahrenheit – 2 inch water/week

95 degrees Fahrenheit – 4 inch water/week

2X Water requirements for every 10F increase

1" Rain = 8 bu. corn, 22" needed for 200 bu. Corn

Rain = 19-23 inch/year in growing season

1" Rain fully used = 8 bu/A * $4 = $32/A

Heat and drought quickly increase yield losses!

By Elwynn Taylor, Iowa Ag. Climatologist

Dynamic Properties: Rooting Volume

- Soil Structure: Arrangement of Soil Particles
  - Root Development
  - Water Infiltration

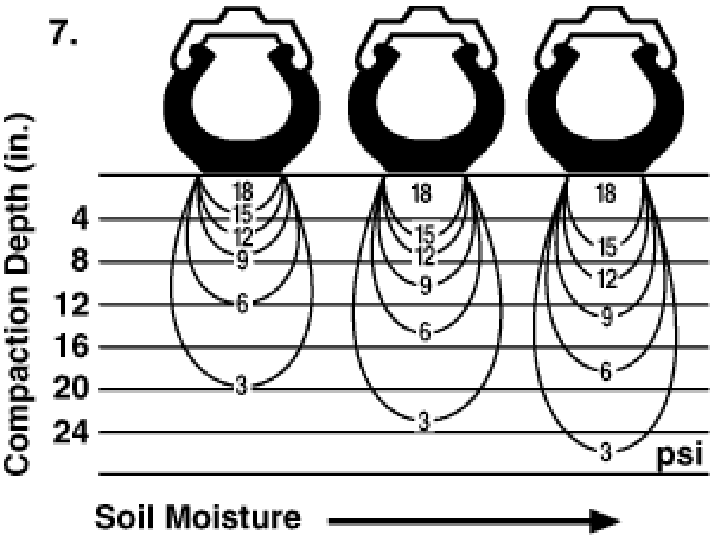
DYNAMIC PROPERTY!

- Soil Compaction: The absence of soil aggregation & pore space
  - Compaction can reduce yields up to 60%.
  - Compaction has been shown to persist up to 9 years.

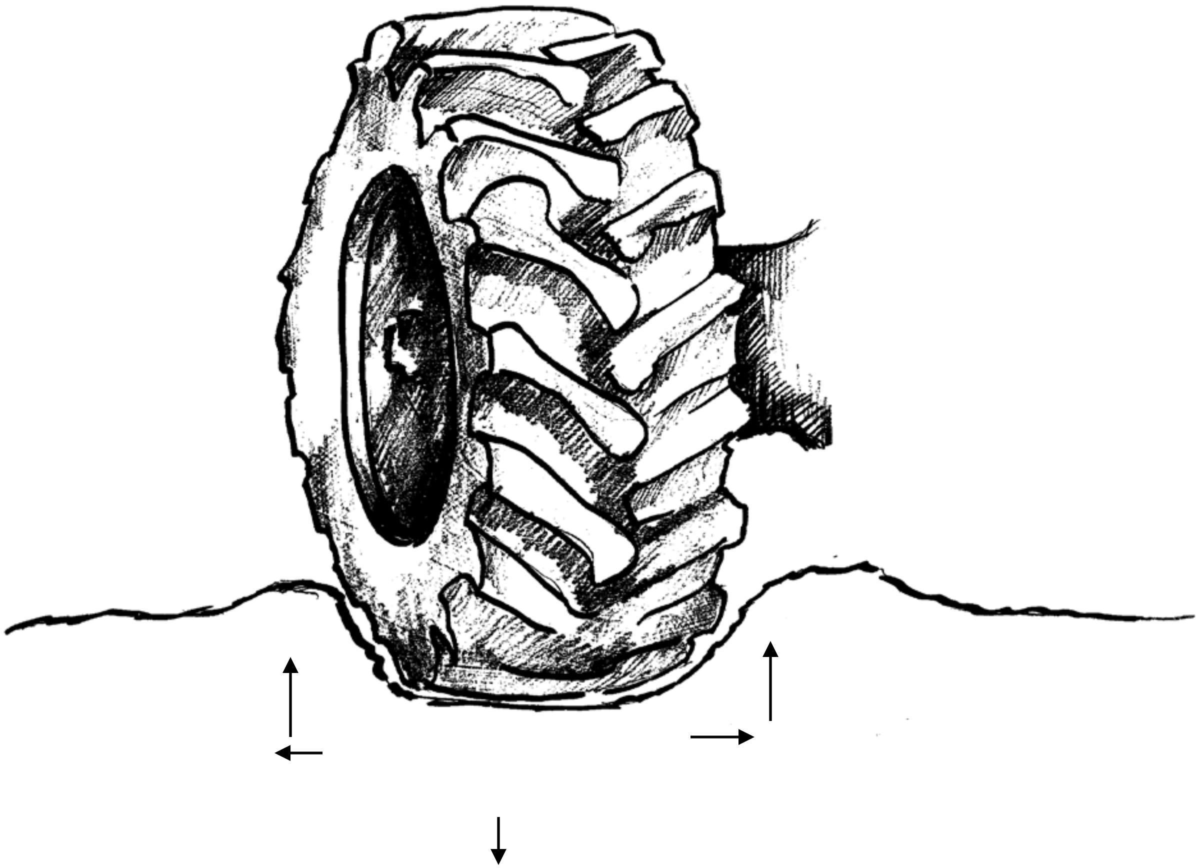
Increasing Root Volume

- Increase Aggregation & Aggregate Stability
  - Promote Biological Activity
  - Increase Organic Matter
  - NoTill

- Prevent Soil Compaction
  - Stay off wet soils!
  - Controlled/managed traffic
    - 80% of soil compaction from wheel traffic occurs on the first pass of a tire.

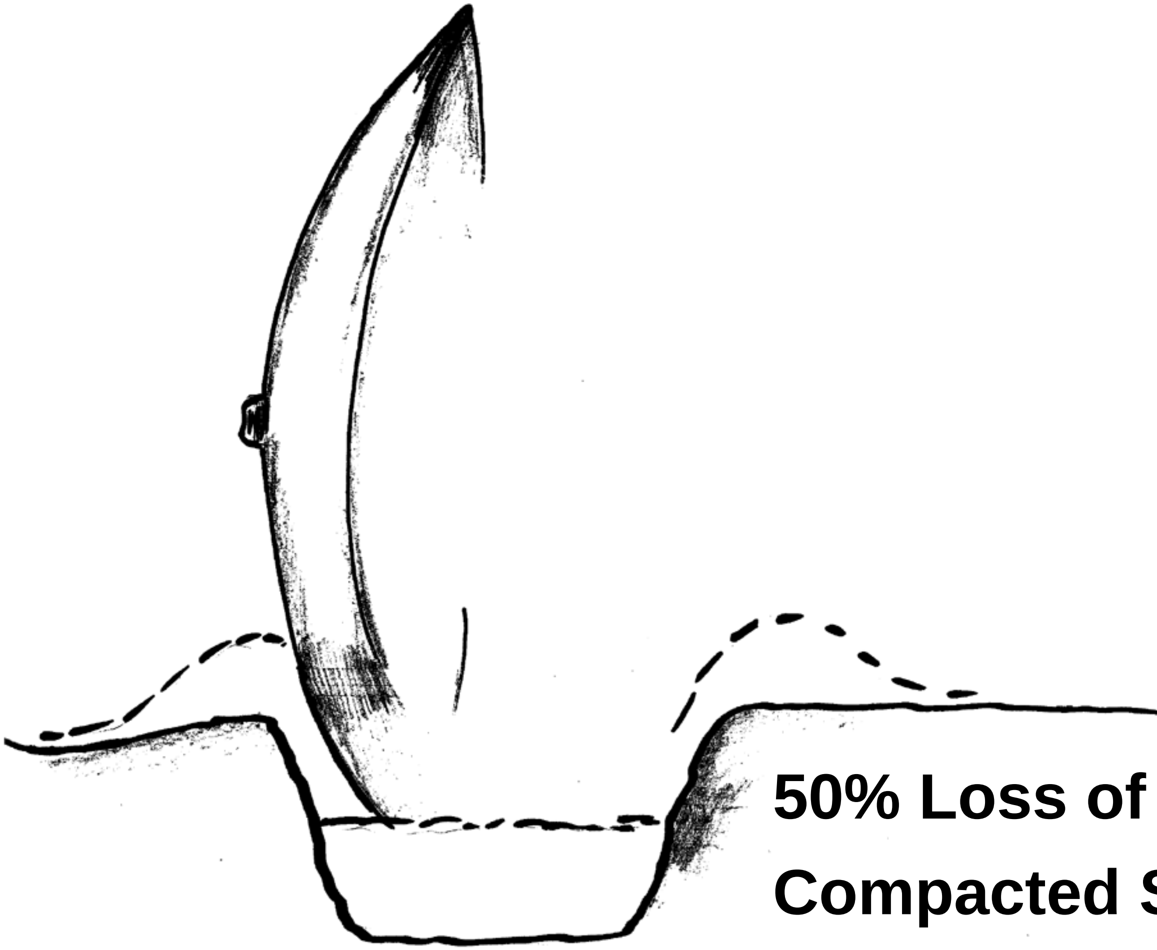


Tire Rut Soil Compaction



Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Loss of Void Space



50% Loss of Void Space

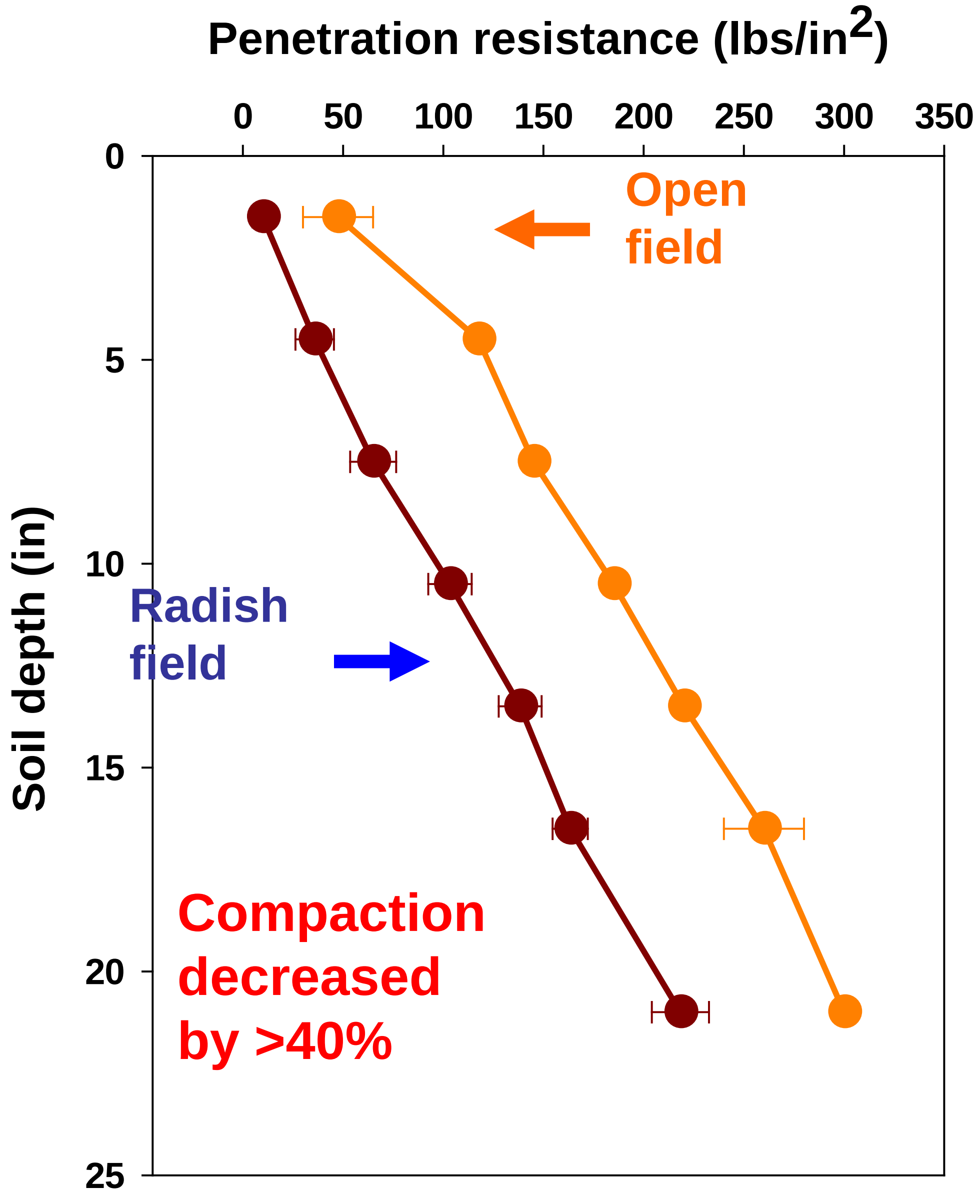
Compacted Soil- 50%

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

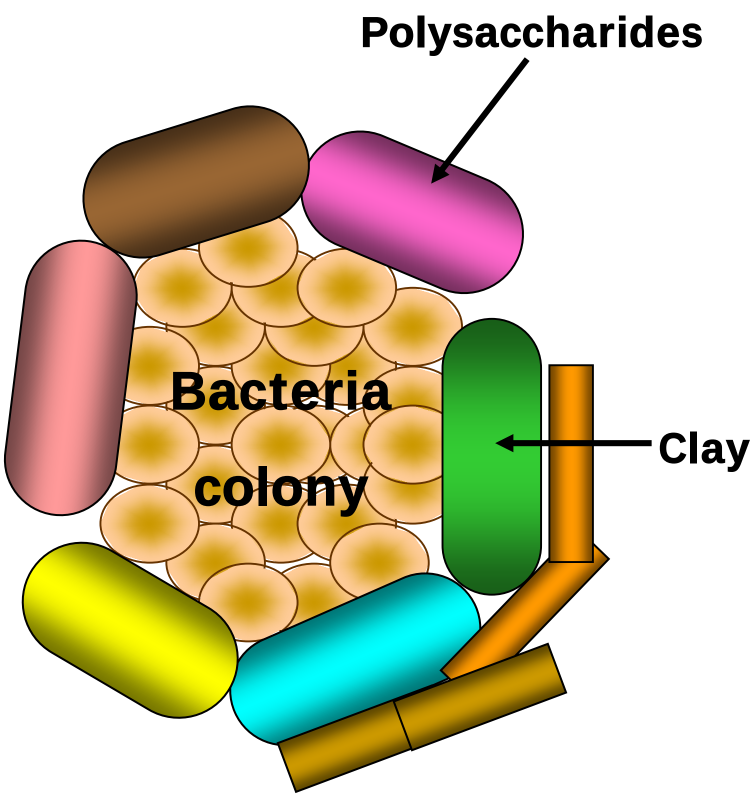
Roots expanding the soil

Roots reducing soil compaction

Measuring soil compaction


Penetration resistance (lbs/in2)
0
50
100
150
200
250
300
350
Soil depth (in)
0
5
10
15
20
25
Open
field
Radish
field
Compaction
decreased
by >40%

Microaggregates formation



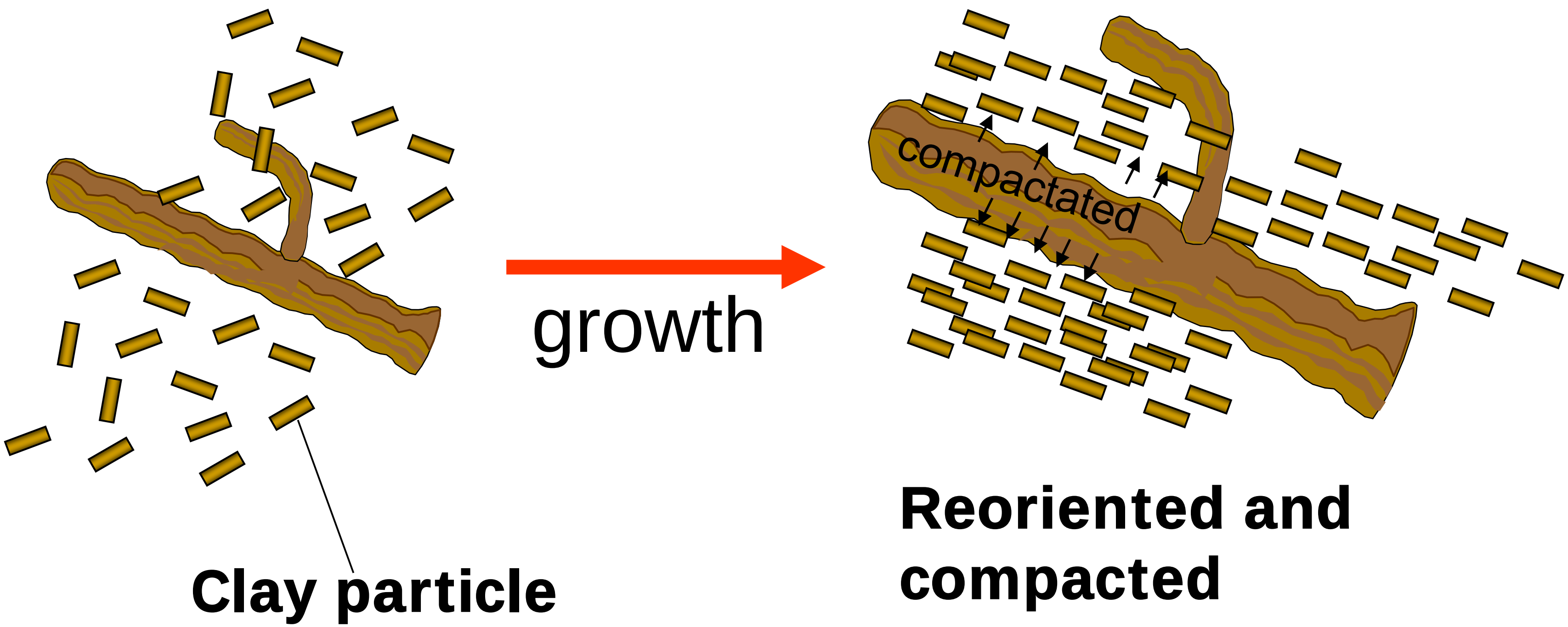
Foster, 1983 - cells and bacteria colonies are enclosed in polysaccharides capsules, aligned by clay particles, forming an aggregate.

40 to 60% of the soil microbial biomass associated with microaggregates

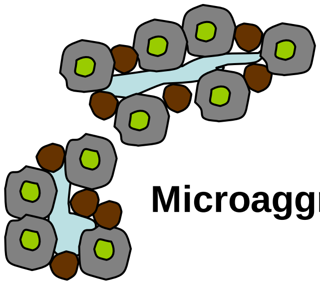
90% of the bacteria linked to clay

Roots and fungi hyphae

Fine roots goes through the soil pores and drying the soil and compress clay particles to form the aggregates that will be stabilized by polysaccharides excreted by microorganisms (Allison, 1968)



Microaggregates-macroaggregates model



Microaggregates 20-90 and 90-250 μm

Plant and fungal debris

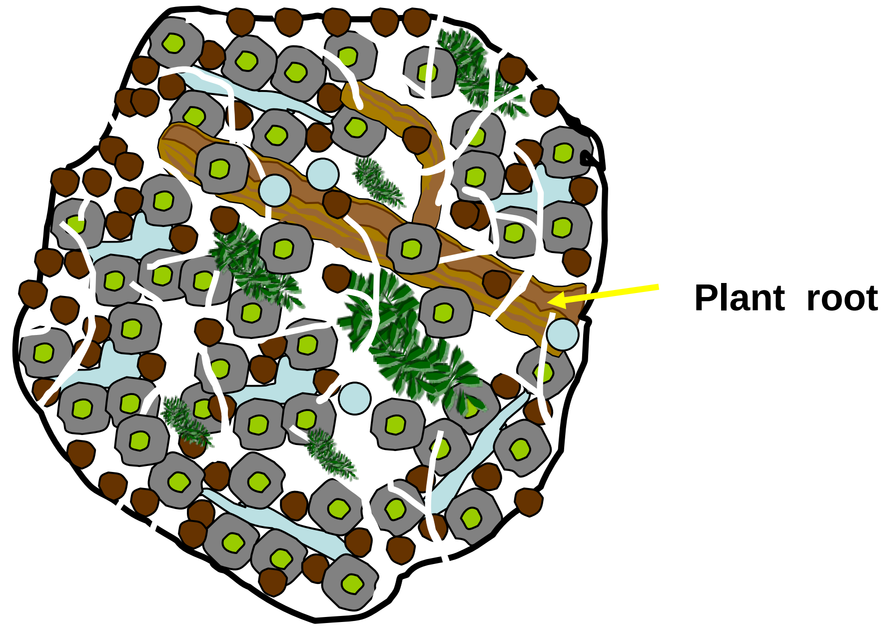
Silt-size microaggregate

Clay microstructures

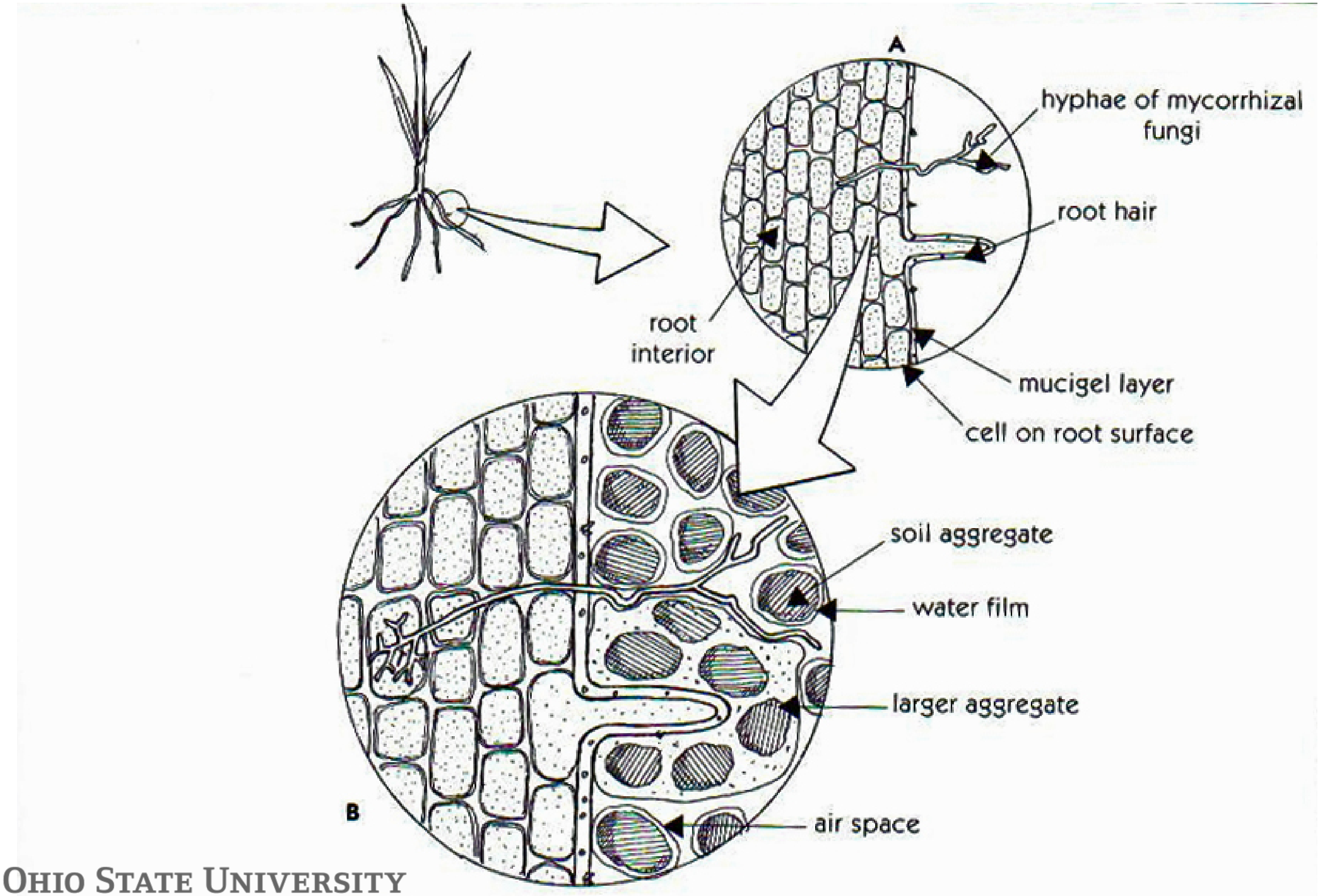
Particulate organic matter

Mycorrhizal hyphae

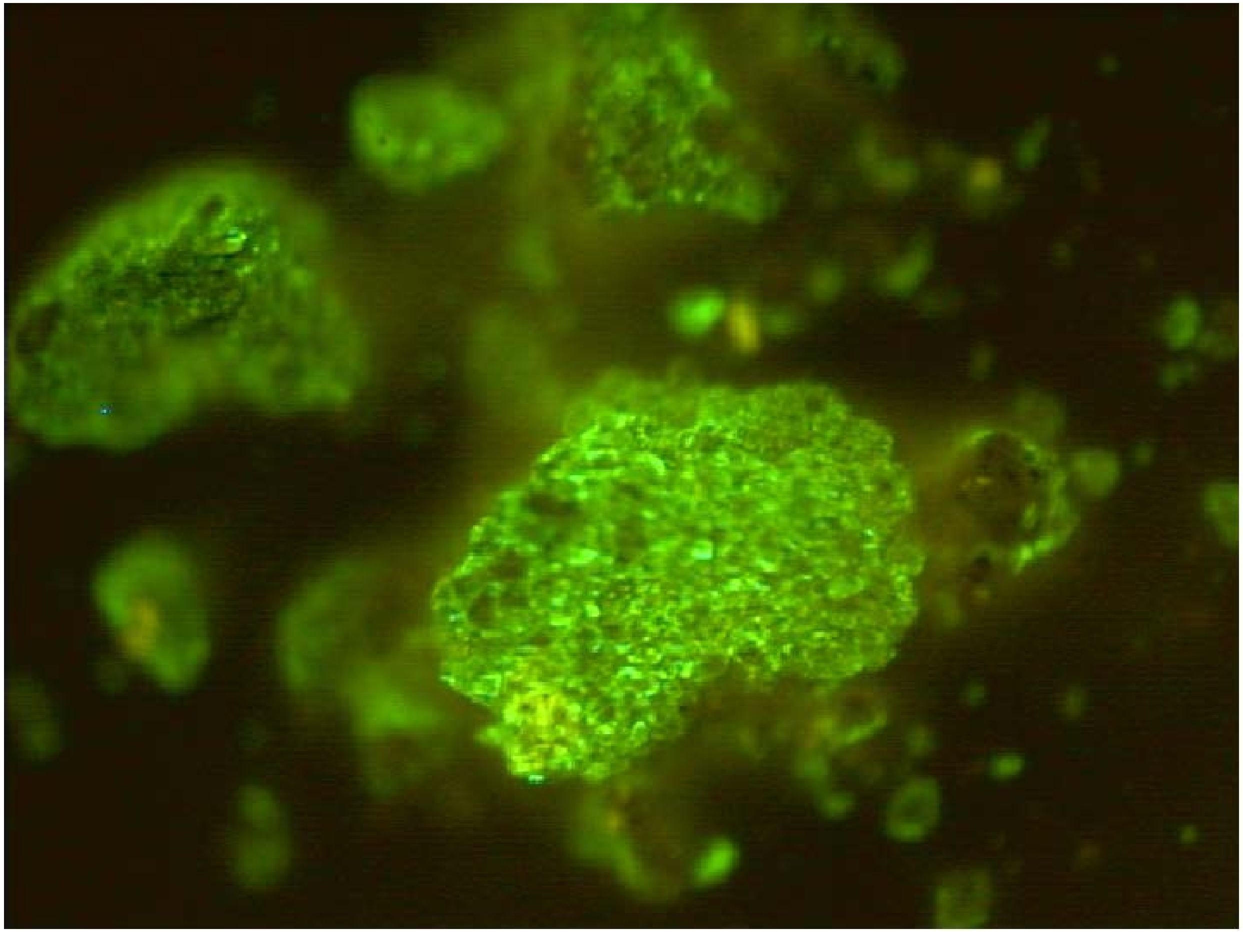
Pore space; polysaccharides and other amorphous interaggregate binding agents



Mycorrhizal Fungus



Source: Better Soils for Better Crops



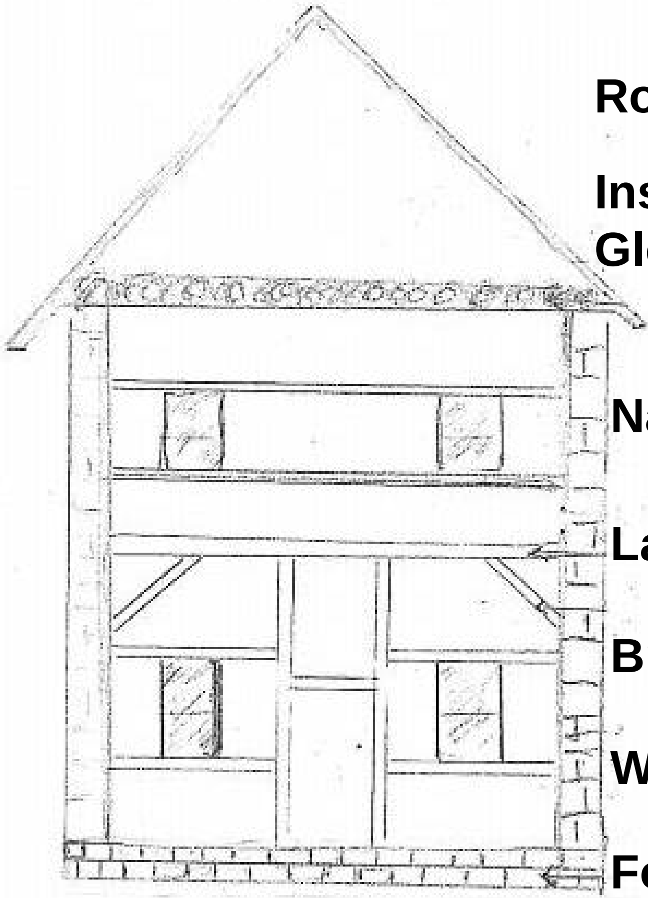
Sticky substance, glomalin, surrounding soil aggregates, water insoluble. Photo by Sara Wright.

Building Soil Structure is like Building a House

Architecture	Mother Nature
Carpenter	Plants
Foundation/Cement	Sand Silt Clay (K^+, Ca^{++})
Frame for House	Roots
Nails/Lag Screws	Humus & P
Braces	N & S
Insulation/Glue	Polysaccharides
House wrap	Glomalin
Roof	Surface Residues

Developed by Jim Hoorman (2010)

Building Soil is Like Building a House



Roof-Subsurface Residue

Insulation/glue/House wrap-Glomalin-G

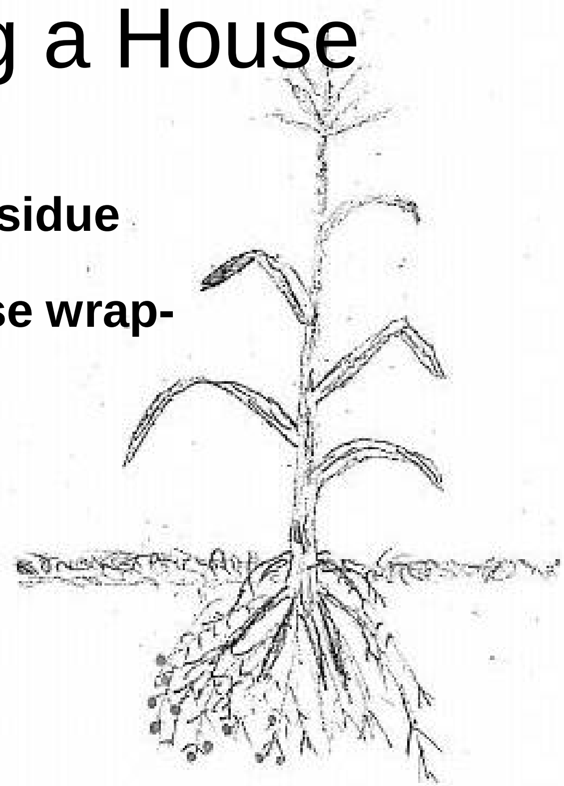
Nails – Humus-OM

Lag Screw - P

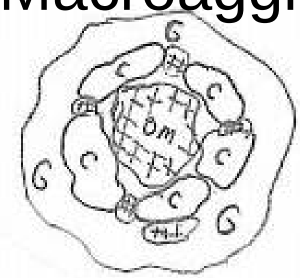
Braces – N & S

Wood – Roots - OM

Foundation-Clay-C



Macroaggregate



Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Oxygen and Carbon Dioxide

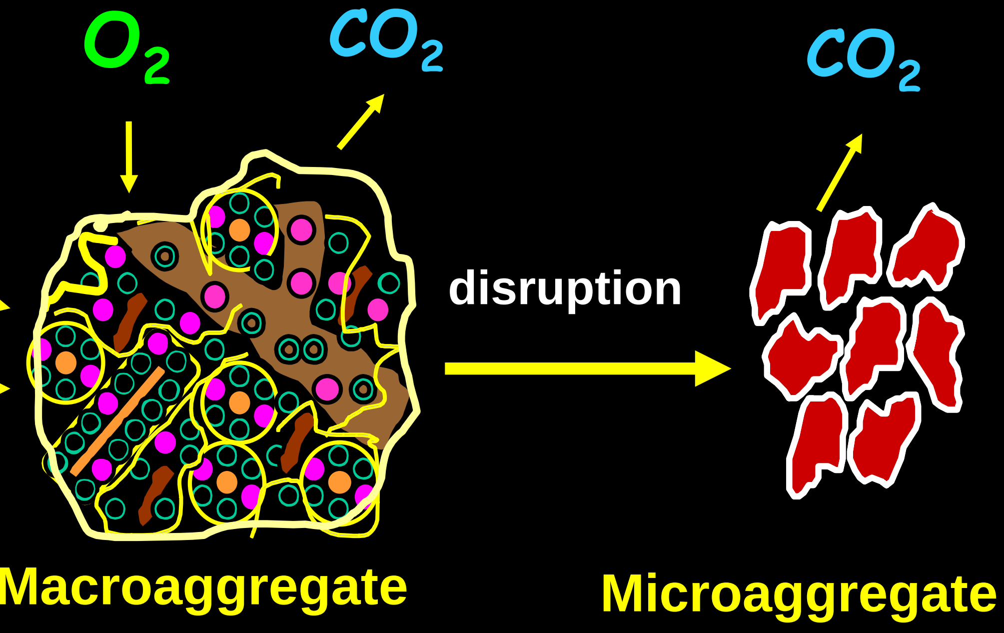
Carbon dioxide (CO_2) is heavier than O_2

CO_2 and O_2 are inversely related in the soil.
If one increases the other decreases.

Too much O_2 in the soil causes CO_2 to be lost from the soil to the atmosphere.

Roots act like a <u>**Biological Valve**</u> to control O_2.

Oxidation and release CO_2



Cold No-till Soils

- Probably due to Compaction.
- Compacted soil hold moisture and heat (cold).

No-till with a Cover Crop

- Aerated soils warm up faster
- Black residue absorbs heat
- Thick residue at surface has biological activity and gives off heat.

Why do our Soils Compact?

- Look at your Crop Rotation
  Drilled Soybeans have poor root system
  Corn has thick roots limited by plow layer

- What percentage of time do we have live roots?
  Corn-Soybean rotation 4/12 months = 1/3 of time

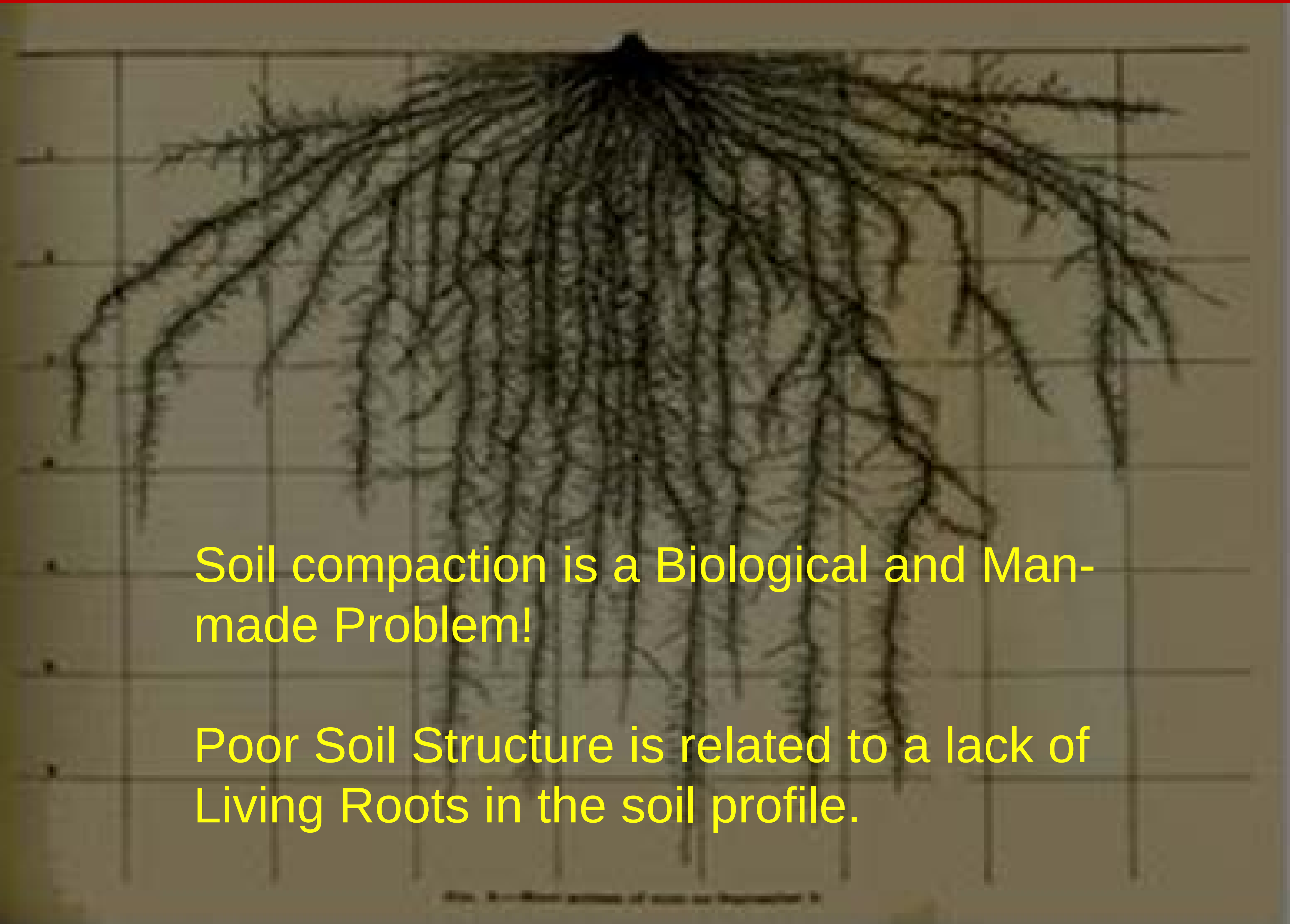
- Does No-till have more Live Roots than Conventional tillage? NO

- What is missing in No-till? Live Roots

Blount soil showing severe compaction

(very low infiltration = very high runoff)

Blount soil under continuous No-Till showing good soil structure (and good infiltration)



Soil compaction is a Biological and Man-made Problem!

Poor Soil Structure is related to a lack of Living Roots in the soil profile.

Subsoiling and Compaction

Subsoiling Yield Gains (Losses)

- Conventional tillage with subsoiling
  Corn Yield gain 1-3 bu or 3%
  Soybean Yield Gain 2-5 bu or 10%

- No-till and subsoiling
  Corn Yield loss 1-3 bu or 3%
  Soybean Yield loss 2-5 bu or 10%

Subsoiling vs. Cover Crops

What can a subsoiler do?

Immediate change in soil structure, 18 inches deep

Increase infiltration

Leaves soil susceptible to compaction later

Subsoiling vs. Cover Crops

What can cover crops do?

Slow change in soil structure, 3 ft deep or deeper.
Increase infiltration, over time
Protect soil from erosion
Add nutrients and organic matter
Fit into a continuous no-till system
Help protect against soil compaction

Soil Resistance to Compaction Ranked

Continuous No-till, controlled traffic, cover crop
Continuous No-till with growing cover crop
Continuous No-till, heavy residue, no cover crop
Continuous No-till, light residue or bare ground
Intermittent No-till
Shallow tillage (Aer-Way, Phoenix harrow…)
Strip-till
Subsoiled, wide spaced shanks
Moldboard or chisel plow, finely tilled seedbed
Subsoiled, deep ripped, full surface tillage

Best Cover Crops to Fight Soil Compaction?

- Grasses: Fibrous Roots
  Sorghum Sudan>Annual Rye> Cereal Rye/Oats

- Brassicas: Large Taproot (Fine root hairs)
  Daikon Radish > Turnips (Shallow rooted)

- Legumes: Large Root Network
  H. Vetch>Cowpeas>Red & Sweet Clover>Winter peas

- For Surface Compaction? For Deep Compaction?
  Buckwheat>Phacelia Sunflowers

Summary

- Soil Compaction is related to the Biology of the Soil & How the Soil was Managed.
- Organic Matter and Microbes influence Soil Compaction.
- Cold No-till Soils result from Soil Compaction and poor Soil Structure.
- Active Living Roots and Microbes work together to Improve Soil Structure.
- Equals No-till plus Cover Crops or a new system called ECO Farming!

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