Indicators of
Physical Soil Health
on NY State Farms

Significance, Measurement, and Interpretation

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Outline

- **Introduction:** What's Soil Health – Why do we care?
- **From the Farmers:** Soil Health Problems in NY State
- **Tour of the Soil Health Lab:** Goals and Methods
- **Results:** what do we know so far?
- **Directions, Conclusions**

Soil Health

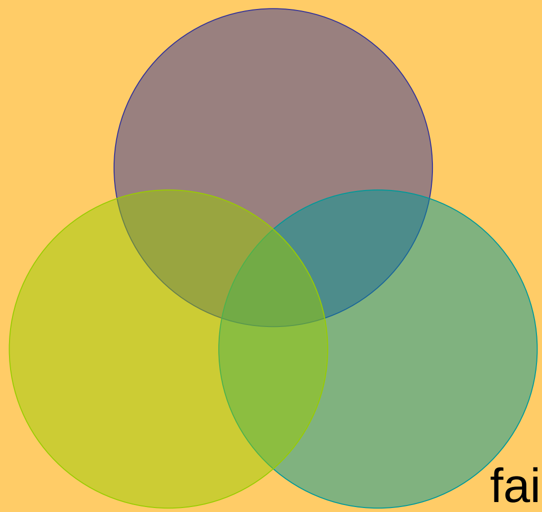
A Definition

"the capacity of the soil, within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental quality, and promote plant, animal and human health"

(Doran and Safley, 1997)

Components of Soil Health

Chemical –
well understood
and applied



Biological –
the least
understood

Physical –
fairly well understood,
BUT barely applied

Relevance of Soil Health in Agriculture

Chemical:

plant nutrition, acidity, toxic substances

Physical:

water infiltration, retention & conductivity

aeration

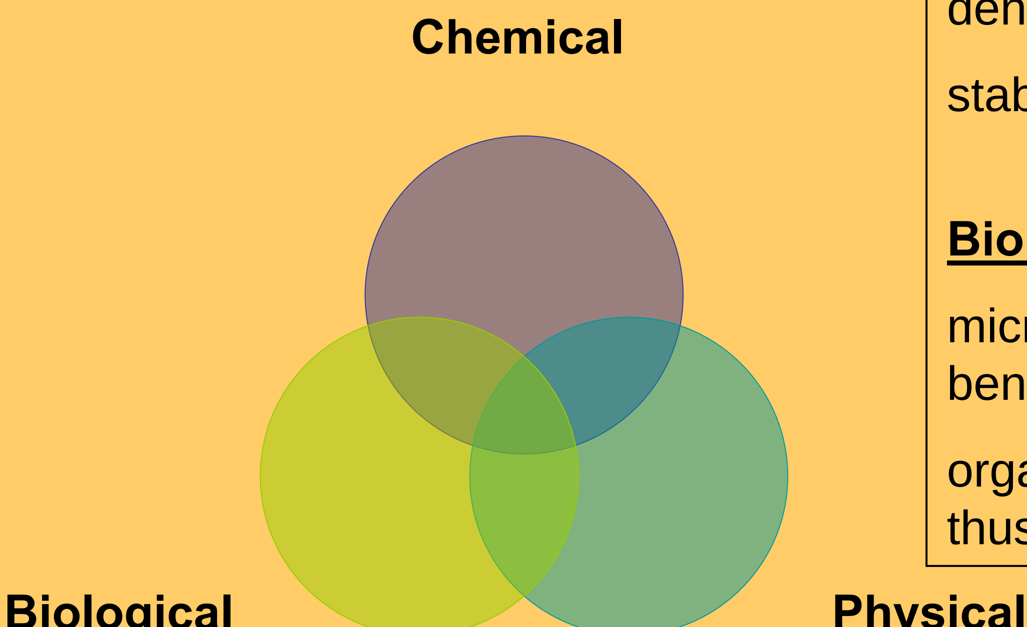
density: resistance to root growth

stability of aggregates

Biological:

microbial communities: symbiotic, beneficial, pests

organic matter decomposition and thus release of nutrients

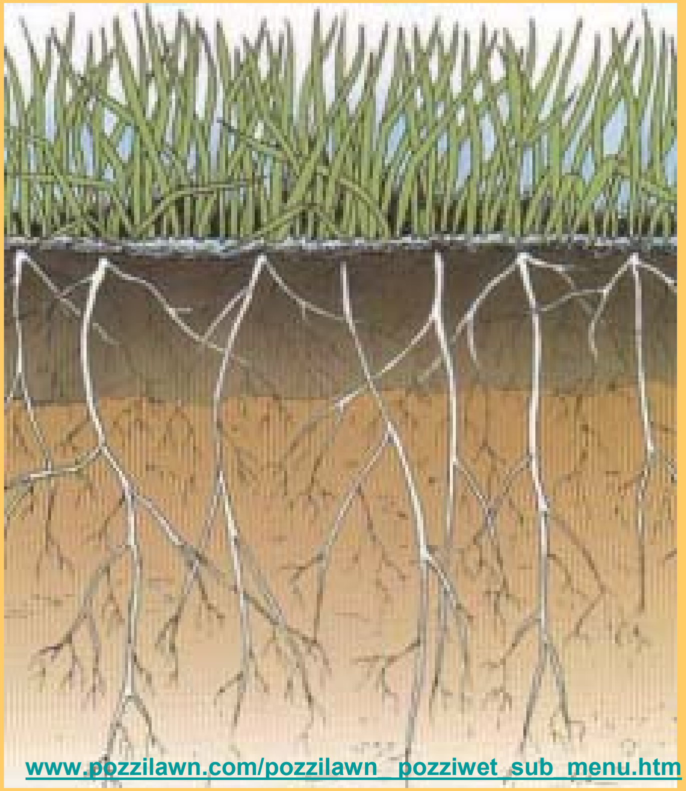


Relevance of Physical Soil Health in Agriculture

Physical Needs of a Plant Provided by the Soil:

Sustained supply of:

- Water
- Air
- Growing Medium for Roots to Stabilize Plant



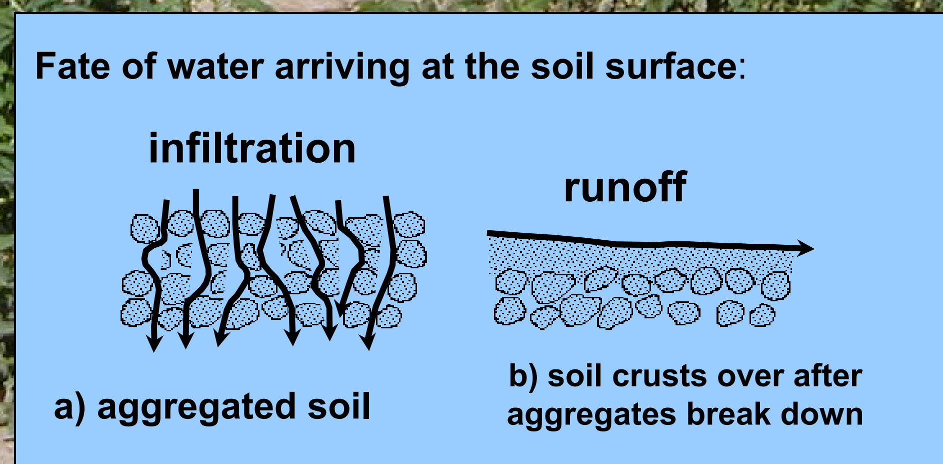
Healthy Soil Meets these Needs and more … however…

Common Soil Problems on NYS Farms

- low organic matter content
- soil compaction
- decreased infiltration
- reduced water holding capacity
- drought-prone soils …

Soil Problems on NYS Farms

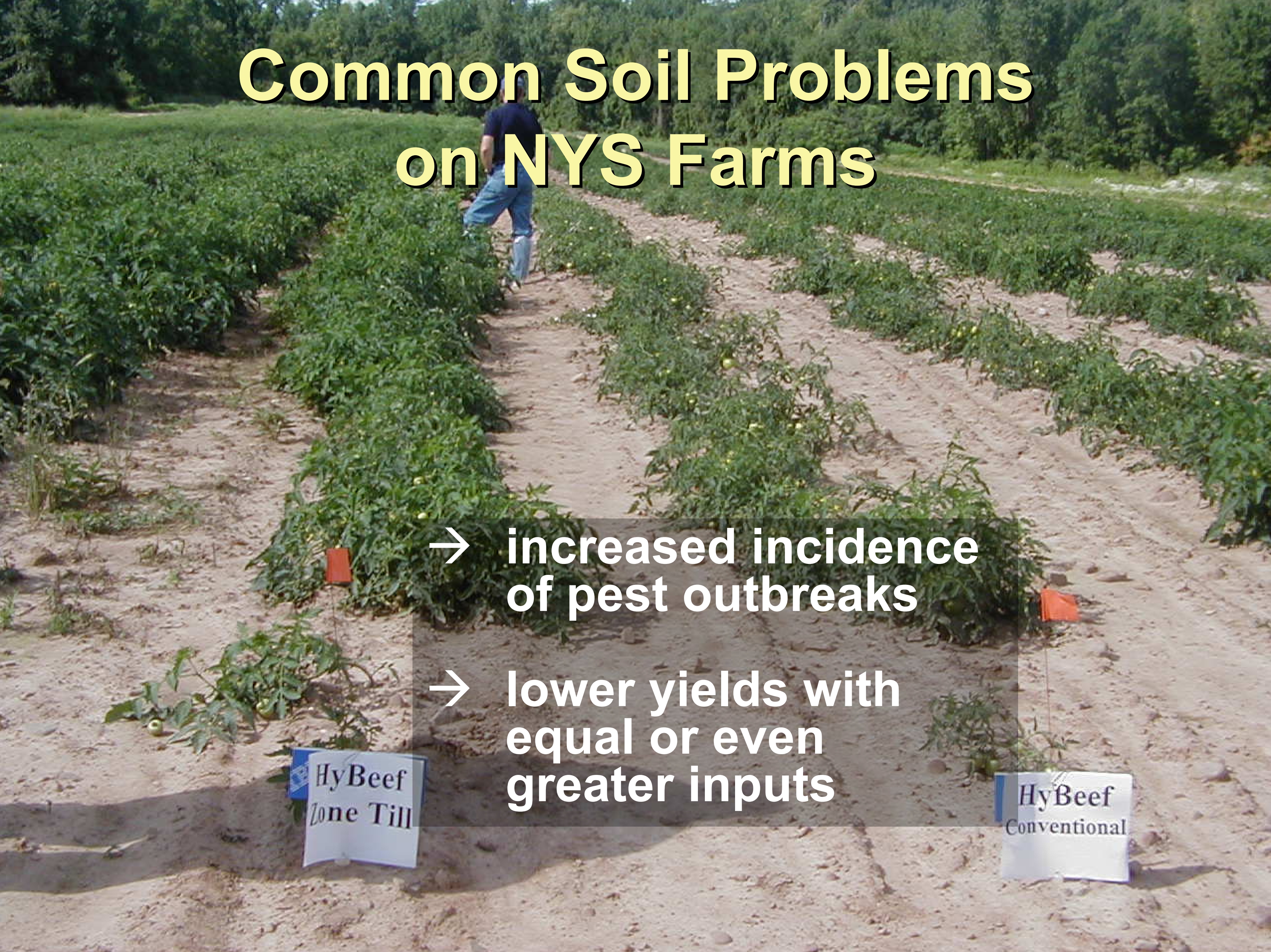
excessive runoff & erosion → surface crusting leads to hardsetting when dry



Common Soil Problems on NYS Farms

→ increased incidence of pest outbreaks

→ lower yields with equal or even greater inputs



How Healthy/Sick is a Soil?

1. How do we measure the extent of the problem?

2. And what do we do about it?

New York State Soil Health Project

Goal: To develop a fee-based Soil Health testing facility

Tests must be:

- Rapid
- Inexpensive
- Scientifically meaningful
- Agronomically useful

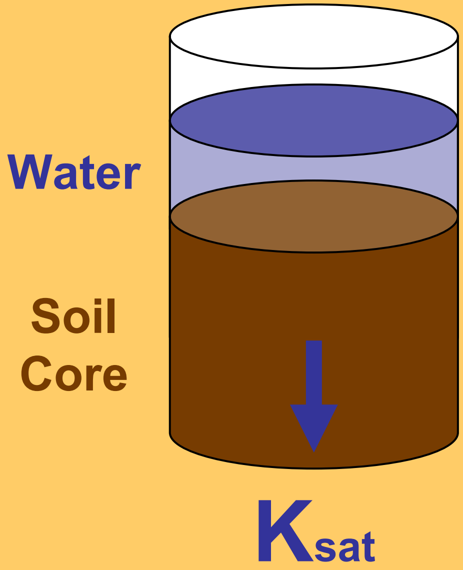
For Physical Analysis:

- disturbed soil samples
- undisturbed stainless steel cores

Use of Physical Characteristics of Soil as *Indicators* of Soil Health:

- **Saturated Hydraulic Conductivity**
- **Porosity & Pore Size Distribution**
- **Penetration Resistance and Bulk Density**
- **Aggregate Stability & Size Distribution**

Saturated Hydraulic Conductivity

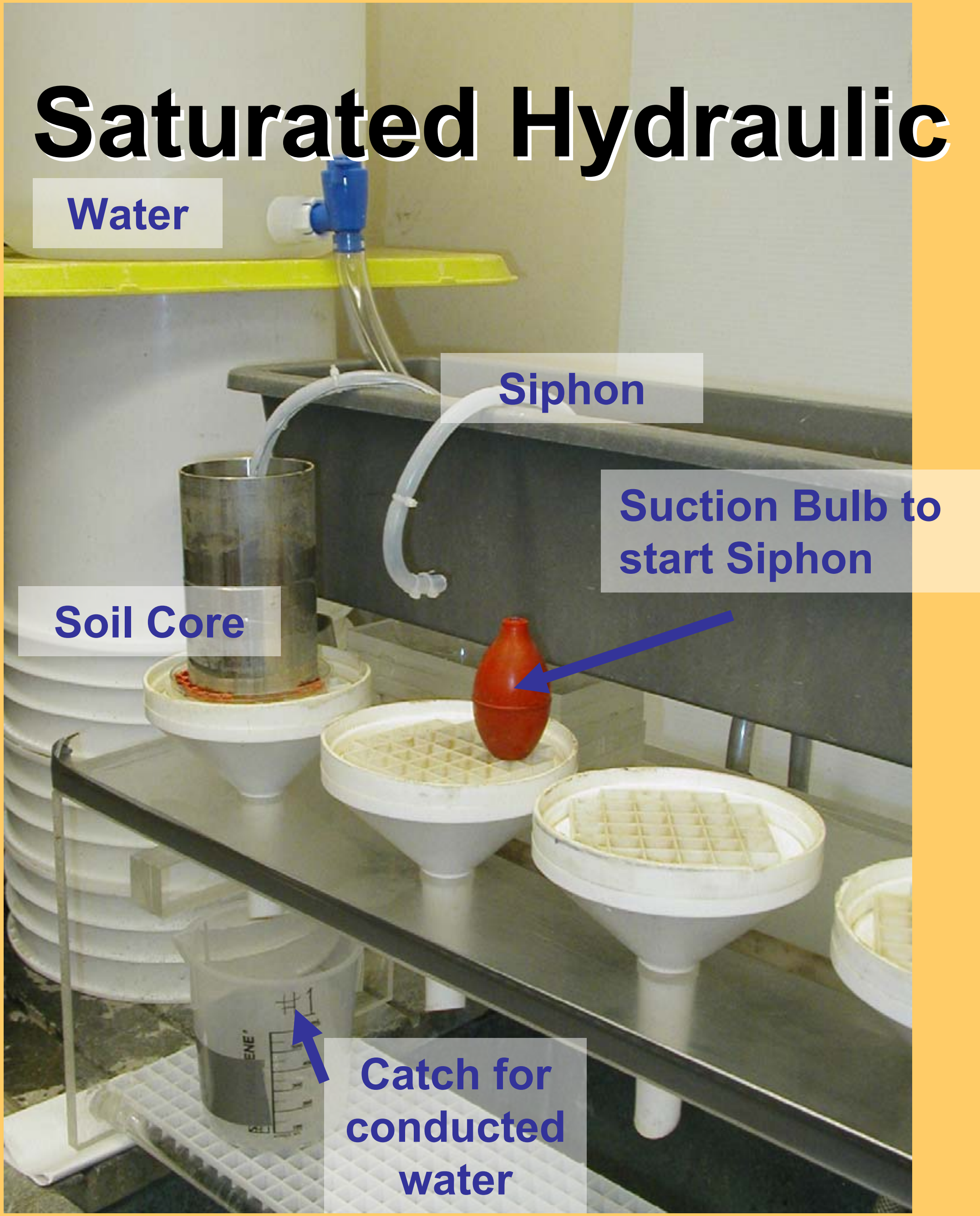


Definition: rate at which the soil conducts water when saturated

Affects:

- *erosion and surface porosity*
- *availability of water to plant*
- *aeration*

Saturated Hydraulic Conductivity



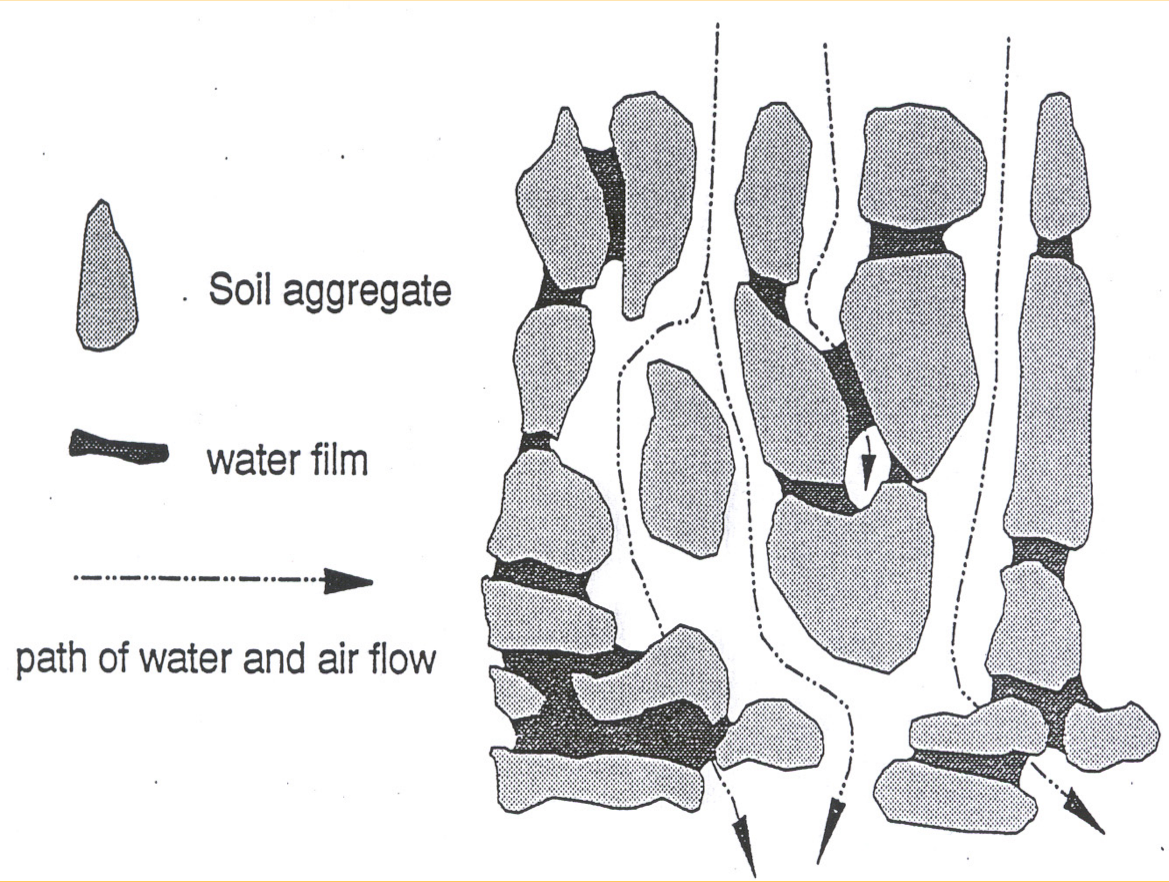
Measurement: rate of water flow through a saturated undisturbed soil core under a constant water head, supplied by siphons from a common reservoir.

Pore Size Distribution

Definition: The proportion of total porosity occupied by each defined size range of pores:

- micropores
- mesopores
- macropores

Pore Size Distribution has Effects on distribution, movement and holding capacity of water and air.



Pore Size Distribution

Total Porosity – fraction of soil for water and air

Macroporosity - drains within ~1hr of a heavy rain storm thus preventing anaerobic conditions (> 1mm)

Mesoporosity - provides for air space and very readily available water (1mm – 10µm)

Microporosity - indicates drought resistance of soil (water stored in small pores, but available to plants) (10µm - 0.2µm)

Residual Porosity - pores too small to provide water to plants (<0.2µm)

Measuring Pore Size Distribution

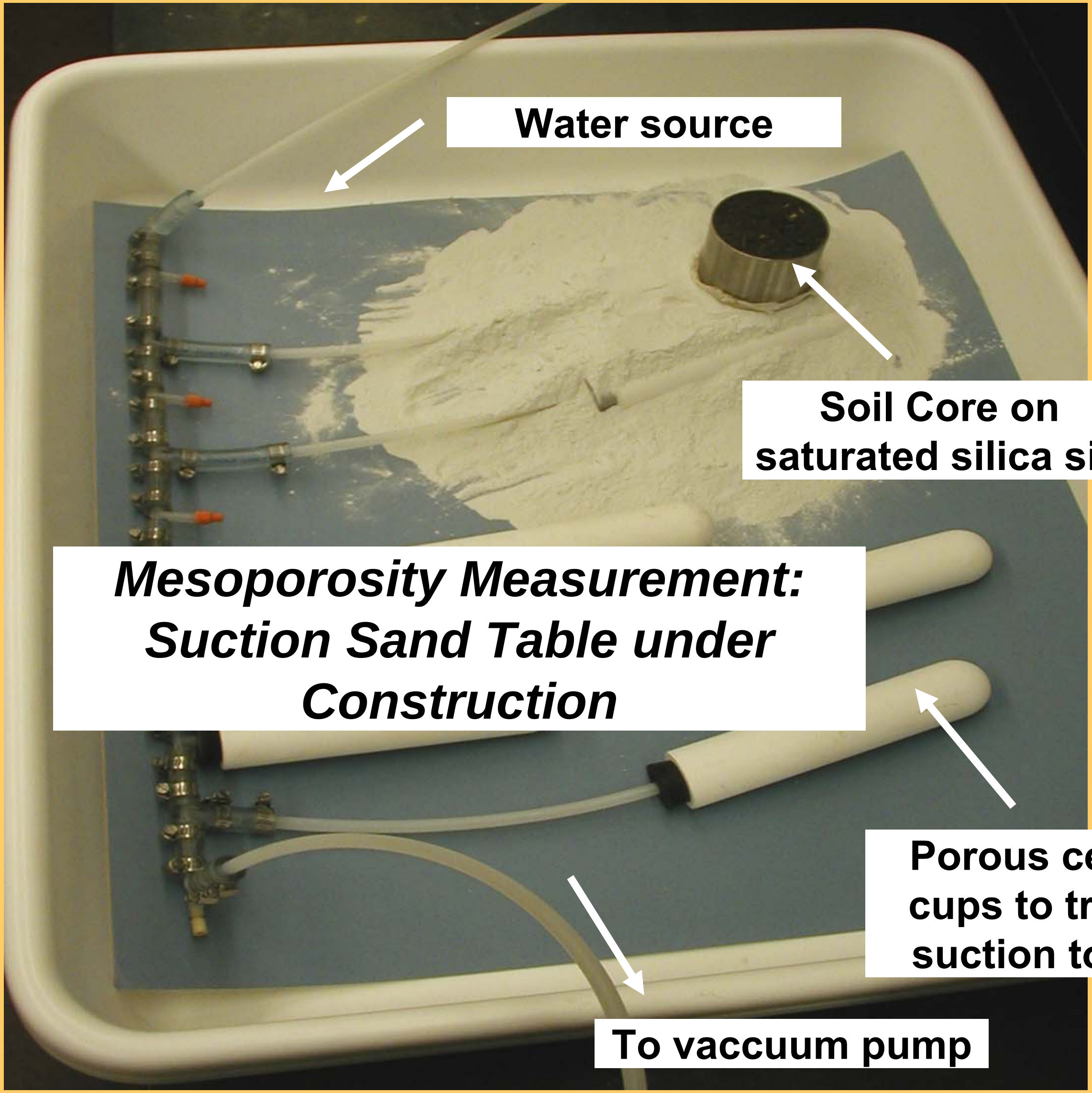
1. **Macroporosity: weigh saturated core samples, then free drain for 3hrs and reweigh**

2. **Mesoporosity: let core samples drain under pressure until at equilibrium at -10kPa, then use VanGenuchten Equations to calculate approx. -30kPa**

Two methods:

- **Pressure Cells**
- **Sand Table**

Measuring Pore Size Distribution

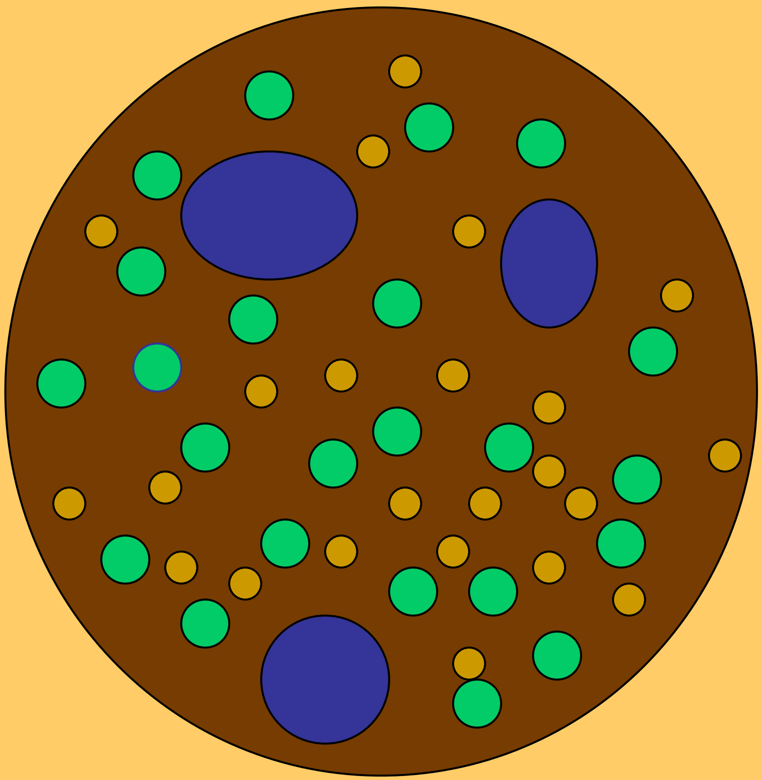


Mesoporosity: let core samples drain under suction until at equilibrium at -10kPa

Measuring Pore Size Distribution

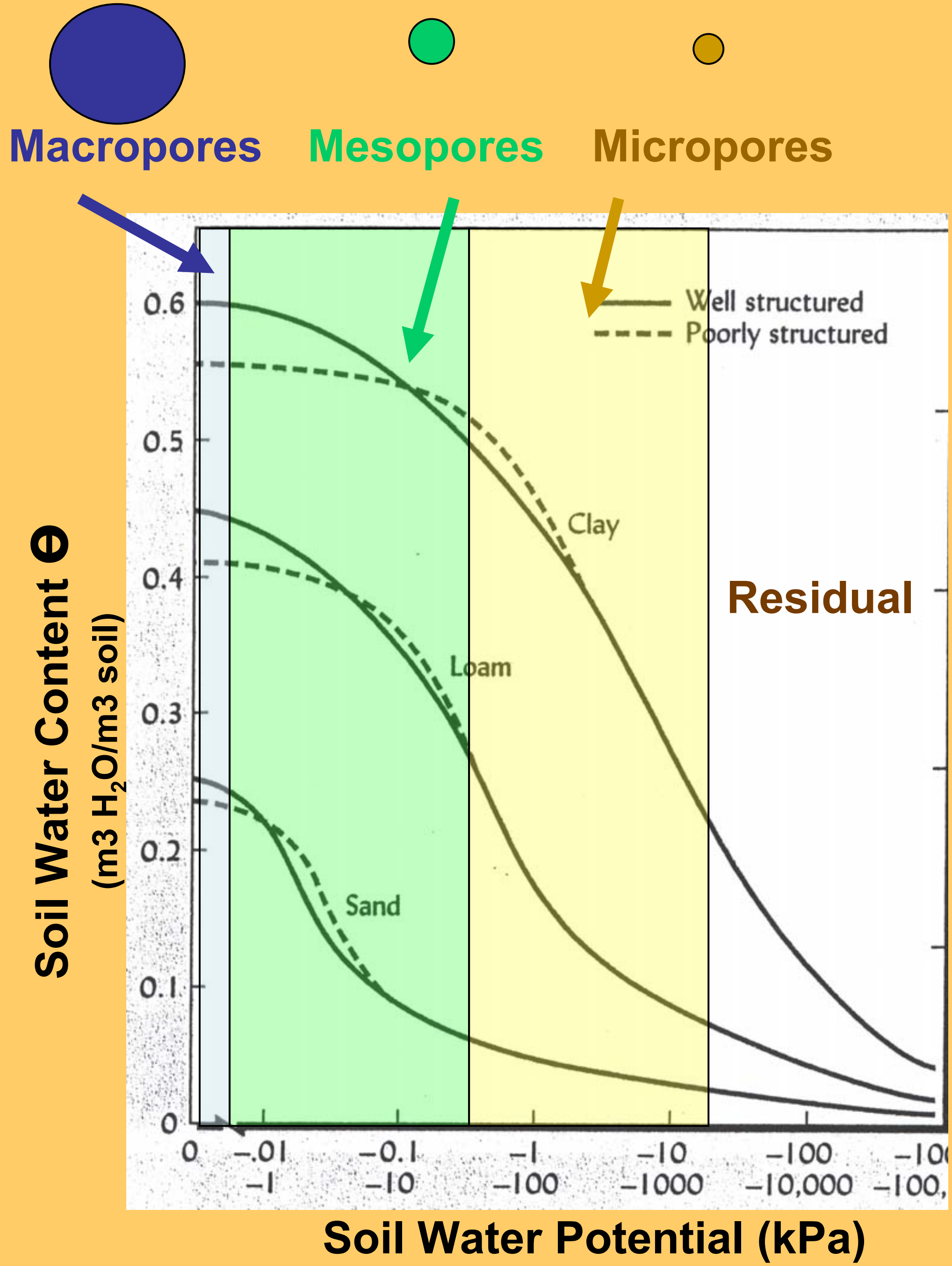
3. After Sand Table or Pressure Cells, determine Microporosity: let drain at -1500kPa in high pressure chambers

Pore Size Distribution



= Pores

= Soil



Penetration Resistance

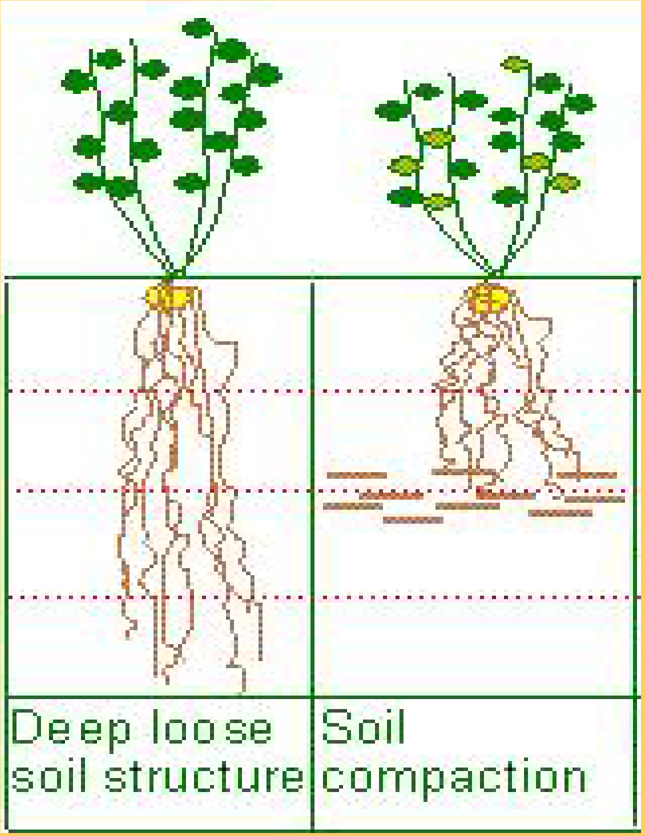
Definition: The resistance of a soil to root growth

Affected by Density of Soil:

Low Bulk Density and high porosity make soil easy to penetrate

Affected by Moisture:

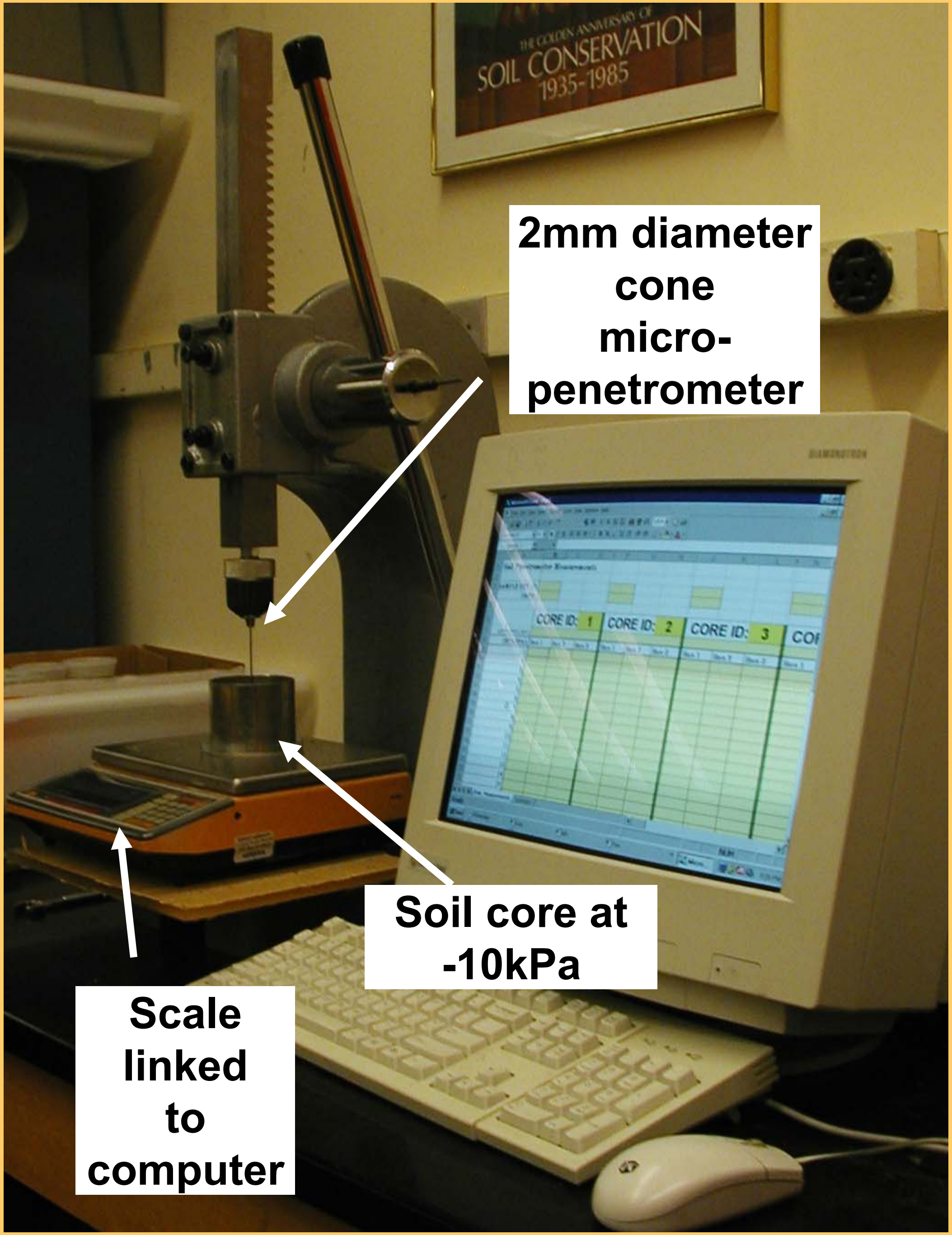
the wetter, the softer!



Measuring Penetration Resistance

- *Constant* Moisture Potential
- 3 penetrations, with one measurement per second
- From here, samples go to biological analyses

Handheld Penetrometer

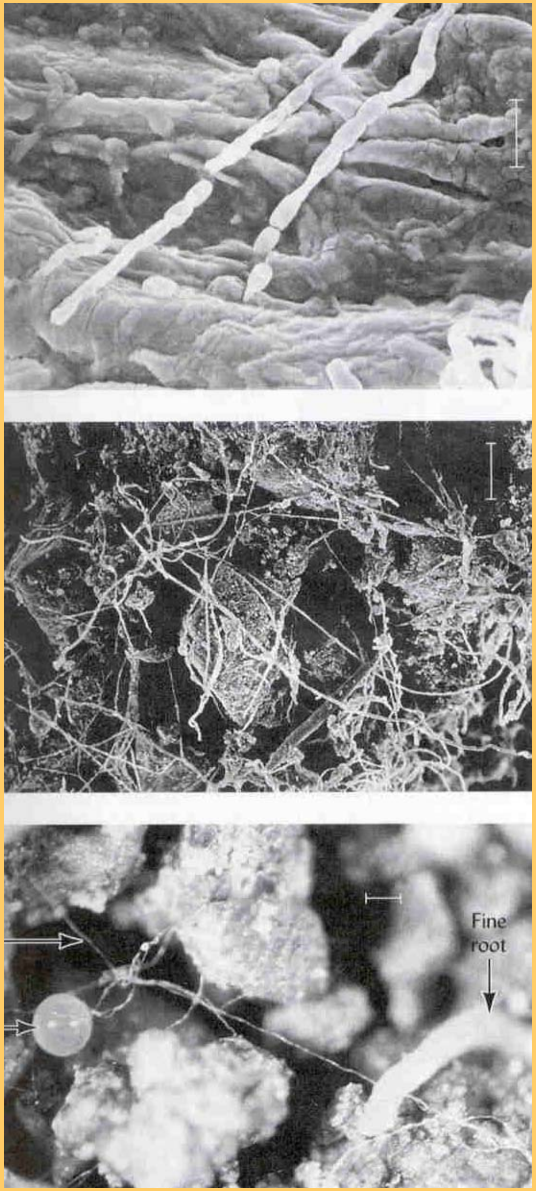


Aggregate Stability

Definition:

Ability of soil aggregates (soil crumbs) to withstand physical stress from rainfall

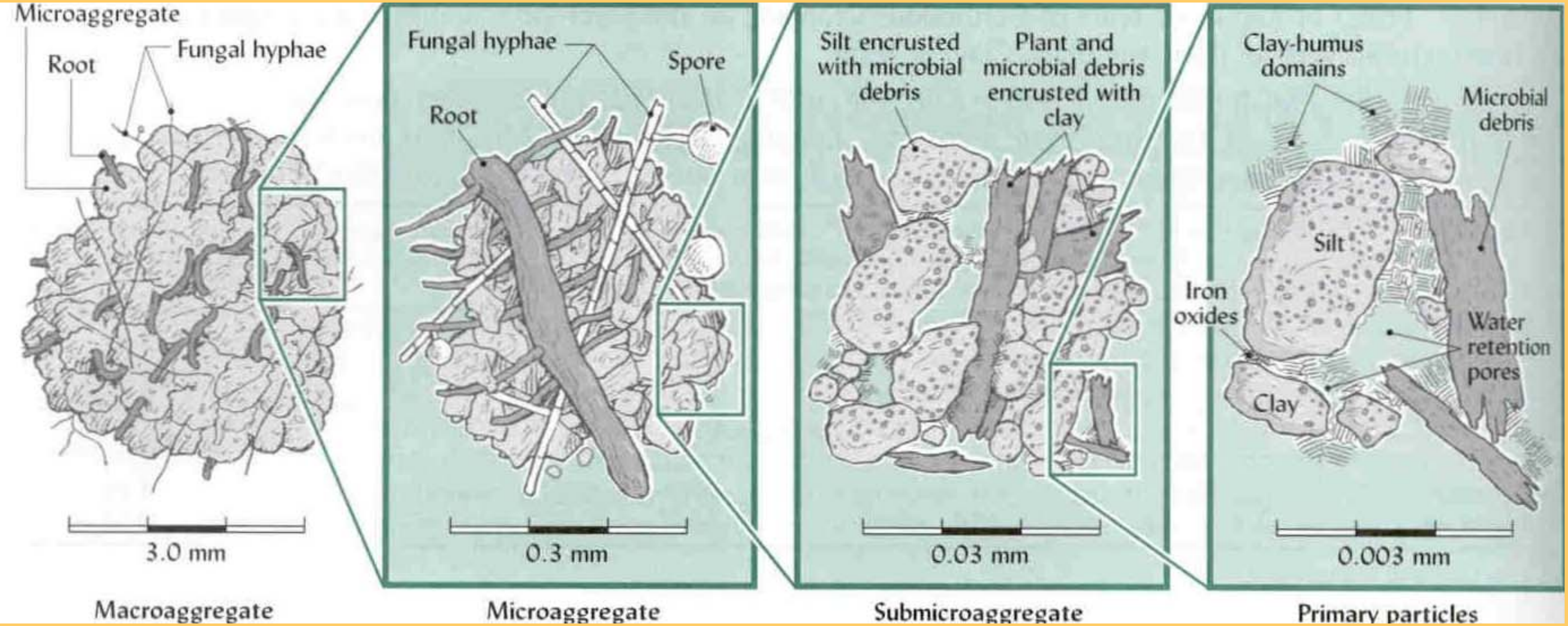
Affects erosion, hardsetting and surface crusting and thus porosity and hydrology



Aggregate Stability

Aggregates are held together by chemical and mostly by biological GLUES such as:

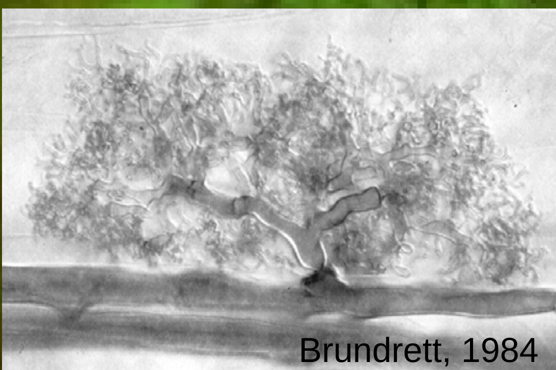
Clay particles, humus, polysaccharides from bacteria, fungi and their secretions,



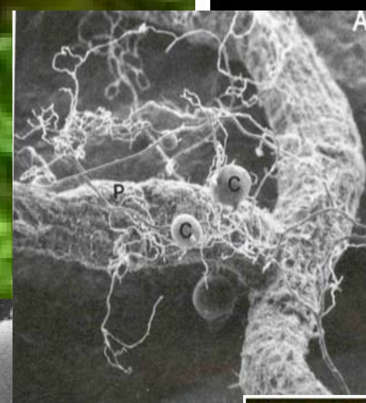
Aggregate Stability and Glomalin

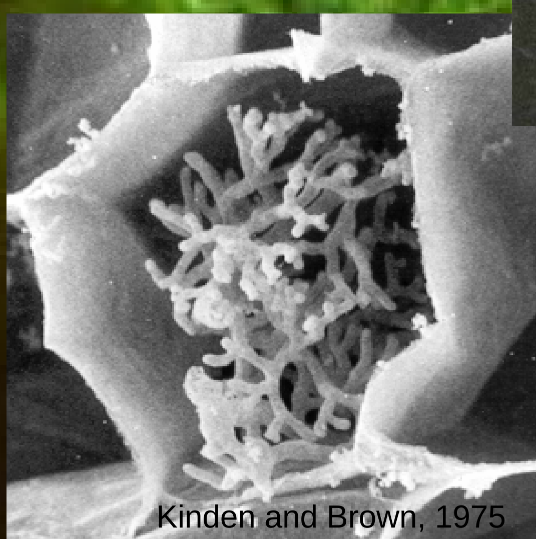
Arbuscular Mycorrhizal Fungi (Glomeromycotan Fungi) produce a glycoprotein called Glomalin

- water resistant
- highly associated with aggregate stability
- recalcitrant, potentially remains in soil for decades!

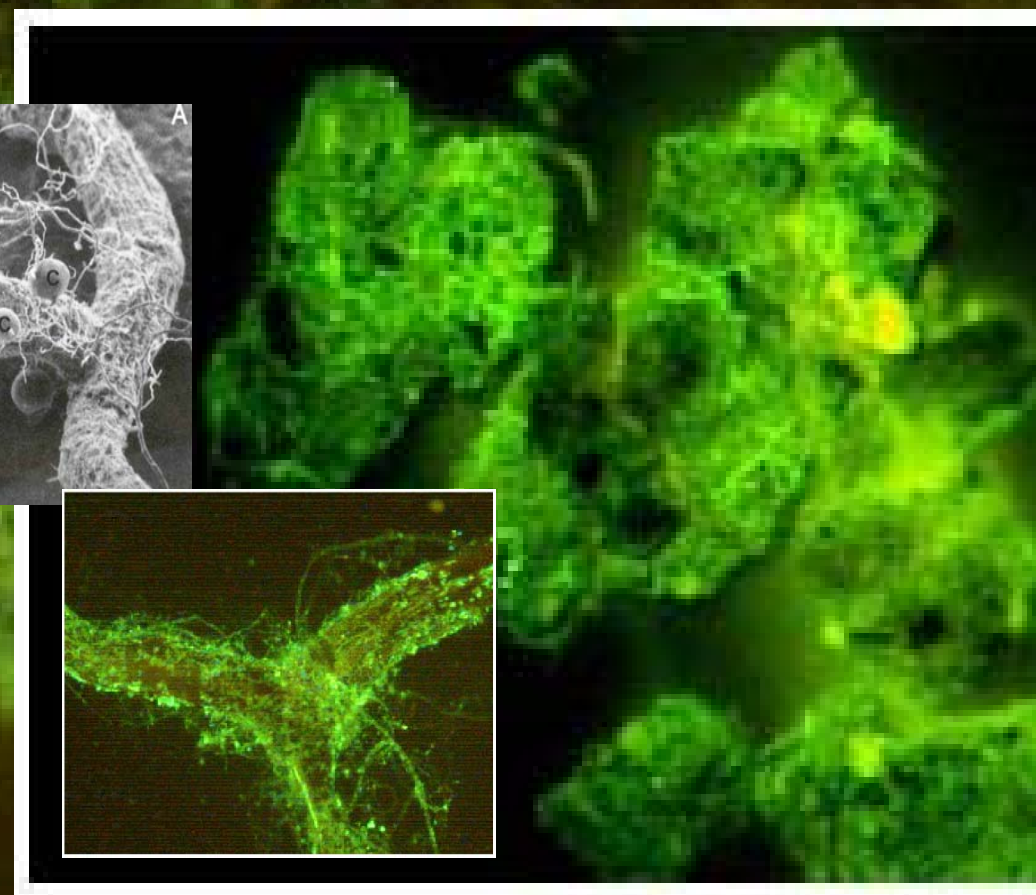


Brundrett, 1984

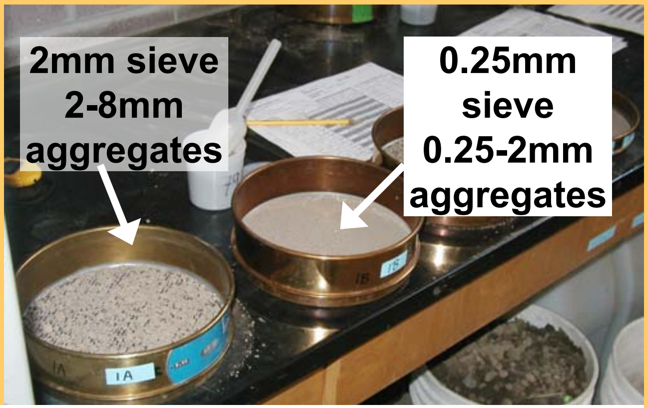




Kinden and Brown, 1975



Measuring Aggregate Stability



Aggregates before stability test

During 5 min - long controlled rainfall test: water drops impact sample aggregates on sieve

The Cornell Sprinkler
suspended 0.5m above the sample aggregates on sieves

Interconnected Physical Soil Characteristics:

Aggregate Stability

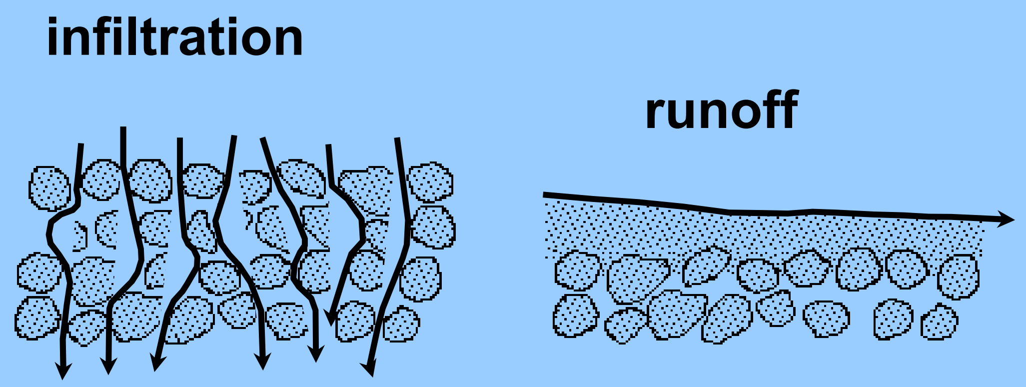
= “integrative indicator” of the sustainability

Provides sustained

Pore

Saturated Hydraulic Conductivity

Fate of water arriving at the soil surface:

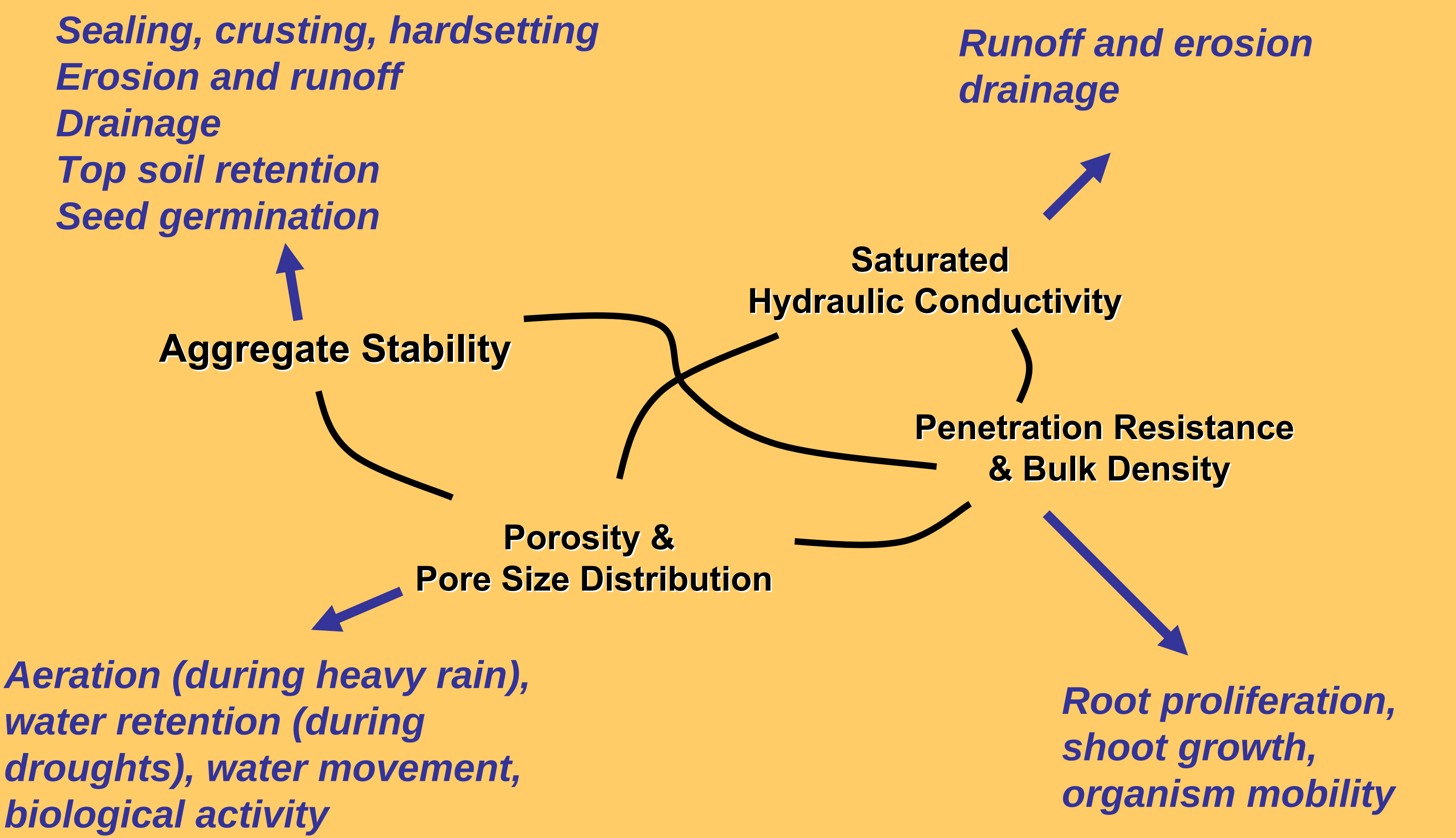


a) aggregated soil

b) soil crusts over after aggregates break down

Effects of Physical Soil Characteristics in Agriculture:

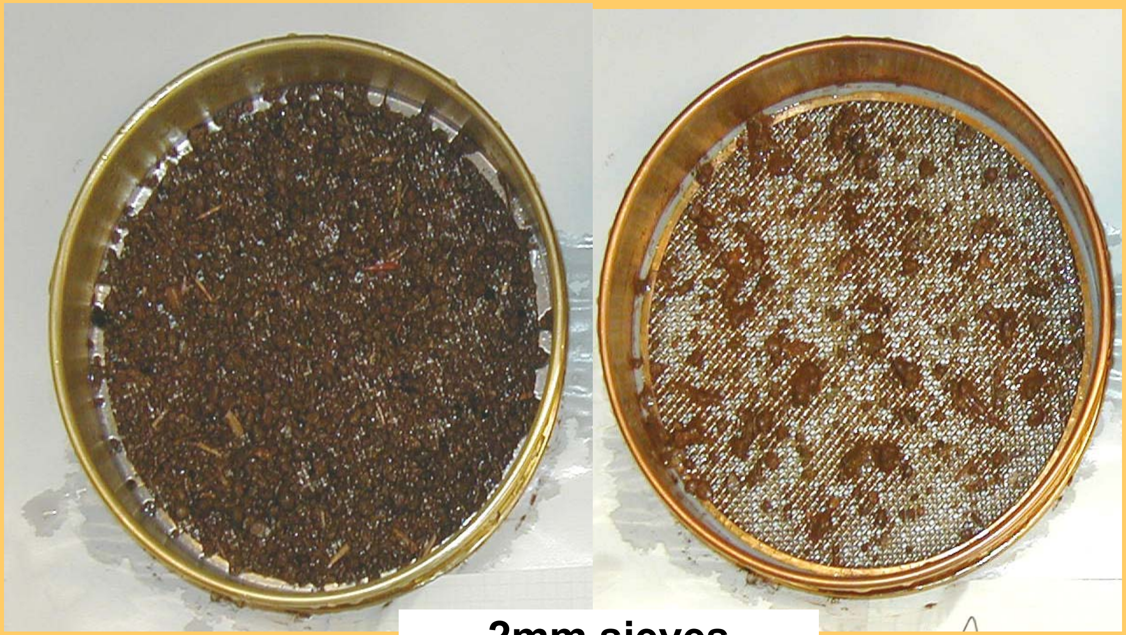
→ = has an effect on



We've measured a bunch of indicators,…
Now What??

Goal: Testing Facility will provide test results along with Management Recommendations

Results and Interpretation of Aggregate Stability Test


2mm sieves

Aggregates after stability test

% of Soil crumbs stable to 1.25cm rain/5mins:

Organic management ~70% - high

Conventional management ~20% - low

Willsboro Drainage Clay Loam

Small Crumbs - Aggregate Stability

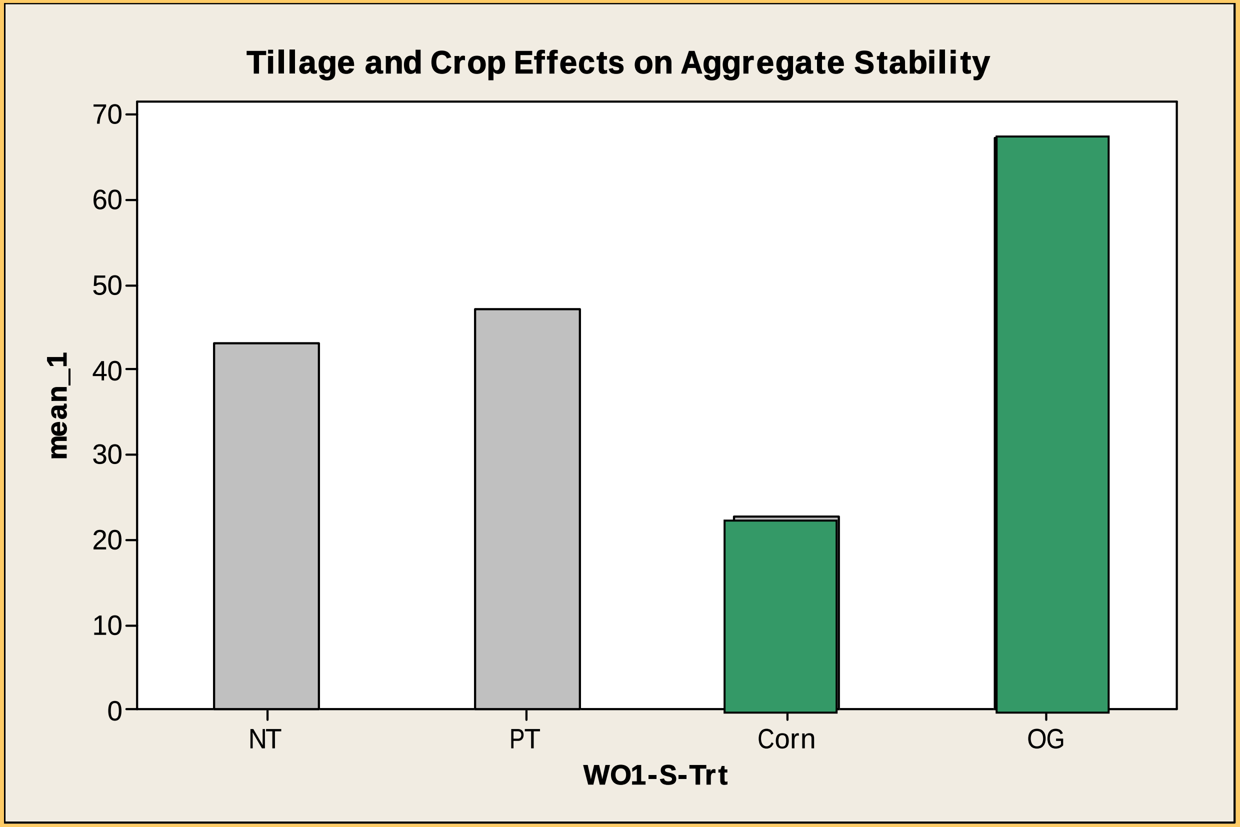
recent NT vs PT, Orchard Grass vs Corn

$AS_{orchard\ grass} > AS_{corn}$

Two-way ANOVA:

AS Small versus tillage, crop

Source	P
tillage	0.341
crop	0.000



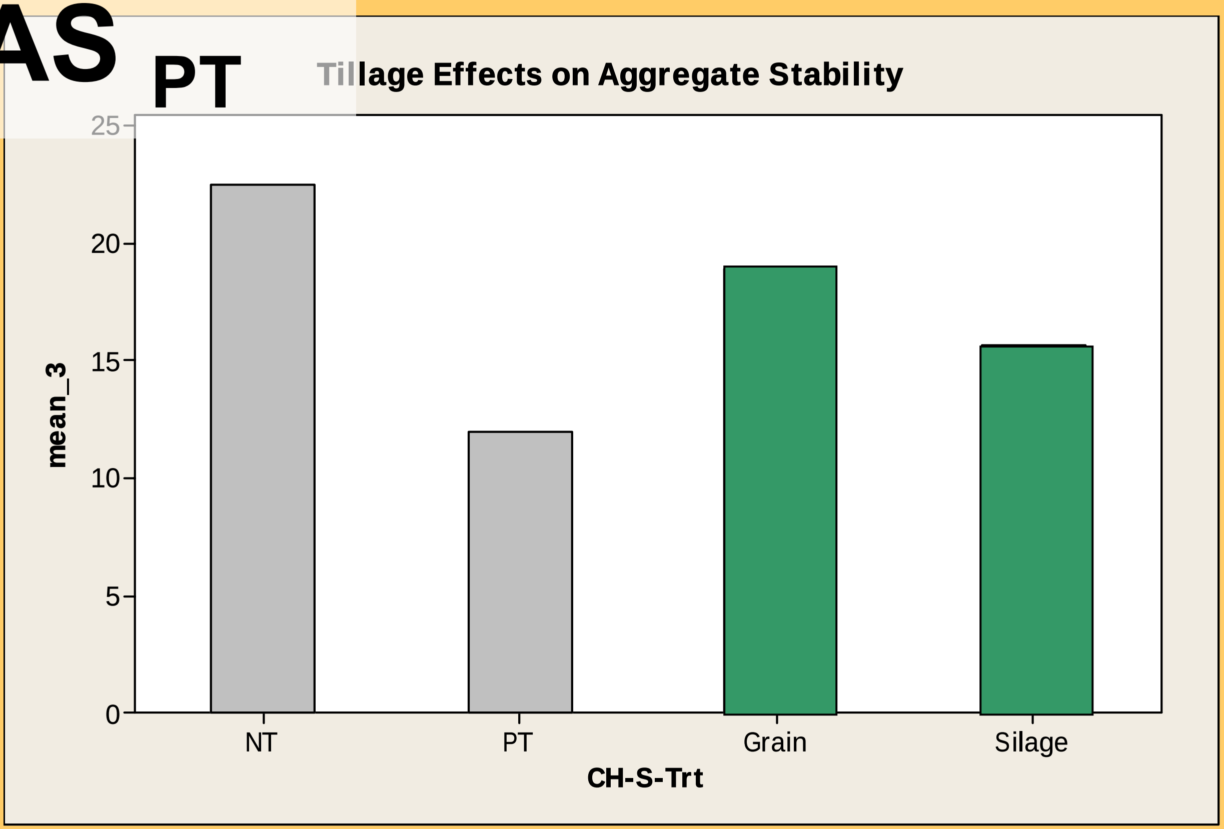
Chazy Tillage Silt Loam
Small Crumbs - Aggregate Stability:
32 yr NT vs PT, Silage vs Grain

$AS_{Silage} > AS_{Grain}$

$AS_{NT} > AS_{PT}$

ANOVA on AS Small, using Adjusted SS for Tests (GLM)

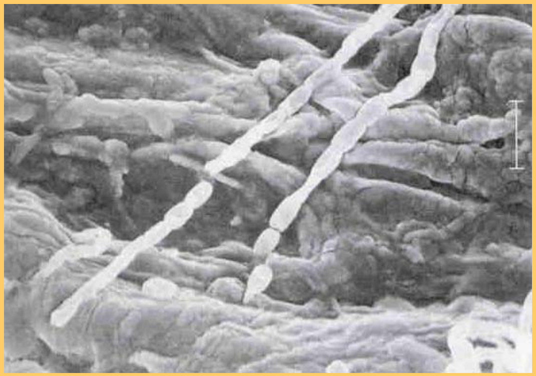
Source	P
tillage	0.038
crop	0.048



Example Comparison of two NY Farms

Example Comparison Indicator Values for two NY Farms under Organic and Conventional Management on Hamlin Silt Loam		
	Management:	
Physical Soil Health Indicator:	Conventional	Organic
Aggregate Stability (%)	20	70
Total Porosity (%)	45 ± 2	59.4 ± 6.6
Macroporosity (%)	2.8 ± 0.8	4.0 ± 2.6
Bulk Density (g/cc)	1.4 ± 0.05	1.2 ± 0.1
Penetration Resistance (MPa)	1.2 ± 0.3	0.8 ± 0.4

Agricultural Management Effects on Soil Health Indicators



Tillage and traffic cause Compaction → loss of Macropores (especially when soil is wet).

Earthworm and other biological activity in minimally disturbed fields → builds Macropores

Organic matter addition and less disturbance → builds aggregates

Organic matter addition and structure development over time →builds mesopores and micropores

Same management practices prevent increasing penetration resistance, retains good conductivity


Recommendations – a work in Progress
Recommendations will take into account
• Soil data
• Crops grown
• Type of farm, farm size, access to mechanization, feasibility …

… to make recommendations for management practices such as:

- Changing tillage regime
- Controlling traffic

… such as using:

- organic matter inputs
- Cover cropping
- Crop rotations

Availability of

Physical Soil Health Tests will:

Provide quantitative way to assess soil health

Provide recommendations for management that are both scientifically tested and farm-tried in NYS

Raise awareness of Soil Health