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GROWING A NEW GENERATION OF ILLINOIS FRUIT AND VEGETABLE FARMERS

SOIL QUALITY

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Objectives

- Define Soil Quality
- Review Soil Quality Factors
  - Physical
    - Structure
      - Aggregate stability
    - Bulk density
    - Porosity
    - Water Relations
      - Permeability
      - Infiltration
    - Crusting
    - Available Water Capacity
  - Biological
    - A living system
    - Organic matter
- Management and Soil Quality
  - Increasing OM
  - Minimizing tillage

Soil Quality Defined

"The capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant, animal and human health."

Soil Quality Defined

- Farmer: sustaining or enhancing productivity, maximizing profits, and maintaining the soil resource
- Naturalists: soil in harmony with the landscape and its surroundings
- Environmentalist: soil functioning at its potential in an ecosystem with respect to biodiversity, water quality, nutrient cycling, and biomass production

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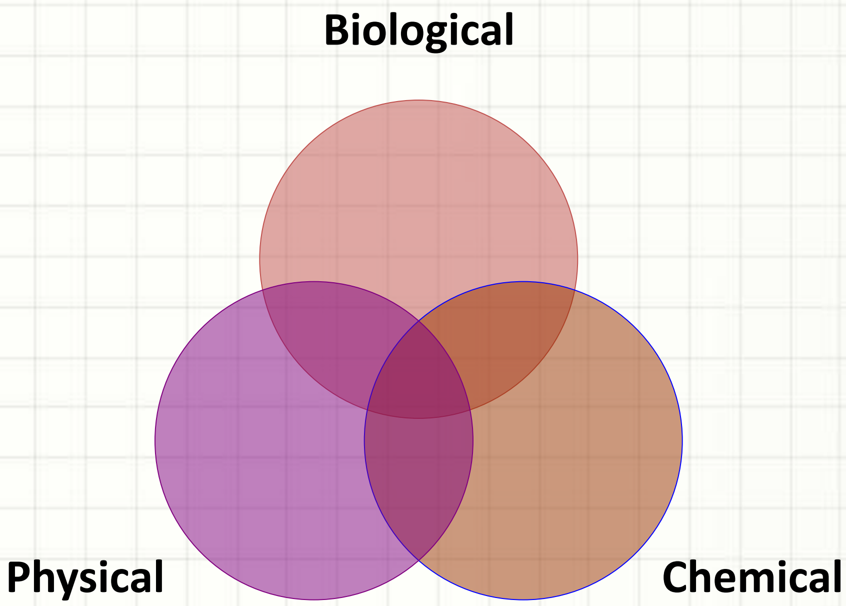
Soil Quality Defined

- Provide hospitable conditions for life within the soil
- Provide ecosystem services
  - Support plant growth
  - Cycle nutrients
  - Hold and release water
  - Exchange gases
  - Conserve natural enemies and suppress pests
  - Store carbon

Soil Quality Factors

- The ability of a soil to function within ecosystem boundaries to support healthy plants and animals, maintain or enhance air and water quality, and support human health and habitation
- **Soil quality** integrates the physical, chemical and biological condition of the soil



Soil Properties

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Physical Factors

- Soil Structure
- Aggregate Stability
- Bulk Density/Compaction
- Soil Pores
- Permeability
- Infiltration
- Surface Crusting
- Available Water Holding Capacity

Affect water movement and storage

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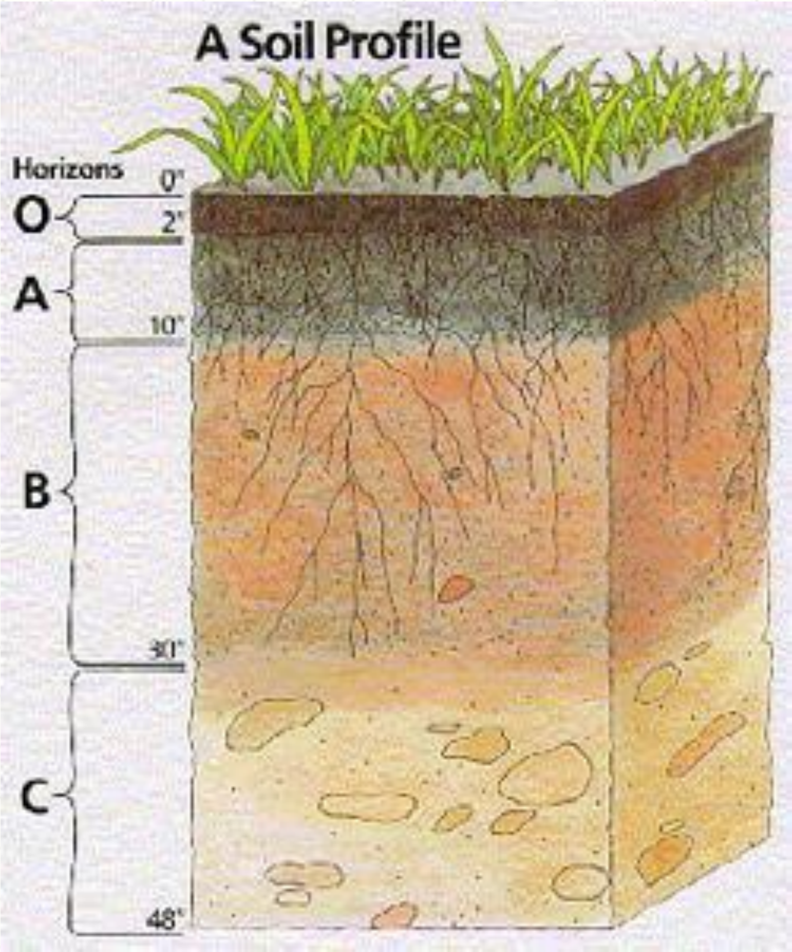
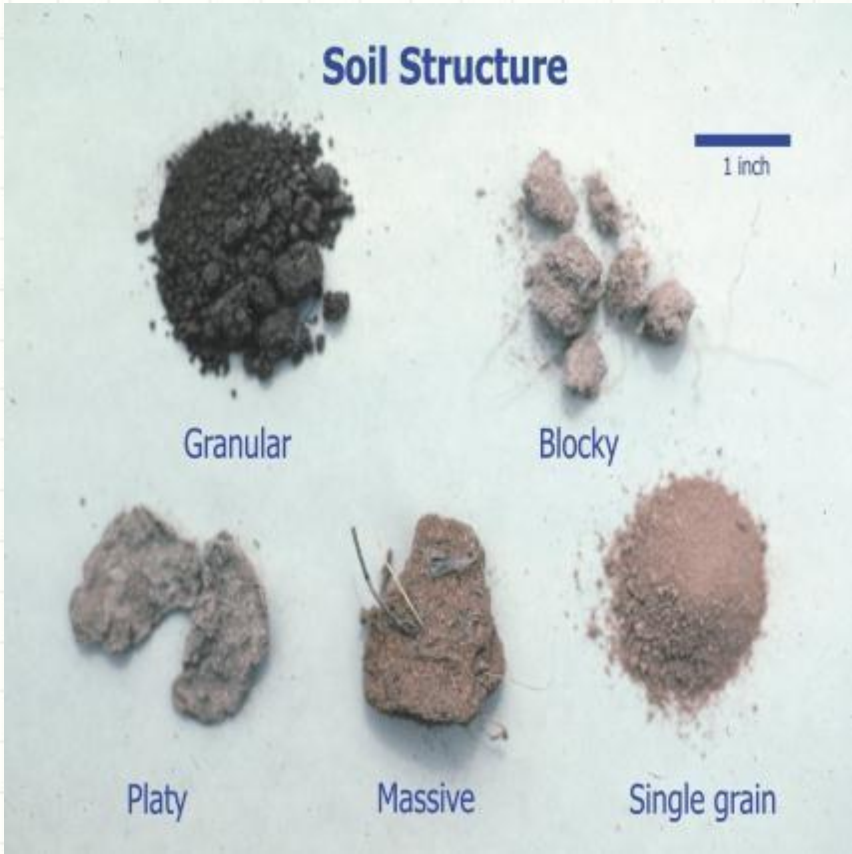
Soil Structure

- Definition
  - The naturally occurring arrangement of soil particles into secondary units or peds
- Why is it important?
  - Infiltration/permeability
  - Soil erosion
  - Root penetration
  - Air movement
  - Reduces susceptibility to compaction

Soil Structure





Example of good blocky structure
in a soil profile.


Structureless
Good Structure

Factors Influencing Soil Structure

- Surface development factors
  - Biological activity
  - Organic matter
  - Tillage
- Subsurface development factors
  - Texture
- Shrink-swell, wetting & drying cycles
- Root growth
- Soil microbial activity
- Soil formation factors

Aggregate Stability

- Definition
  - The ability of soil aggregates to resist disruption.
- Why is it important?
  - Good aggregate stability reduces erosion
  - Facilitates water movement into and through soil
  - Increases plant root growth
  - Decreases surface crusting
  - Increases water and gas movement
  - Aggregates protect organic matter

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Aggregate stability

Similar sized aggregates are placed in the water and dunked a couple of times . Look at not only the aggregates left, but the sediment in the water.

Factors Influencing Aggregate Stability

- Organic matter content
- Clay content
- Tillage
- Microbial activity
  - Glomalin
    - a sticky protein secreted by mycorrhizal fungi that binds soil particles together

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Bulk Density/Compaction

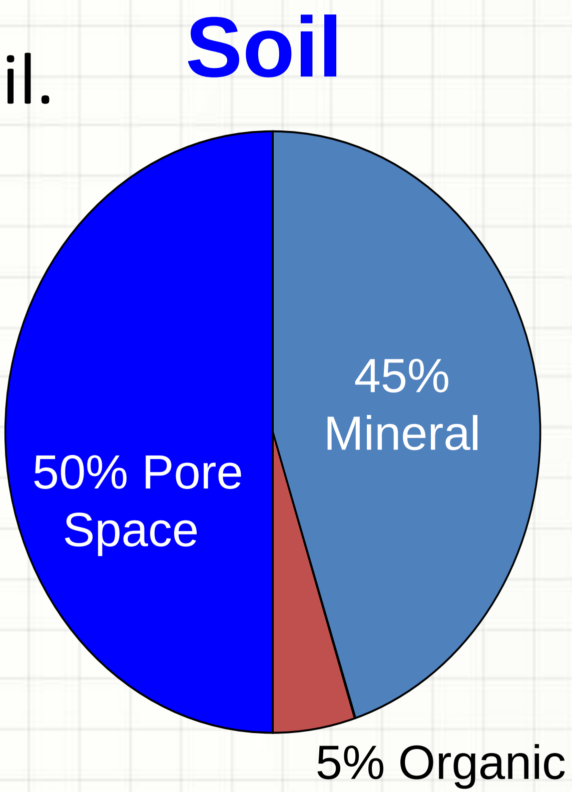
- Definition
  - the weight of a given volume of soil
  - Compaction is the reduction of pore space
- Why is it important?
  - Root growth and development
  - Water and air movement
  - Increases runoff/erosion
  - Earthworm movement

Compacted

Compacted zone

Soil Pores

- Definition
  - Air or water filled voids in the soil.
- Why is it important?
  - Infiltration
  - Permeability
  - Root Penetration
  - Air Exchange
  - Macropores vs. Micropores



Factors Influencing Soil Pores

- Soil aggregates
- Plants and animals
- Soil texture
- Organic matter
- Tillage
- Compaction
- Plow pan

Soil at Bottom of Soil Core

Earthworm channels

Conventional Tillage

18 Years No-till

Ant burrows create a network of soil macropores.

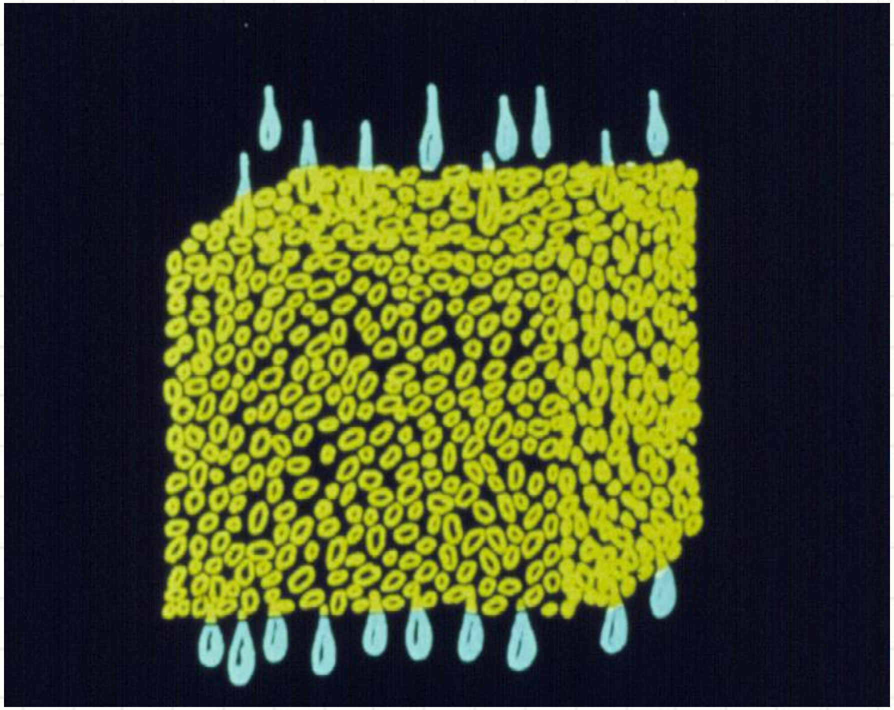
Larger animals such as rodents create very large macropores.

Soil Permeability

- Definition
  - The ease with which fluids or gasses can flow through soil.
- Why is it important?
  - Leaching of fertilizer or pesticides
  - Slow permeability increases water erosion

Factors Influencing Permeability

- Texture
- Compaction
- Porosity
- Structure



Infiltration

- Definition
  - The process of water entering the soil from the surface.
- Why is it important?
  - Soil as storage medium for water
  - Good infiltration reduces erosion, runoff, and ponding.

Infiltration

0.1 in/min

5 in/min

35%

Water Stable Aggregates

88%

Water Stable Aggregates

Factors Influencing Infiltration

- Soil structure/ Aggregate strength
  - tillage
  - compaction
  - surface crusting
- Organic matter
- Biological Activity (earthworms, etc.)
- Soil Texture (sandy soils have higher rate)
- Crop rotation with deep roots

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Earthworm Burrows

middens

Middens: piles of residue around the mouth of earthworm burrows.

Surface Crusting

- Definition
  - Thin layer on the soil surface that restricts water and air entry and seedling emergence.
- Why is it important?
  - Reduces infiltration
  - Increases Runoff
  - Reduces oxygen diffusion to roots

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Factors Influencing Surface Crusting

- Organic Matter
- Aggregate Stability
- Rainfall Intensity
- Residue Cover
- Sodium content

Available Water Capacity (AWC)

- Definition
  - amount of water that is between field capacity &permanent wilting point
- Why is it important?
  - Water supply for plants between each rainfall or irrigation
  - Each extra inch of water added to AWC increases yield
  - Water supply for soil inhabitants (fungi, bacteria, etc.)

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Factors Influencing AWC

- Texture
- Organic matter
- Structure (Rocky Soils)
- Bulk density
- Plow Pans destroy pore space
- Rooting depth
- Salinity

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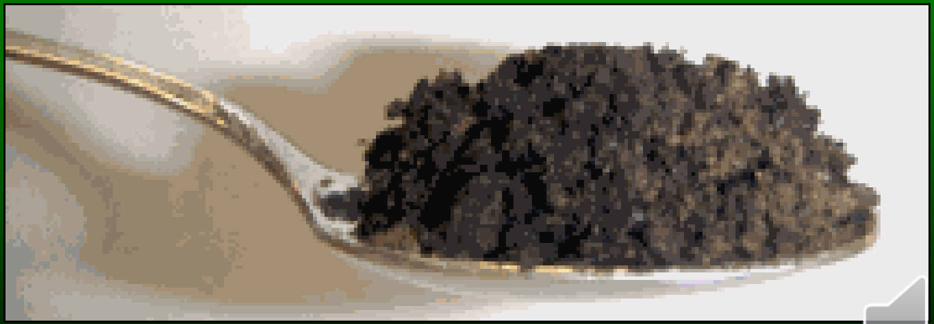
  - **Biological**
    - A living system
    - Organic matter
- Management and Soil Quality
  - Increasing organic matter
  - Minimizing tillage

Biological Factors

- Earthworms, soil arthropods, nematodes, fungi, bacteria, algae
  - Contribute to nutrient cycling, buffering, filtering
  - Improve soil structure, aggregation
  - Resistance to disease
  - Holds organic matter

In 1 teaspoon of healthy soil there are…

Bacteria	100 million to 1 billion
Fungi	6-9 ft fungal strands put end to end
Protozoa	Several thousand flagellates & amoeba One to several hundred ciliates
Nematodes	10 to 20 bacterial feeders & a few fungal feeders
Arthropods	Up to 100
Earthworms	5 or more



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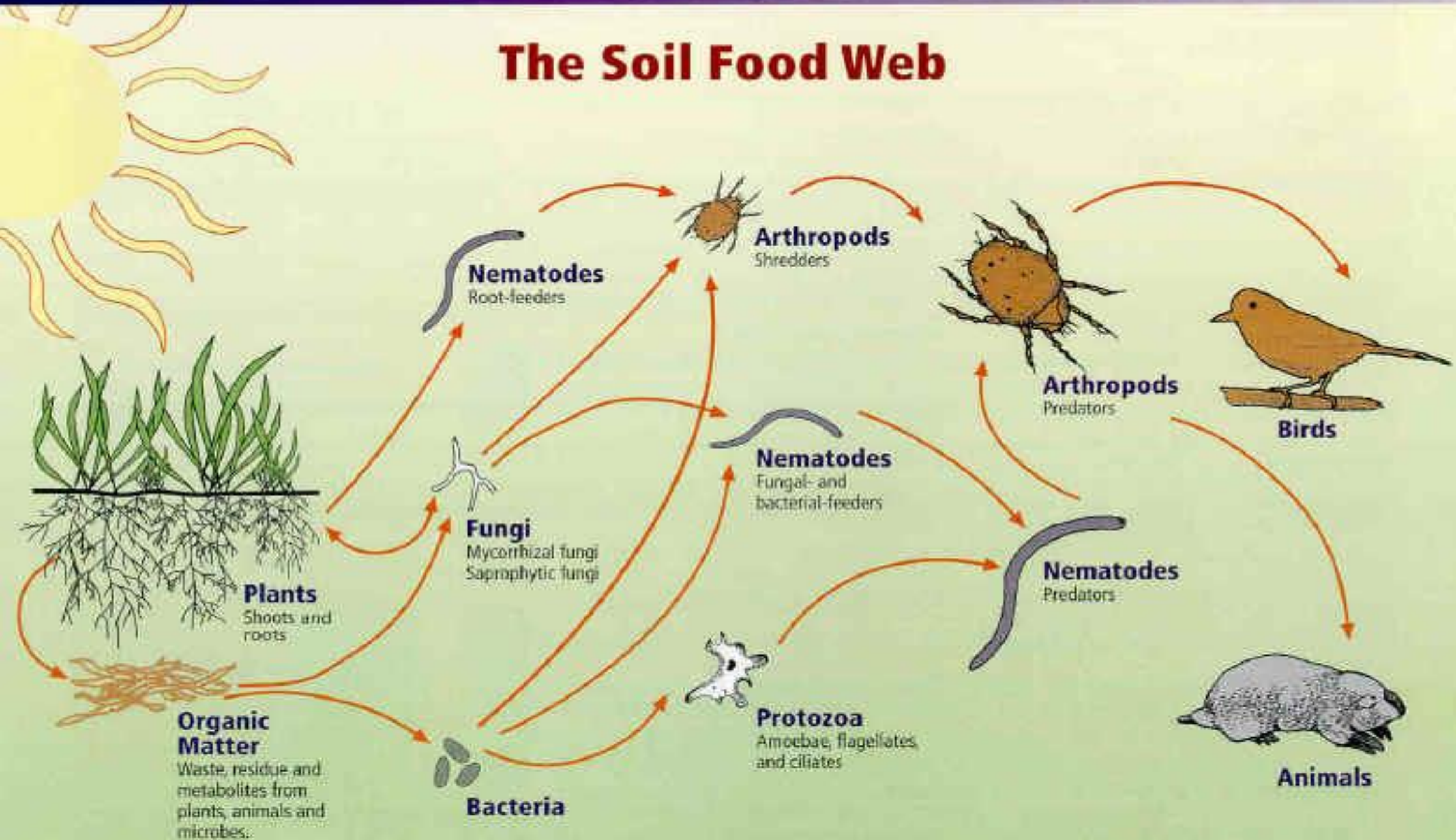
The Soil Food Web



First trophic level:
Photosynthesizers

Second trophic level:
Decomposers
Mutualists
Pathogens, parasites
Root-feeders

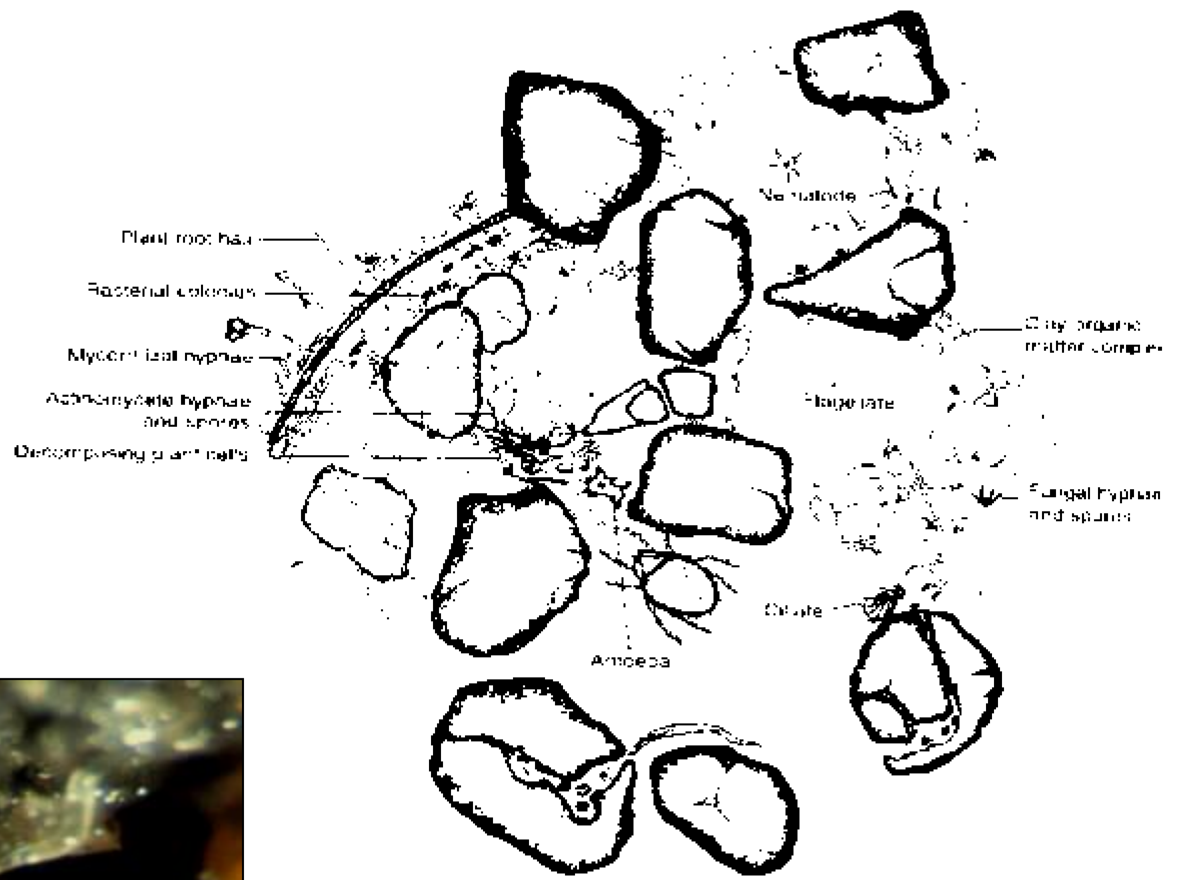
Third trophic level:
Shredders
Predators
Grazers

Fourth trophic level:
Higher level predators

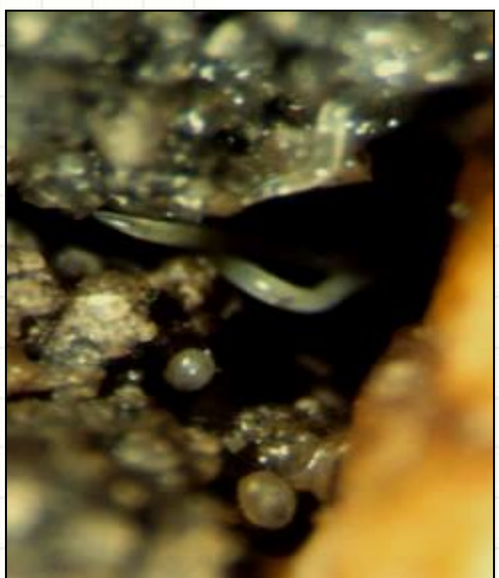
Fifth and higher trophic levels:
Higher level predators

What Do Soil Organisms Need?

- **Space**
- **Water**
- **Air**
- **Food**
  - **C:N=30:1**



Rose & Elliot



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Ecosystem Services Provided by Soil Organisms

- Decomposition and mineralization
- Contribute to plant nutrition
  - *Rhizobia associated with legumes*
  - Mycorrhizae fungi associated with many plants
- Soil aggregation, aggregate stability, and porosity
  - Humic acids and gummy material to trap OM
- Infect, compete with or antagonize pests

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  - Biological
    - A living system
    - Organic matter
- **Management and Soil Quality**
  - Encourage an active biological community
  - Increasing organic matter
  - Minimizing tillage

Management of Soil Quality

- Inherent vs. dynamic soil properties
  - Inherent:
    - Change little with management
    - texture, clay mineralogy, drainage class, etc.
  - Dynamic:
    - Change over months and years in response to management
    - organic matter, structure, bulk density, water and nutrient holding capacity, etc.
- Do the management practices improve, sustain, or degrade soil quality?

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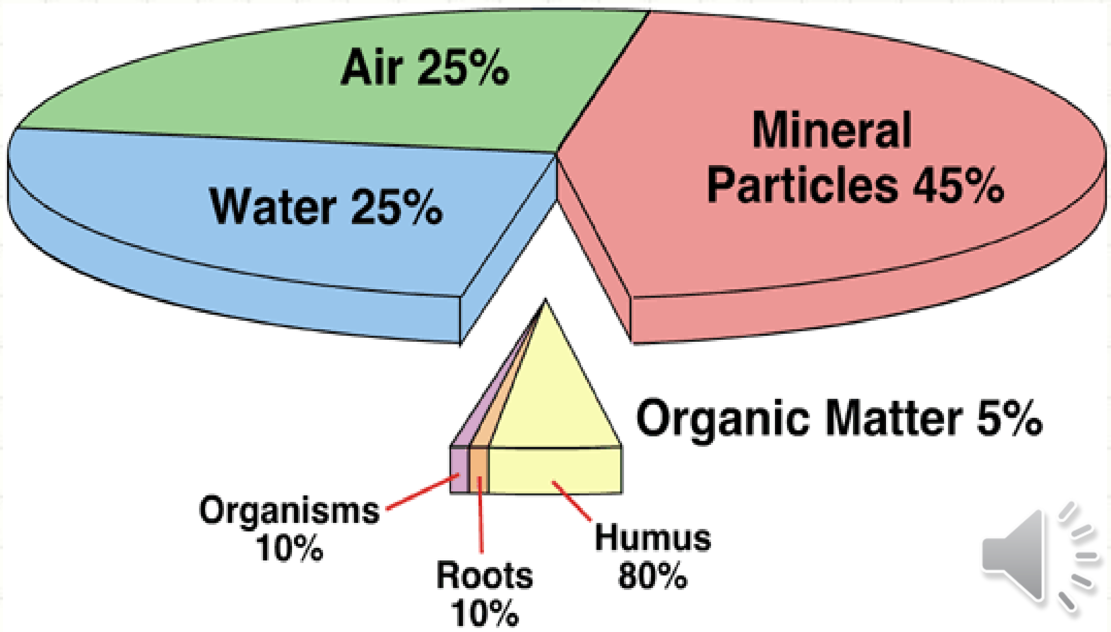
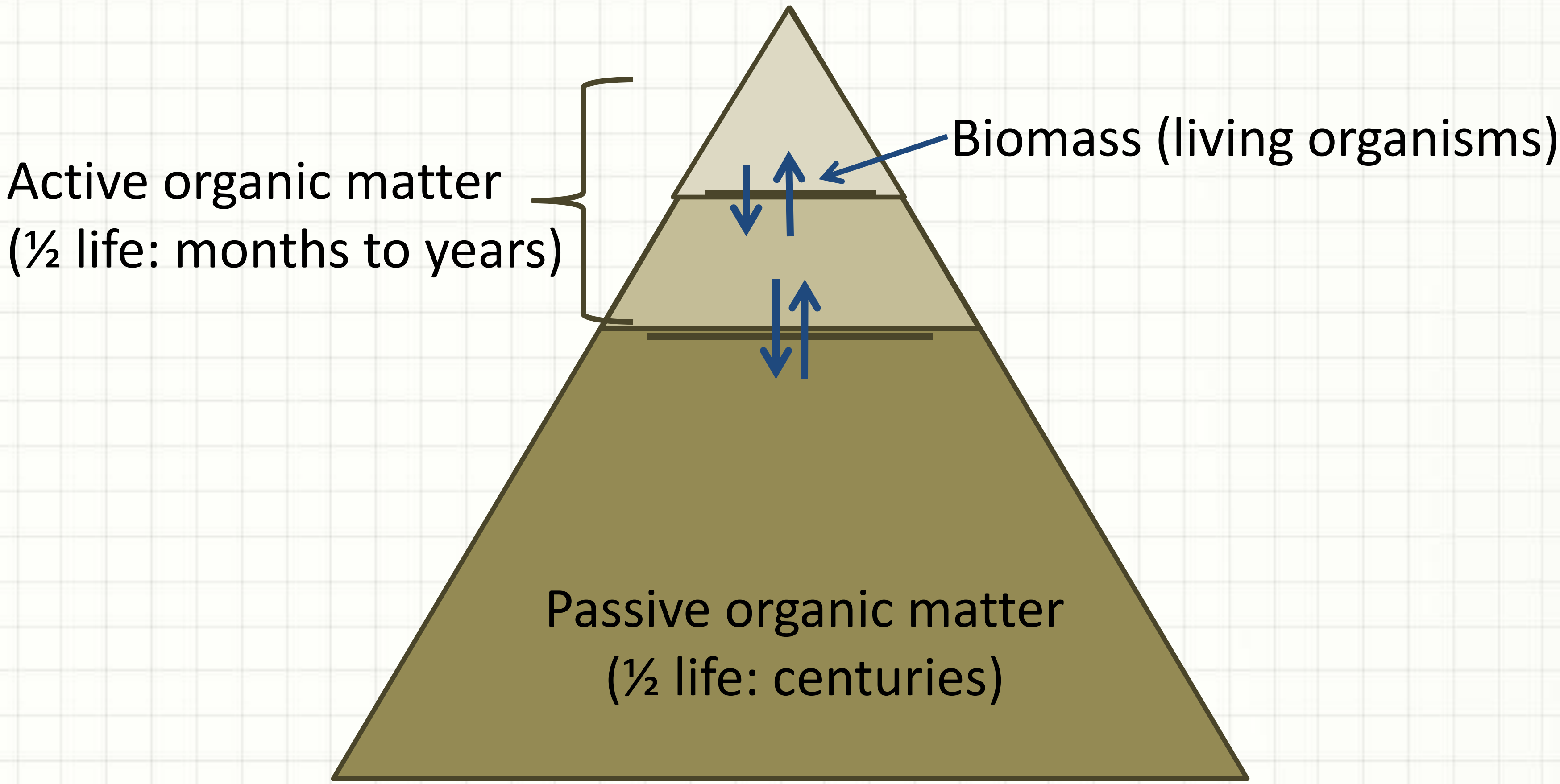
Soil organic matter (SOM)

- Overwhelming impact on most soil properties
  - Improves all aspects of soil quality
- Typically 1 to 6% in agricultural soils
- Living organisms, fresh residues, & well-decomposed residues



(Magdoff and van Es, 2009)

Soil organic matter



(adapted from Magdoff and Weil, 2005)

Active or labile organic matter

- Materials of recent origin
  - Till cover crops, cured compost, manure
- High nutrient/energy value
- Most important to:
  - Soil aggregation
  - Nutrient mineralization
    - Efficient cycling of N,P, & S
- Most sensitive to management changes
  - Difficult to change overall percentage OM when just adding this type of OM

(Magdoff and Weil, 2005)

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Passive or recalcitrant organic matter

- Physically protected or stable due to biochemical properties or mineral association
- Humic substances, aliphatic molecules, lignin's, etc
- Responsible for much of CEC
  – Greater % in coarse-textured soils
  – Lots of negative charge
- Nutrients in organic-mineral complexes
- Key role in water holding capacity, bulk density, etc

(Magdoff and Weil, 2005)

Soil organic matter management

- Effectively use crop residues and add new residues (cover crops, local residues)
- Use varied residues to maintain diverse population of soil organisms
- Balance farm exports and inputs of nutrients so as not to build excessive nutrients
- Use practices that do not accelerate decomposition or erosion
  - Excessive tillage
  - Excessive N fertilization
  - Lack of cover
  - Removal of residues

(Magdoff and van Es, 2009)

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Impacts of tillage

- Traditional tillage
  - Disrupts soil aggregates
  - Disrupts soil organisms
  - Makes soil less resistant to:
    - Compaction
    - Erosion
    - Breakdown of organic matter

(Bellows, 2005; ok.gov)

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Sustainable tillage & cultivation

- Minimizes compaction
- Minimizes loss of aggregates
- Promotes infiltration
- Protects soil from wind/water erosion
- Minimizes disruption of beneficial soil organisms
- Maintains soil cover by residues

(Bellows, 2005; ipm.iastate.edu; newdeal.feri.org)

Sustainable tillage & cultivation

- Minimize tillage
  - Undercutter or roll-chopper
  - Mulch tillage or add mulches
    - No-till
    - Disk plant or Chisel plant
    - Ridge tillage
    - Strip tillage
  - Chisel/sweep plows vs. moldboard and disk plows
- Maintain residues (>30%) and increase surface roughness

(Bellows, 2005; fao.org; photo: Les Everett, UMN)

Conventional no-till vs. organic

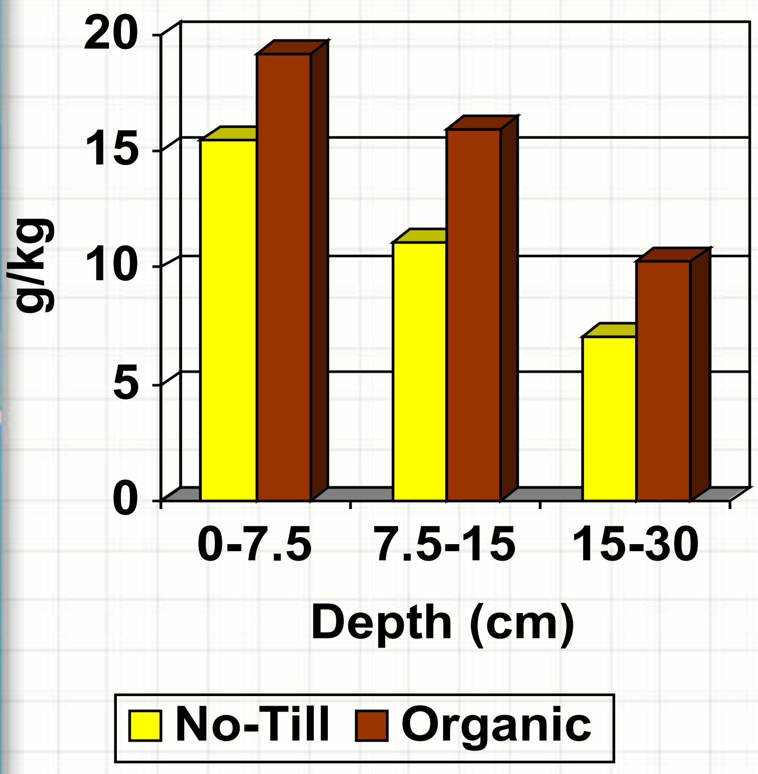
- Numerous benefits of conservation tillage or no-till over conventional tillage systems
- With proper management, organic systems can exceed no-till in terms of C storage and increased soil organic matter
  - Extensive use of cover crops, green manures
  - Composts, manures
  - Lack of inorganic N fertilizers
  - Lack of herbicides/pesticides

(Teasdale, 2007)

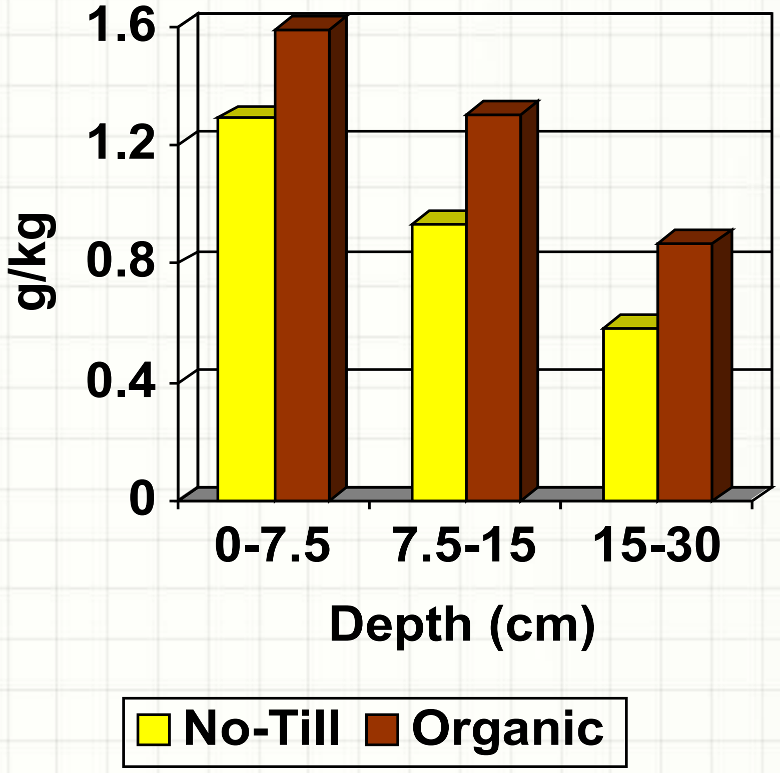
SQ in Organic vs. No-Till

Sustainable Agriculture Demonstration Project, USDA, Beltsville, MD
1994-2002

Total Soil C, 2002



Total Soil N, 2002



Teasdale et al., 2007. Agron. J. 99: 1297-1305.

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SQ in Organic vs. No-Till

Sustainable Agriculture Demonstration Project, USDA, Beltsville, MD
1994-2002
Uniformity Trial

System 1994-2002	Grain Yield, 2004 (Mg/ha)	Soil Nitrate N, 2004 mg/kg	Corn Ear Leaf N, 2004 (%)
No-Till*	5.8	14.8	2.49
Organic	6.7	21.0	2.99

*All significant at $P < 0.05$

Teasdale et al., 2007. Potential Long-Term Benefits of No-Tillage
And Organic Cropping Systems for Grain Production and Soil Improvement.
Agron. J. 99: 1297-1305.

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Conventional no-till vs. organic

- Look for opportunities to integrate perennial crops into organic rotations
  - Eliminate tillage for a few years
  - Perennial hay or pasture crops
- Utilize mechanically-killed/ winter killed cover crop residues for weed suppression
- Continuous no-till probably not feasible in organic vegetable production at this time

(Teasdale, 2007; forages.tennessee.edu)

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Management for Soil Quality

- Encourage an active biological community
- Enhance organic matter
    - Keep the ground covered
    - Diversify cropping systems
        - crop rotation and cover crops
    - Reduce disturbance
        - polyculture, orchards, reduce or rotate tillage,
        - perennial crops or cover crops
- Avoid excessive tillage
    - Prevent soil compaction

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