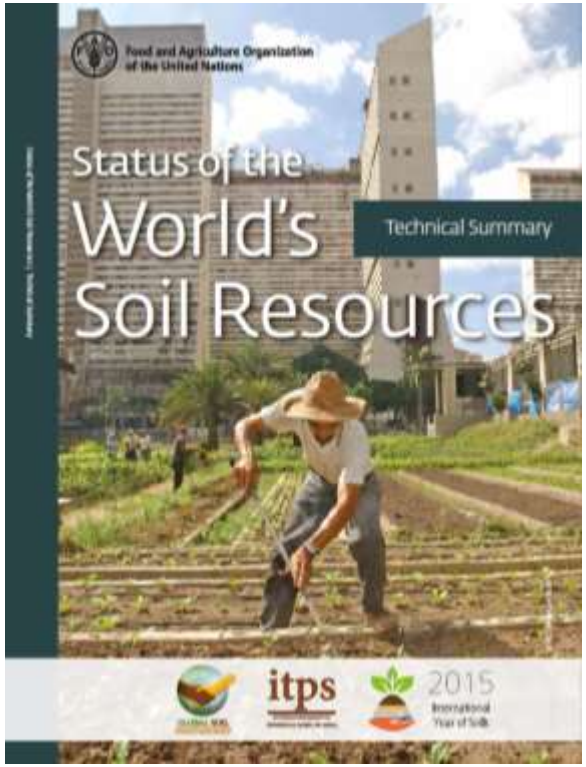
Celebrate!

2015 International Year of Soils
December 5, World Soil Day



2015
International
Year of Soils

World
Soil Day

Food and Agriculture Organization
of the United Nations
www.fao.org/soils-2015/en/
See also
www.SSSA.org/IYS

RUTGERS
New Jersey Agricultural Experiment Station

Start with the Soil: The Groundwork for Healthy Plants

Stephanie Murphy, Ph.D.
Rutgers Soil Testing Laboratory

What is Soil?

"Soils are developed; they are not merely an accumulation of debris resulting from decay of rock and organic materials…
In other words, a soil is an entity – an object of nature which has characteristics that distinguish it from all other objects in nature."

Millar & Turk, 1943

Factors of Soil Formation

- Parent Material
- Biological activity
- Climate processes
- Topography
- Time

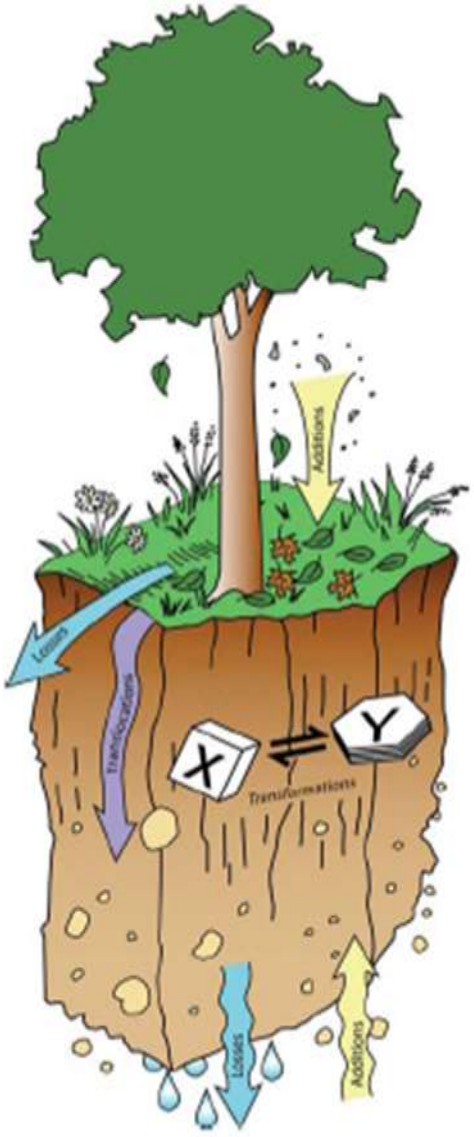


Figure 2.5: Soil-forming processes.

What is Soil?

Most definitions refer to soil as a media for plant growth

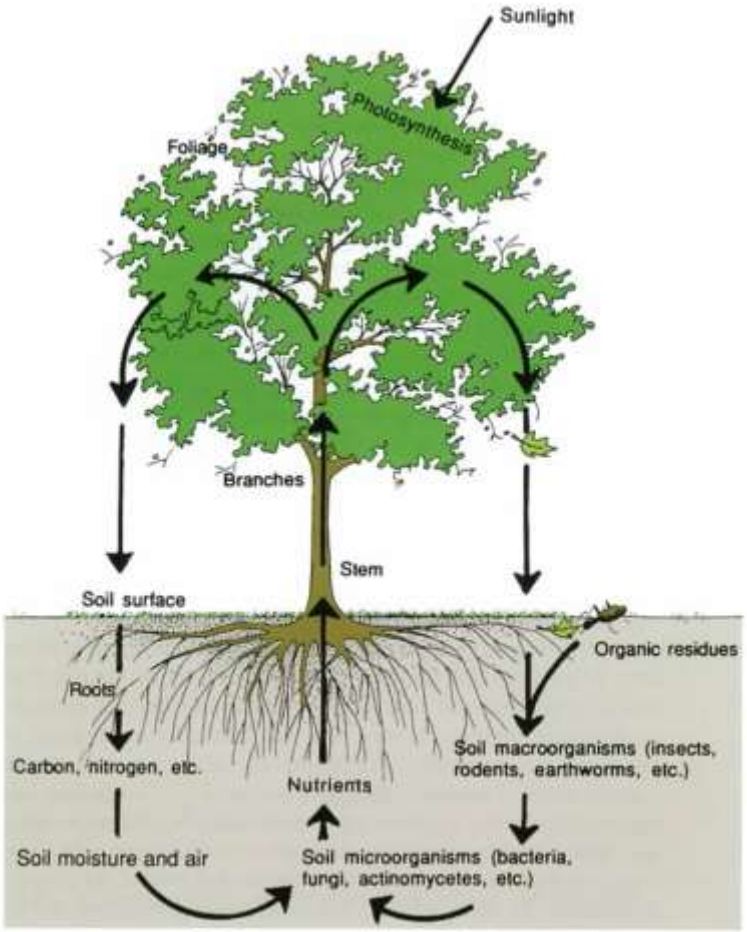


Fig. 3.2. The role of the biotic community in soil formation (schematic).

The unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants.

Soil Science Society of America

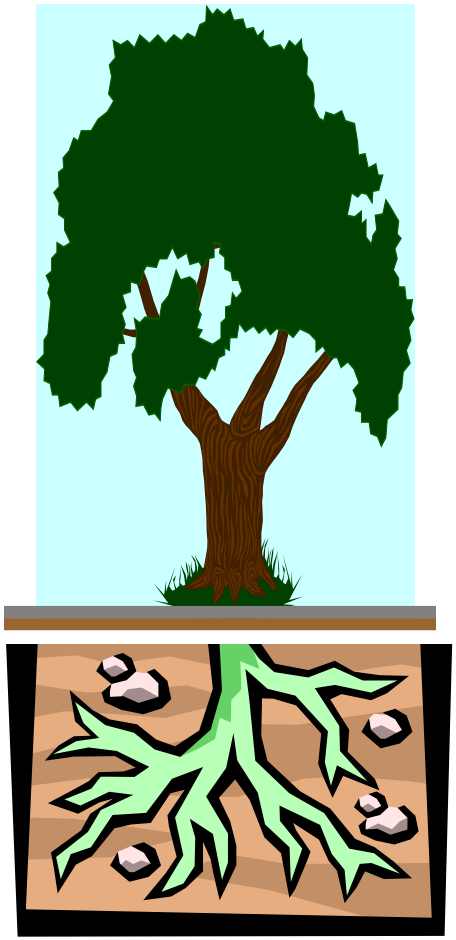
"…soil is the link between the rock core of the Earth and the living things on its surface…"

Simonson, 1957

Soil: plant growth medium

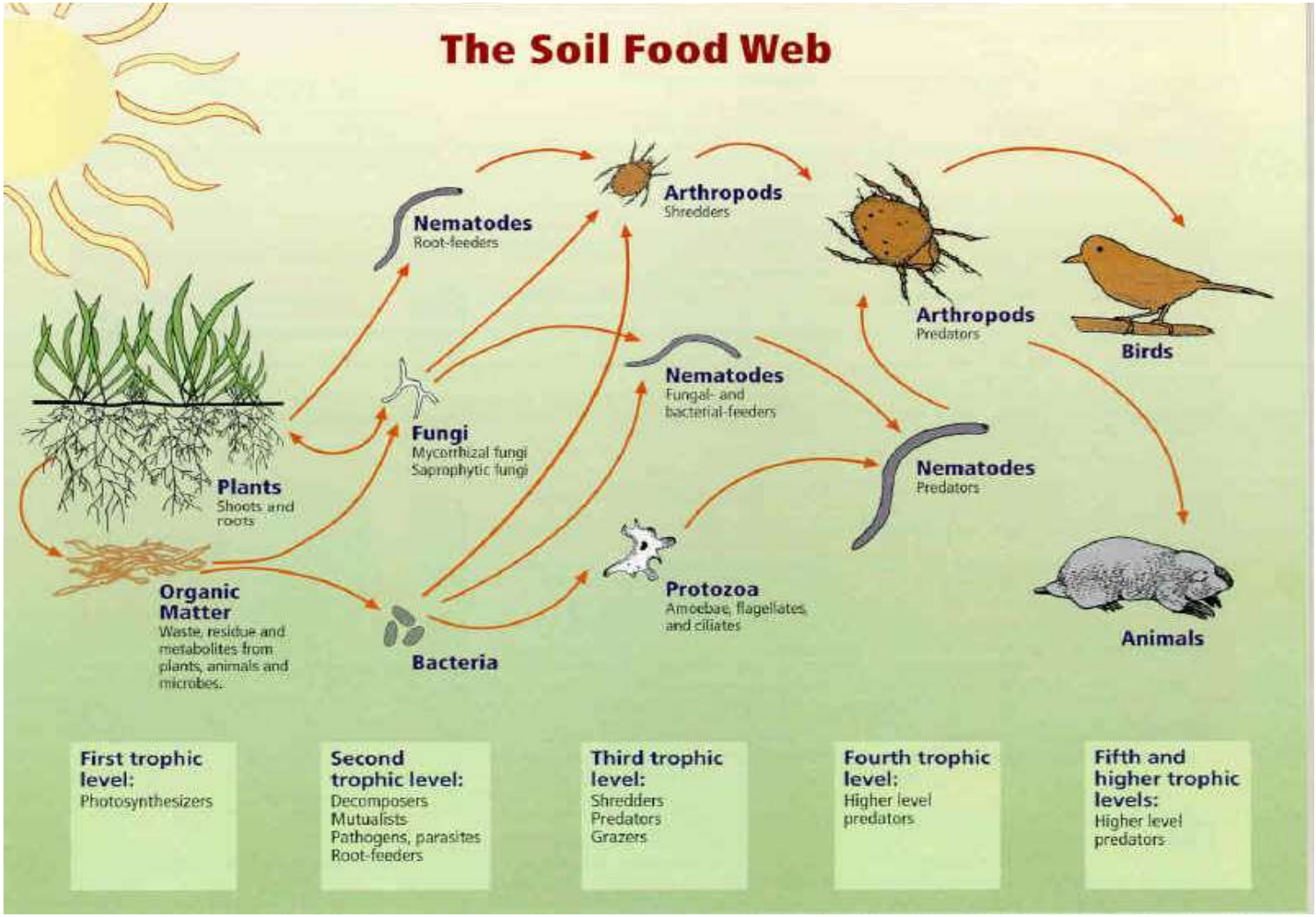
Soil provides:

- Storage of water
- Bank of nutrients
- Physical support, anchoring roots
- Diffusion if gases (O_2, CO_2, etc.)



Soil: Habitat for Organisms

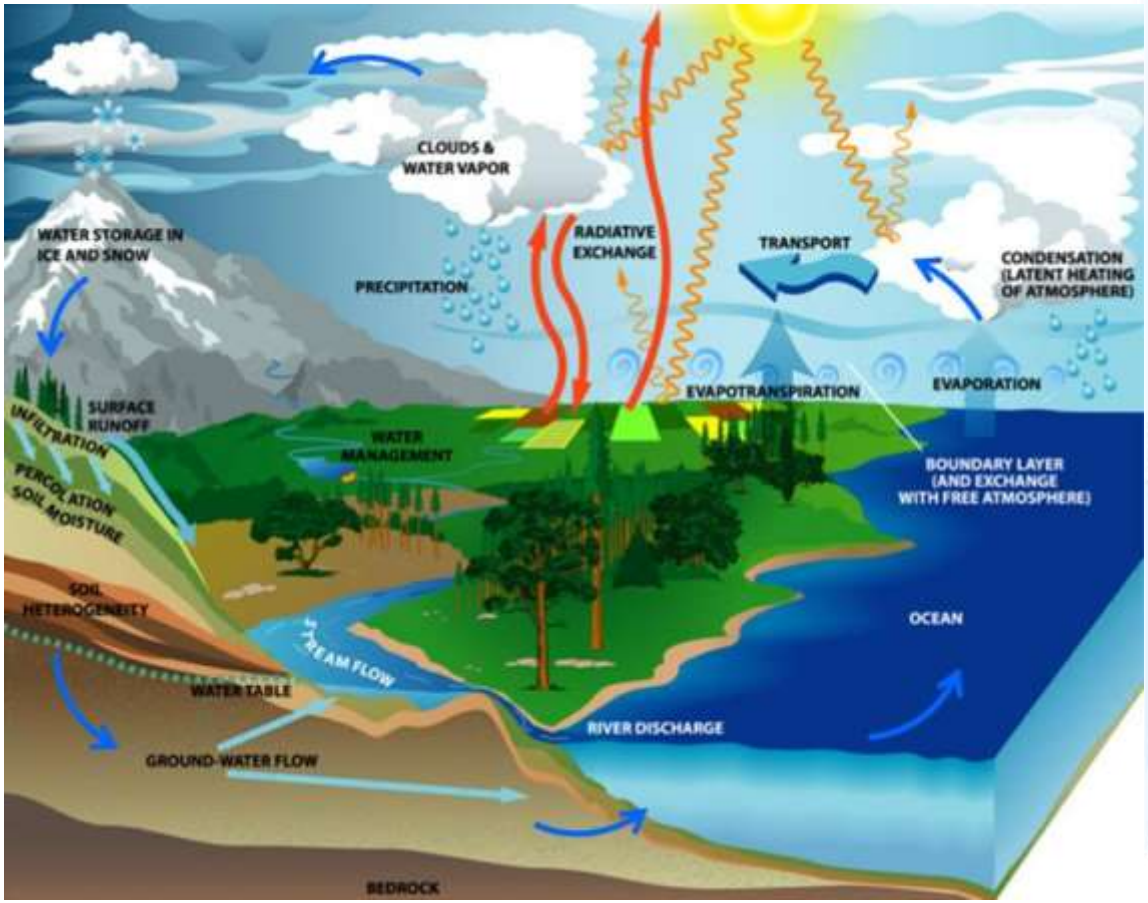
- Soil is an ecosystem; soil is "alive"…



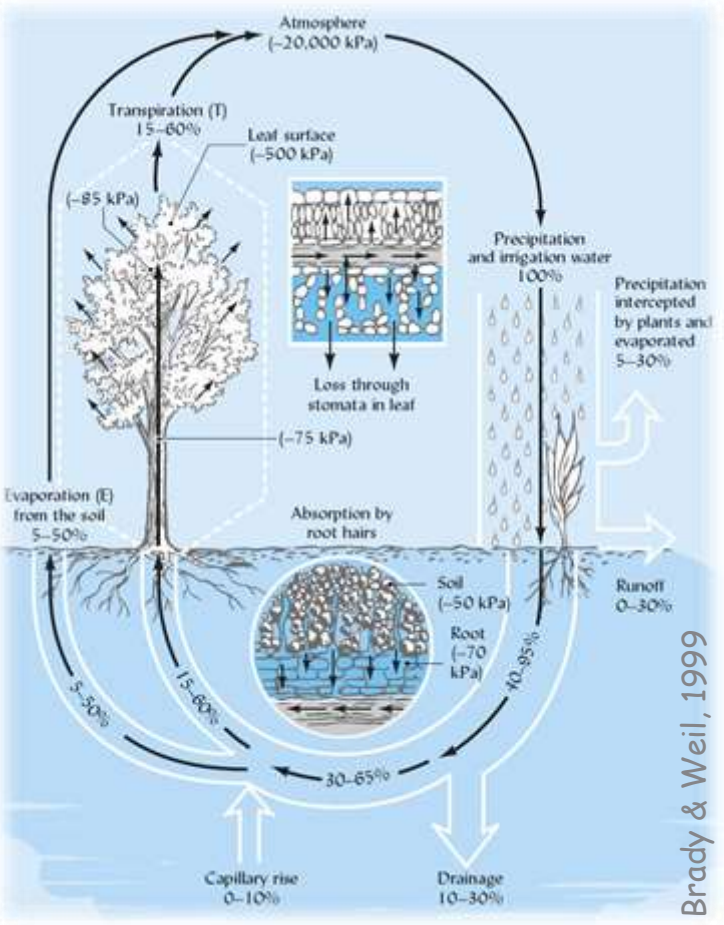
USDA-NRCS

Soil: Regulator of water

The Hydrologic Cycle

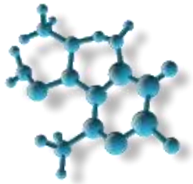


usgs.gov

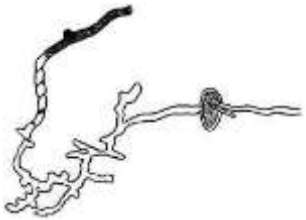


Soil-Plant-Atmosphere water cycle

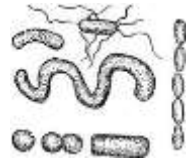
Soil: Recycler of raw materials



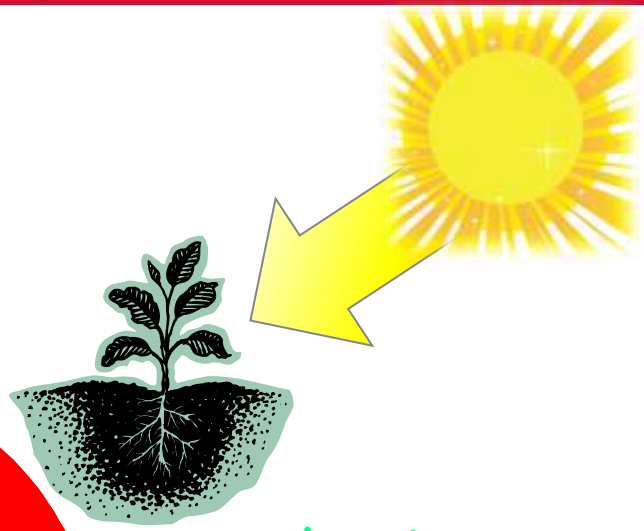
Organic



Fungi
c/o chestofbooks.com

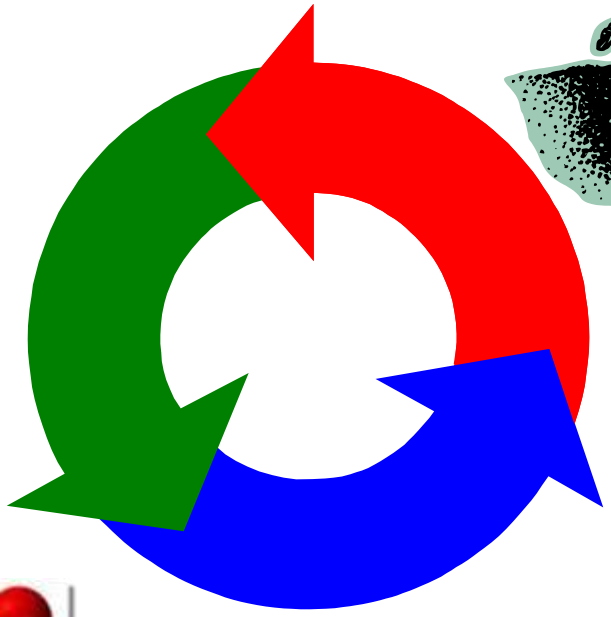


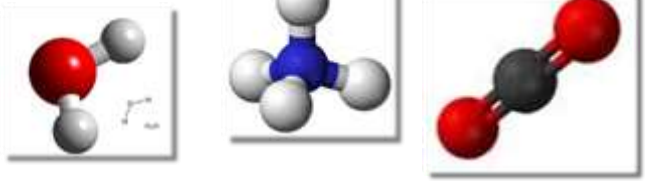
Bacteria
c/o etc.usf.edu



synthesis in plant

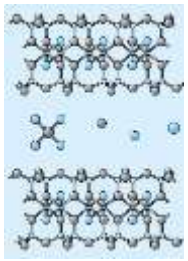
decomposition in soil



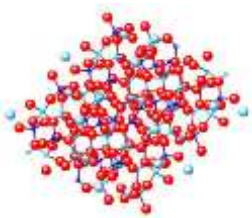


H_2O, Ammonium, Carbon dioxide

Inorganic



2:1 clays
wsu.edu



Feldspar
sci-culture.com

Mineral nutrients

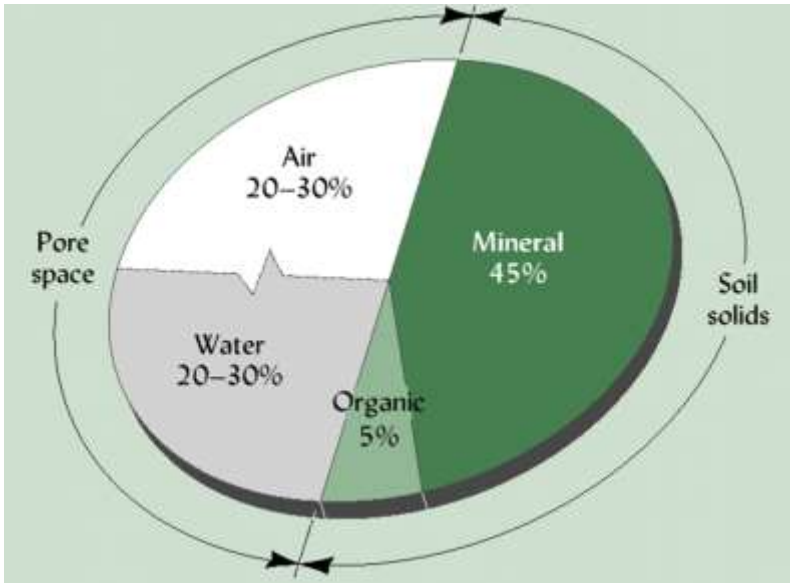
Soil: Engineering medium

- foundation of roadbeds, buildings, and other infrastructure
- Berms, bioretention basins, and other constructed "root zones" are engineered plant media

What is Soil?

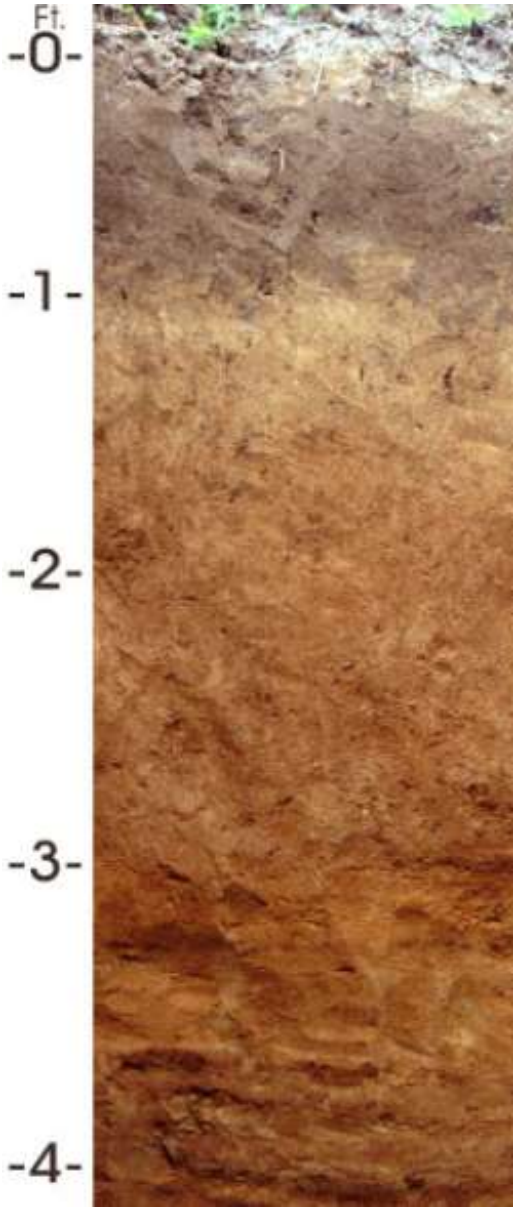
Components of soil

- mineral particles
  (inorganic)
- organic matter
  (derived from organisms)
- water
  (H_2O and dissolved salts)
- air
  (N_2, O_2, CO_2, H_2O vapor, etc.)



Brady & Weil, 1999

Soil is 3-D!

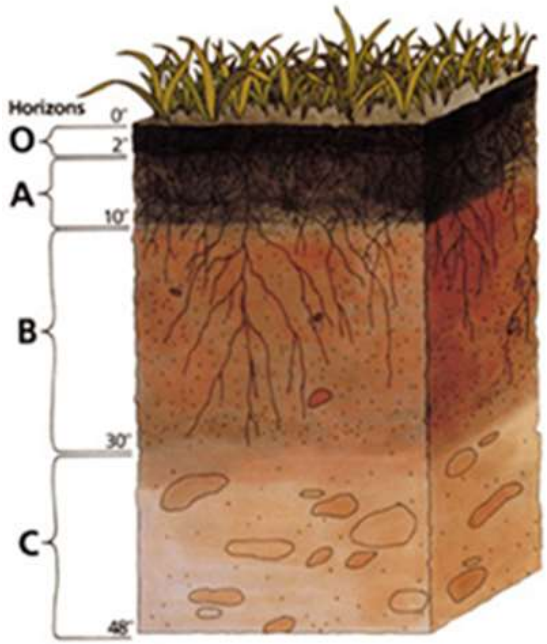


Soils change across the landscape

soil **profile** - a vertical cross-section of soil exhibiting its horizontal layering

soil **horizon** - layer approximately parallel to the soil surface

Horizons result from soil-forming processes, including:
additions,
losses,
transformations,
translocation



Model of soil horizons

http://soils.usda.gov

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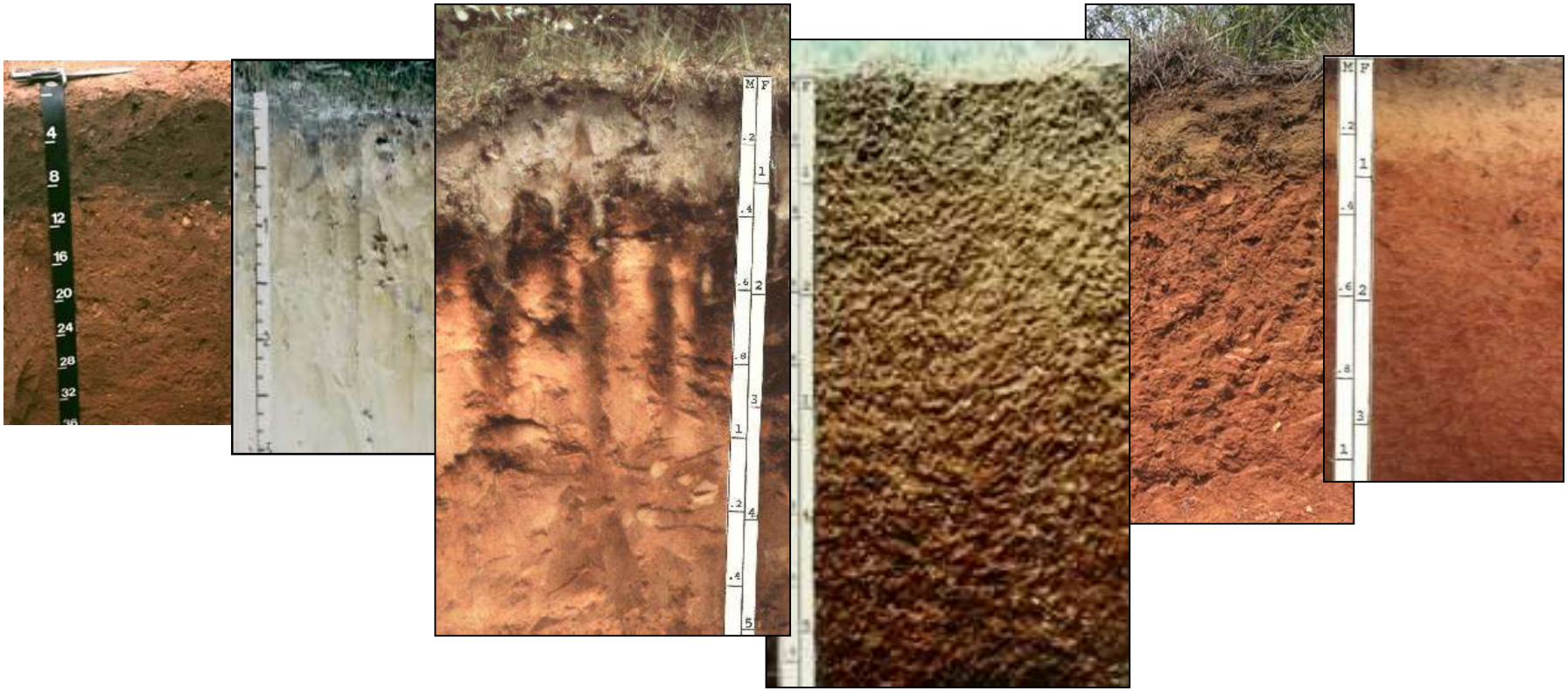
Characterizing soils

- Measuring various properties of soils to understand processes and effects of management
- Features of horizons in a soil profile allows classification & mapping
- Soil properties are measured as indicators of soil quality



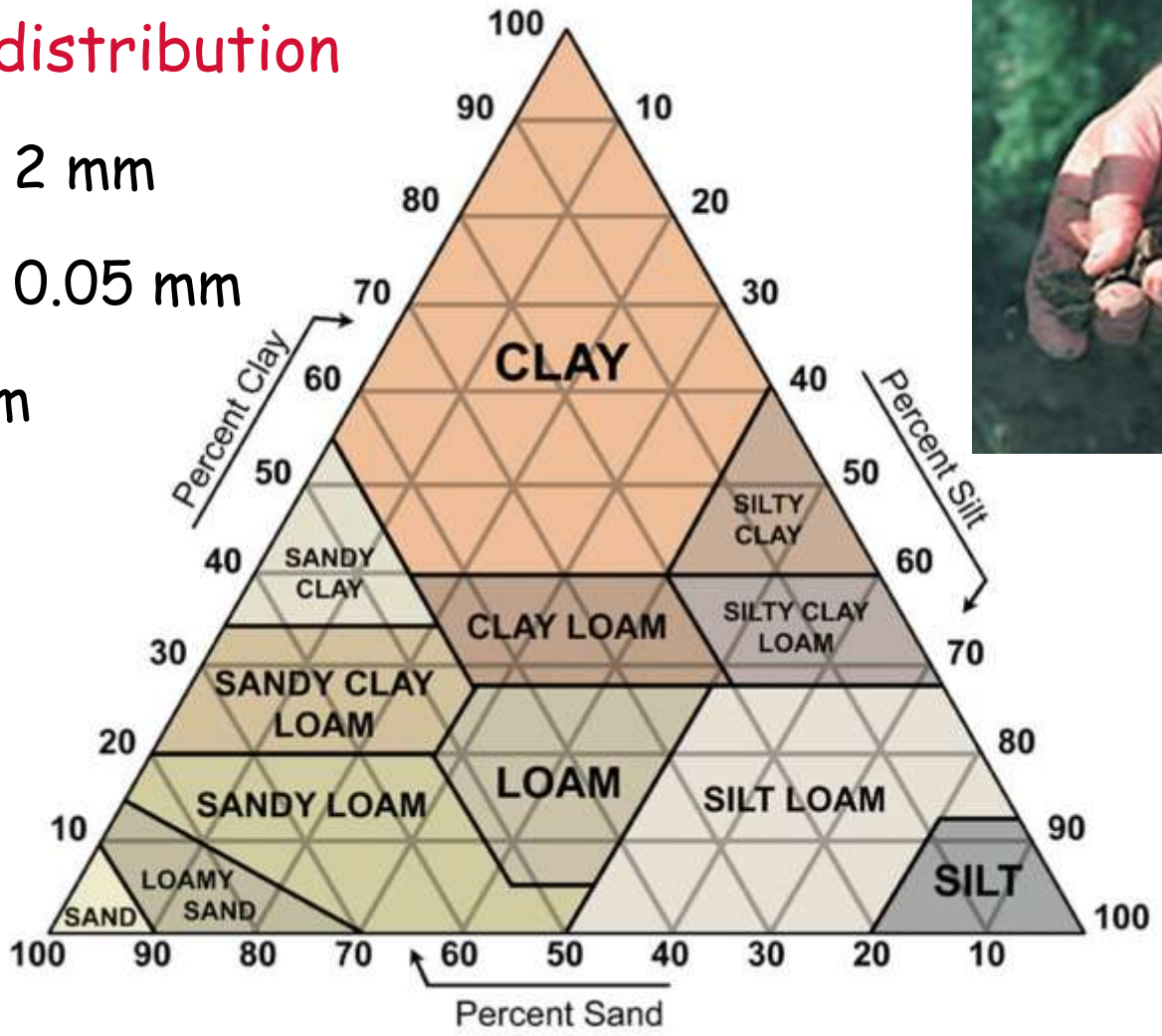
Soil Texture

Particle-size distribution

Sand = 0.05 to 2 mm

Silt = 0.002 to 0.05 mm

Clay < 0.002 mm



Larger than 2mm: not-soil; gravel, cobbles, stones, etc.

Soil Texture influences...

- pore space, soil density
- soil structure
- water retention, available water
- aeration
- water infiltration
- runoff, erosion
- cohesion, plasticity
- temperature
- shrink-swell character
- pH (acidity)
- microbial activity
- o.m. content
- fertility, productivity
- management

Between particles: Pores

Pores - containing water and/or air

Two main classes of pore size

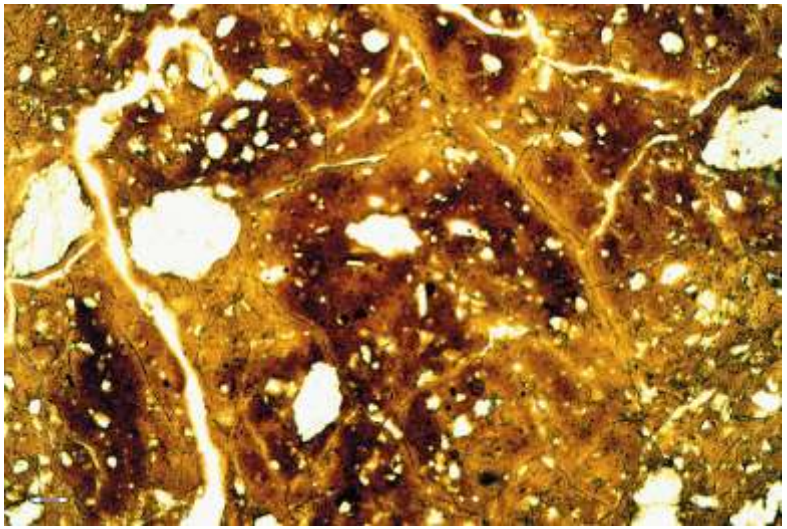
Macroporosity -

- responsible for transmission of water & air (aeration)

Microporosity -

- responsible for retention of water against the force of gravity

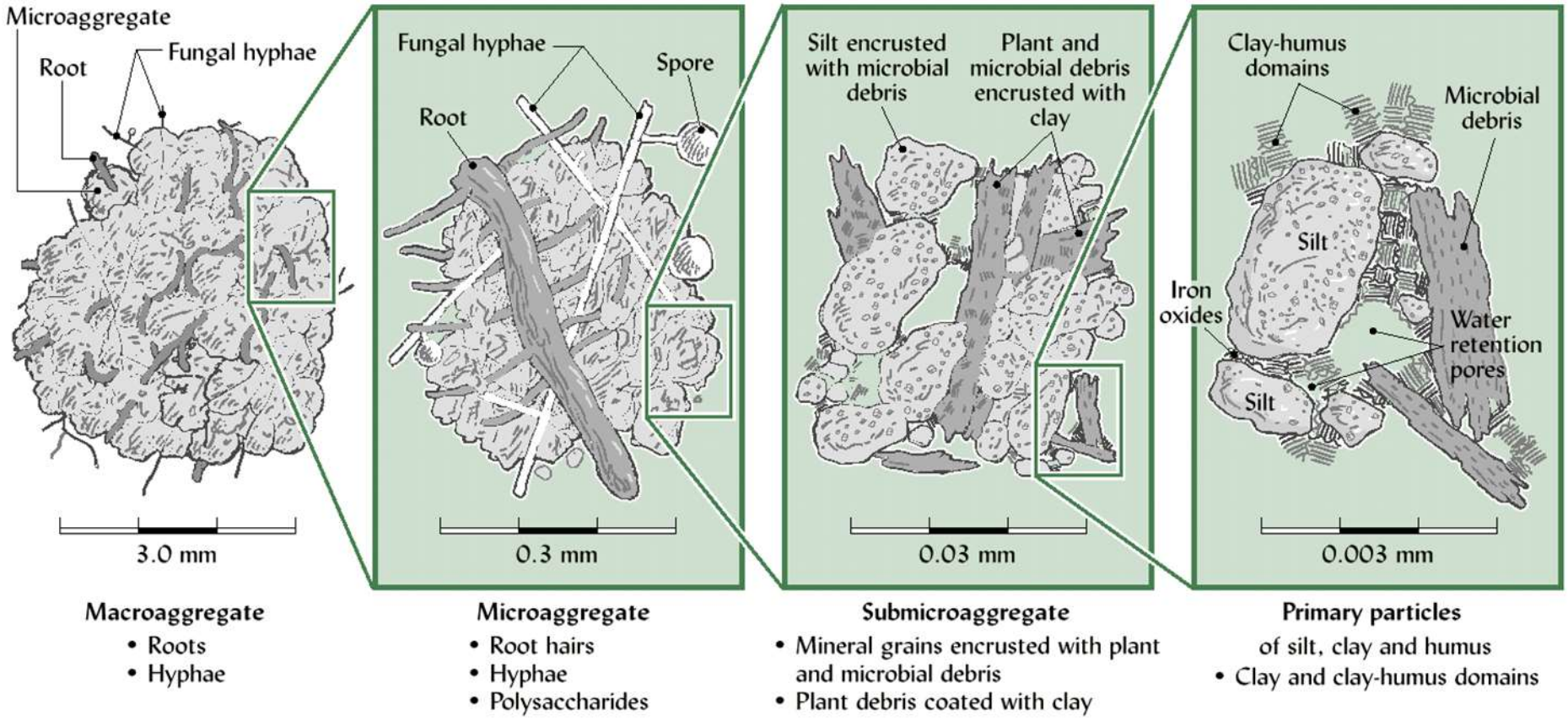
Thin section of soil



http://edafologia.ugr.es/iluv/media/hor4.gif

Soil structure

-the arrangement of soil particles into aggregates



Brady & Weil, 1999

Soil aggregates are held together by humus, microbial gums, clays.

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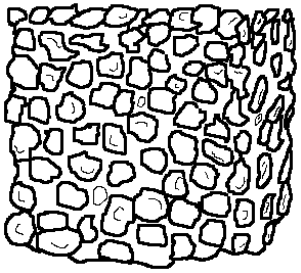
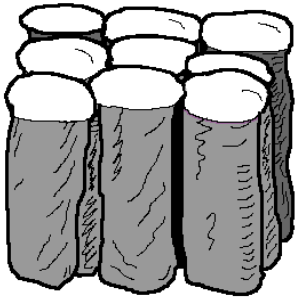
Types of Soil Structure

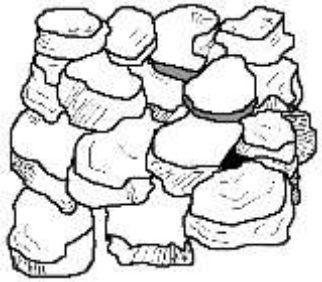
Granular



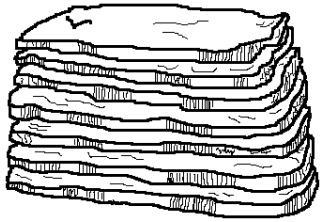
Prismatic



Blocky



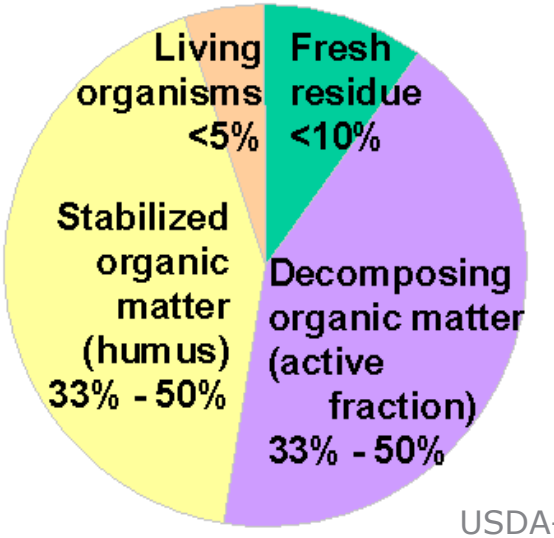
Platy



Structure alters pore size distribution of a soil.

Good soil structure promotes water and air movement into and through soil, and allows unobstructed root growth.

Soil organic matter

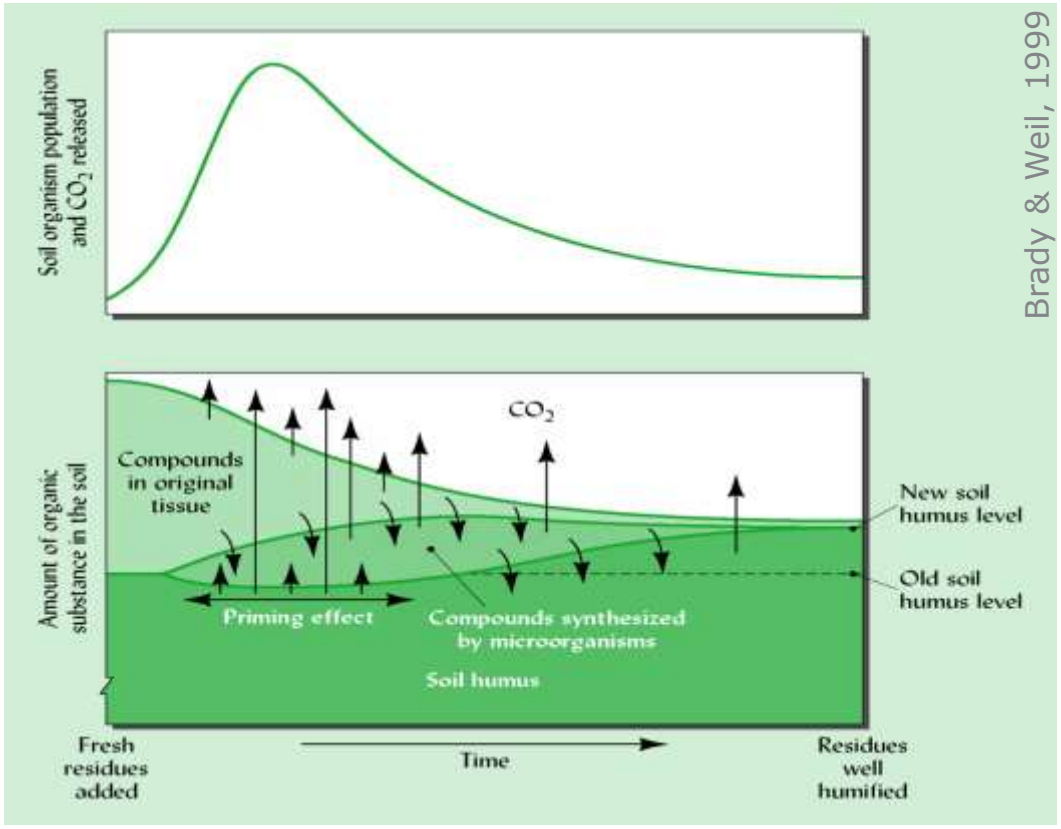


USDA-NRCS

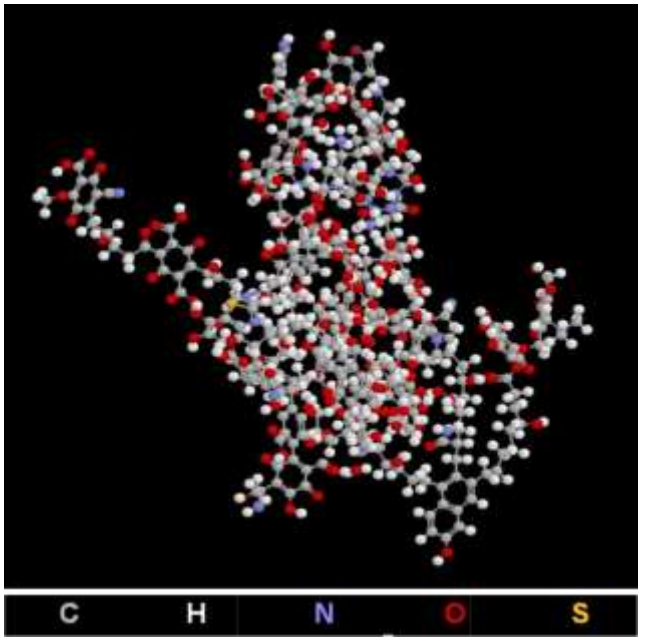
http://nesoil.com/images

- Organically-derived component of soil
- "Active" organic matter – relatively fresh
- "Humus" – highly decomposed fraction
- Strongly influences many soil properties
- In "upland" soils, amount and distribution
  - Compare to organic soils

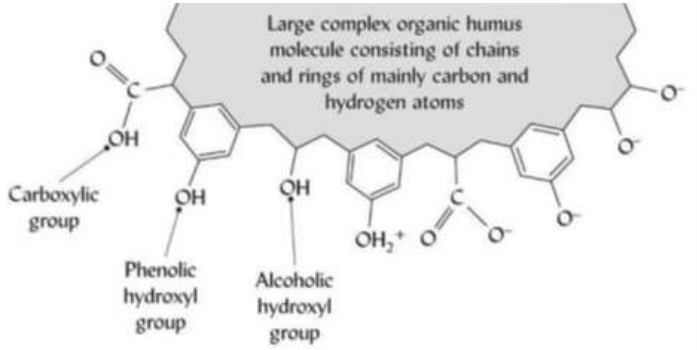
Plant Residue to Soil Humus



Brady & Weil, 1999



www.soils.wisc.edu/virtual_museum/som/index.html



Soil Organic Matter elemental analysis:

C	50-60%
N	5%
P	0.6-1.2%
S	0.5%

C:N ratio=10:1

Soil Organic Matter Effects

Characteristic	Effect in soil
Adsorption of humus to soil particles	Aggregation of particles (soil structure development, tilth, porosity, drainage)
High water-holding capacity	More plant-available water
Contains Nitrogen, Phosphorus, Sulfur, etc.	Source of plant nutrients, short- and long-term
Ion exchange capacity: Cations & Anions	Nutrient retention, buffering capacity
Contains carbon	Energy source for microbes, storage of C
Chelation of metals	Increase bioavailability of certain mineral nutrients
Adsorption of organic molecules	Reduced effectiveness of certain pesticides
Black color	Heat absorption

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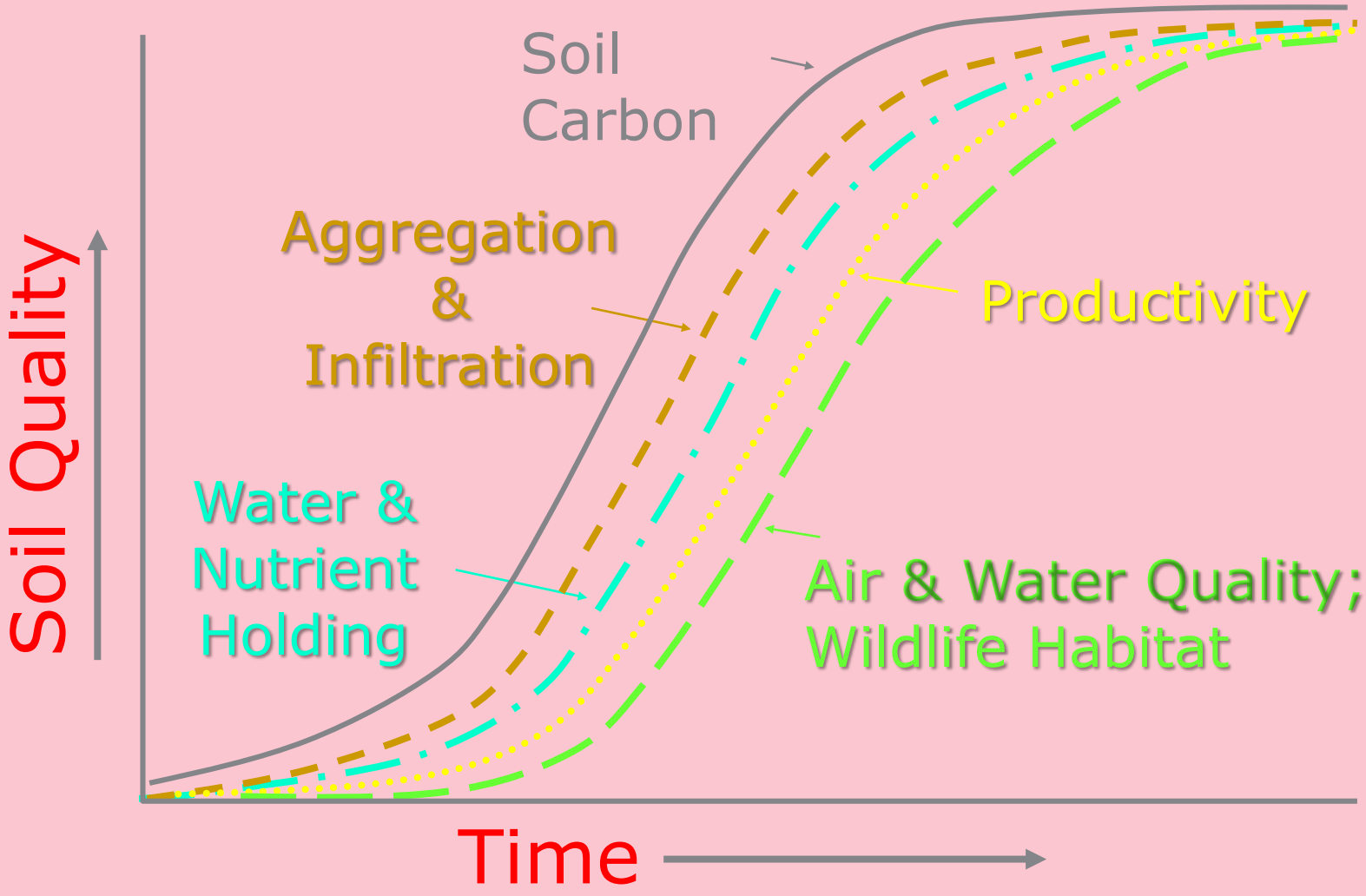
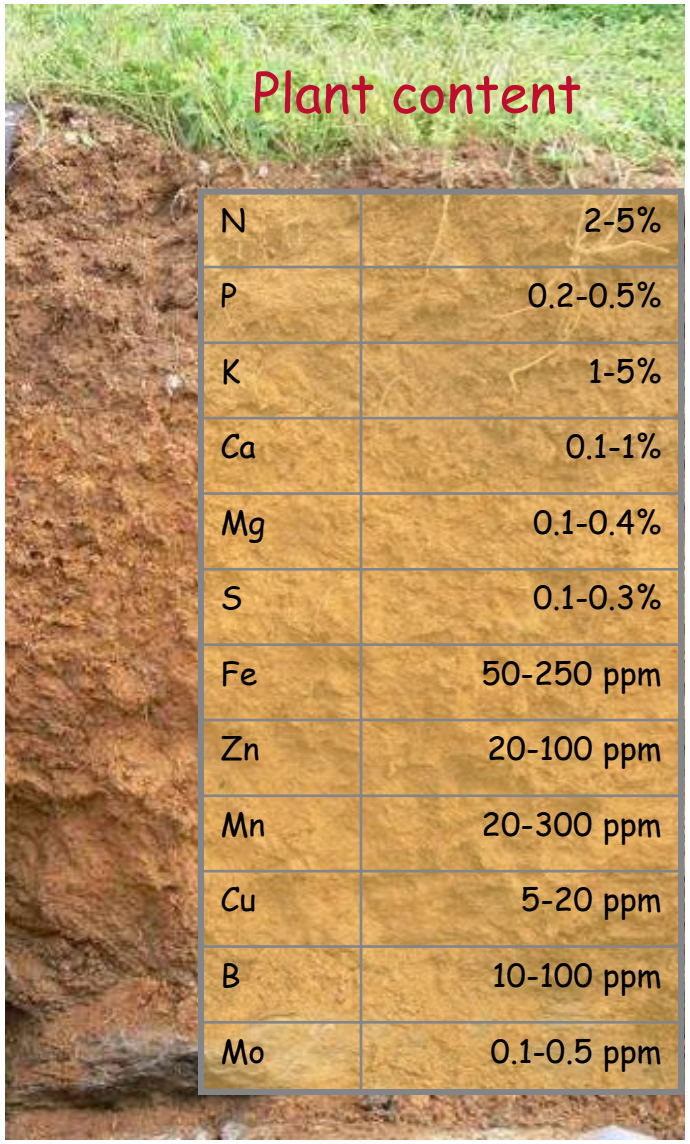
Benefits of Soil Carbon



USDA-NRCS

Nutrient Supply

- "Essential nutrients" – necessary for the growth and reproduction of plants
- From air or water:
  - C, H, O
- From soil:
  - Macronutrients
    N, P, K, Ca, Mg, S
  - Micronutrients
    Cu, Mn, Zn, B, Fe, Mo



N	2-5%
P	0.2-0.5%
K	1-5%
Ca	0.1-1%
Mg	0.1-0.4%
S	0.1-0.3%
Fe	50-250 ppm
Zn	20-100 ppm
Mn	20-300 ppm
Cu	5-20 ppm
B	10-100 ppm
Mo	0.1-0.5 ppm

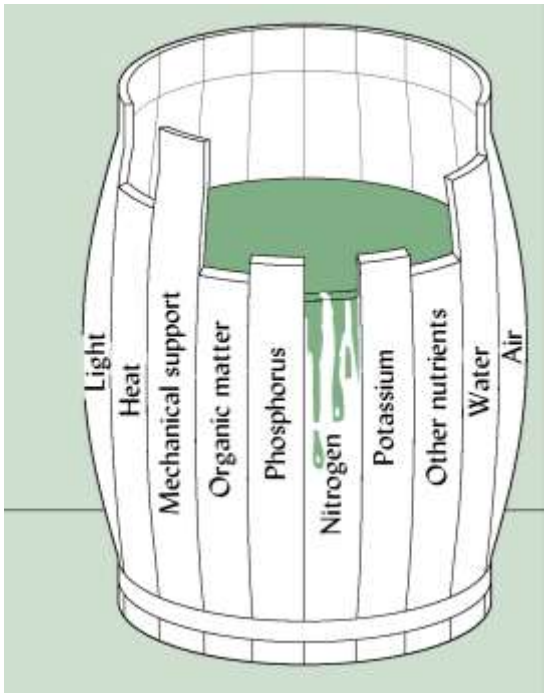
Bennett, 1993

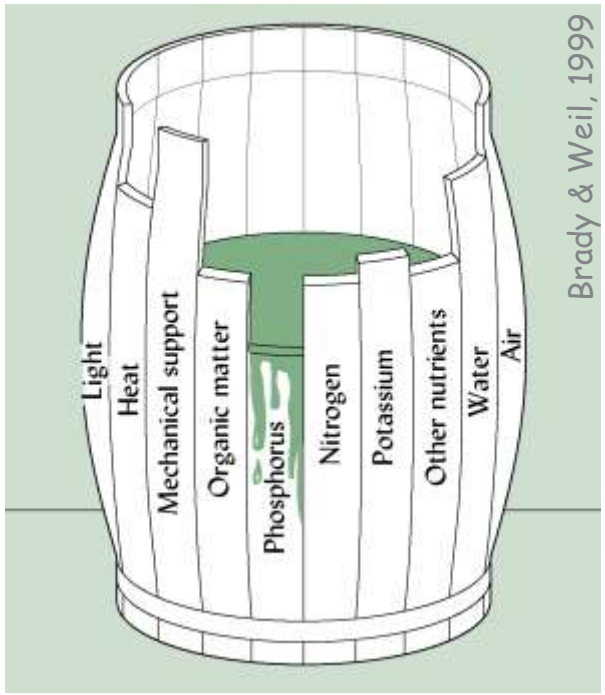
Concept of the limiting factor

Plant production is constrained by the most-limiting growth factor

Potential limiting factors

essential elements
pH
light
water
temperature
oxygen
CO_2
etc.





Increasing the level of a non-limiting factor will not improve production

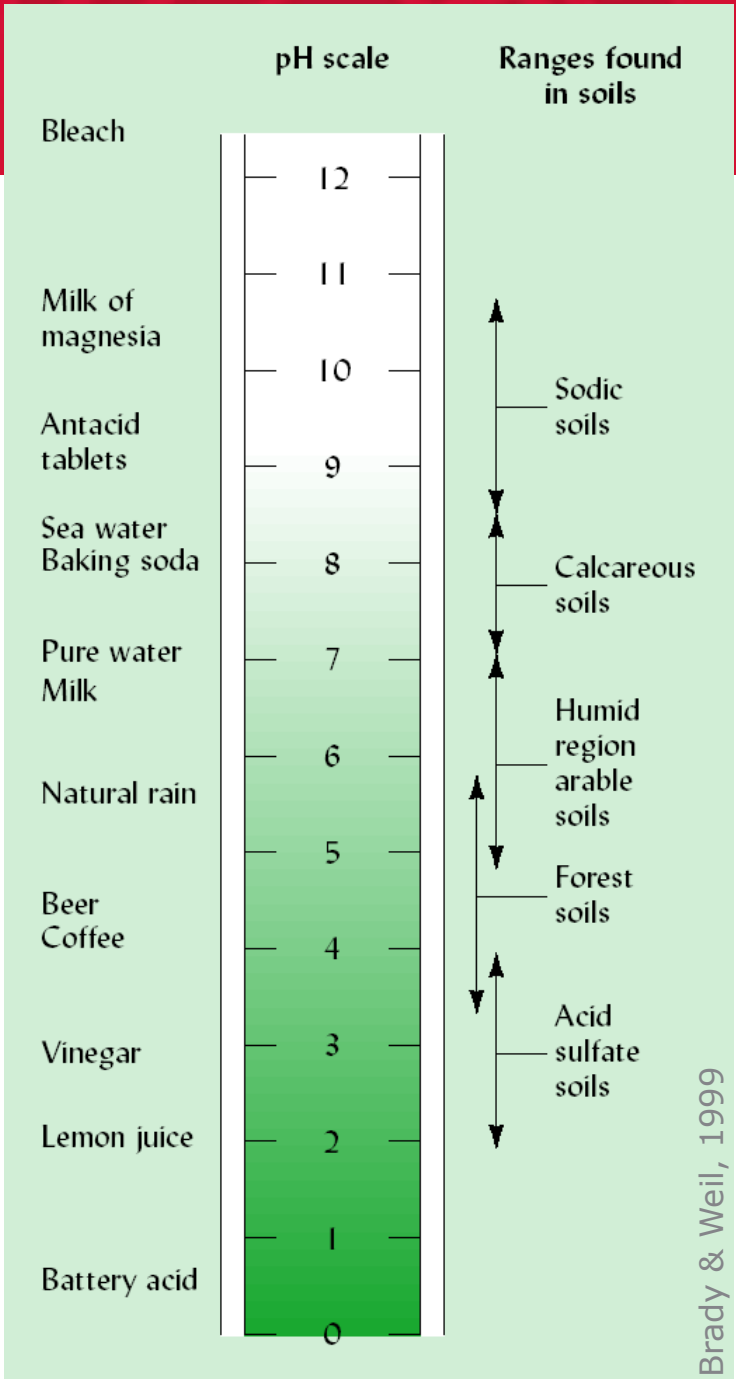
Soil pH

Alkaline

Neutral

pH 7
$[H+] = 10^{-7}$

Acidic



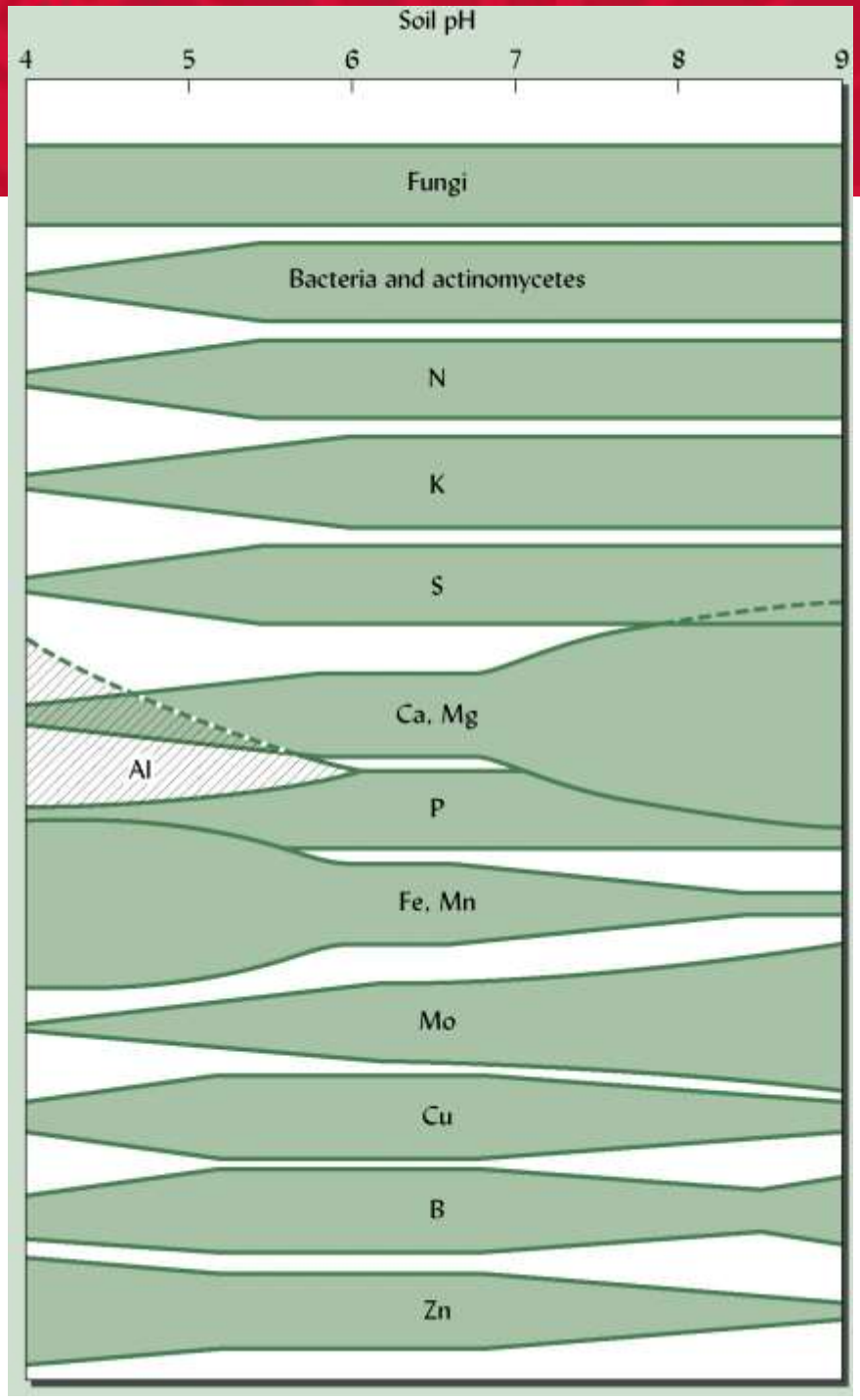
Degree of Acidity [H+] or Alkalinity

an important plant-growth factor that can be managed

Optimum for most plants:
pH 6.5 to 6.8

Acid-loving plants: adapted to
pH 4.5 to 5.5

Effects of Soil pH

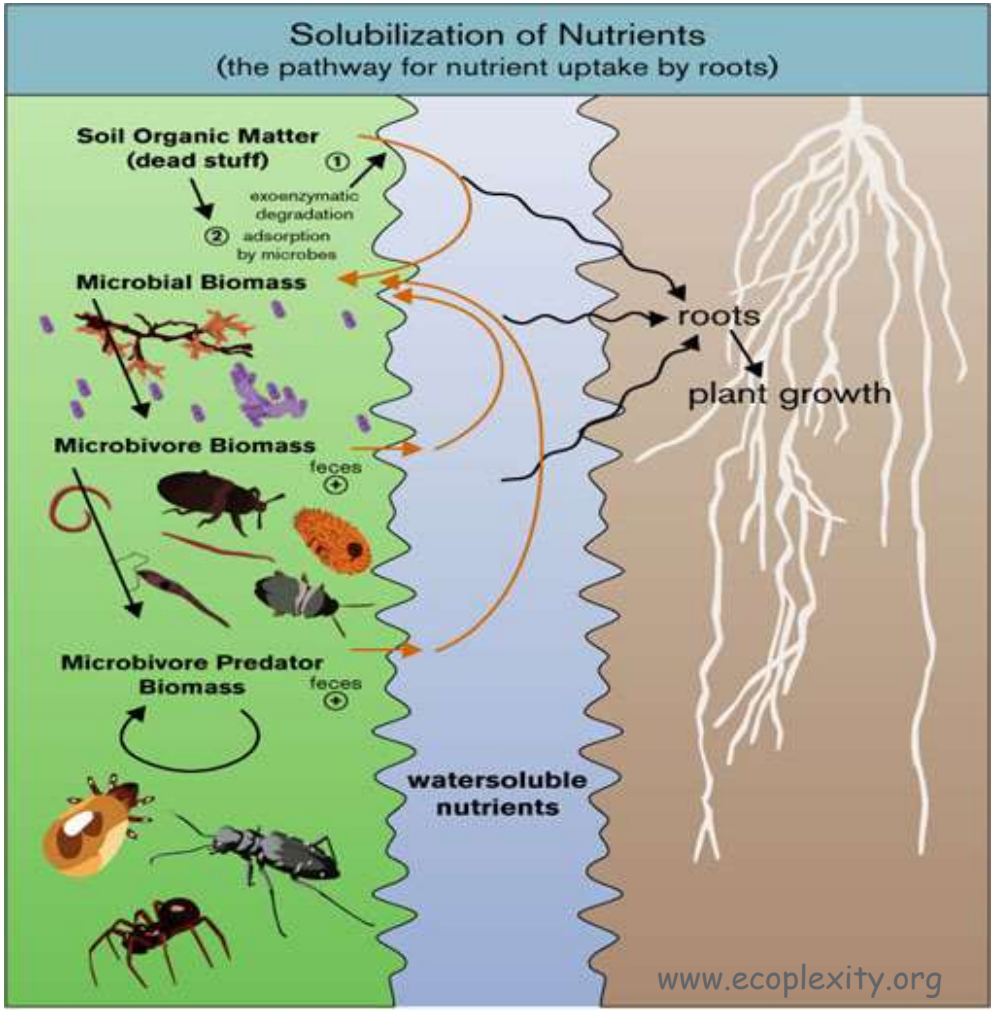


- Soil pH affects nutrient availability (solubility)
- Aluminum toxicity damages roots at low pH
- Direct damage also possible at high pH

Brady & Weil, 1999

Soil Ecology and Plant Nutrition

- Plants are the dominant primary producers in soil.
- Nutrient cycling and sustainable systems depend on soil organisms.
- Plant residues etc. broken down to release (recycle) nutrients.
- Symbiotic relationships contribute to plant nutrition.
  - Mycorrhizae
  - Rhizobia/Legume
  - other
- Diversity helps maintain balanced populations.



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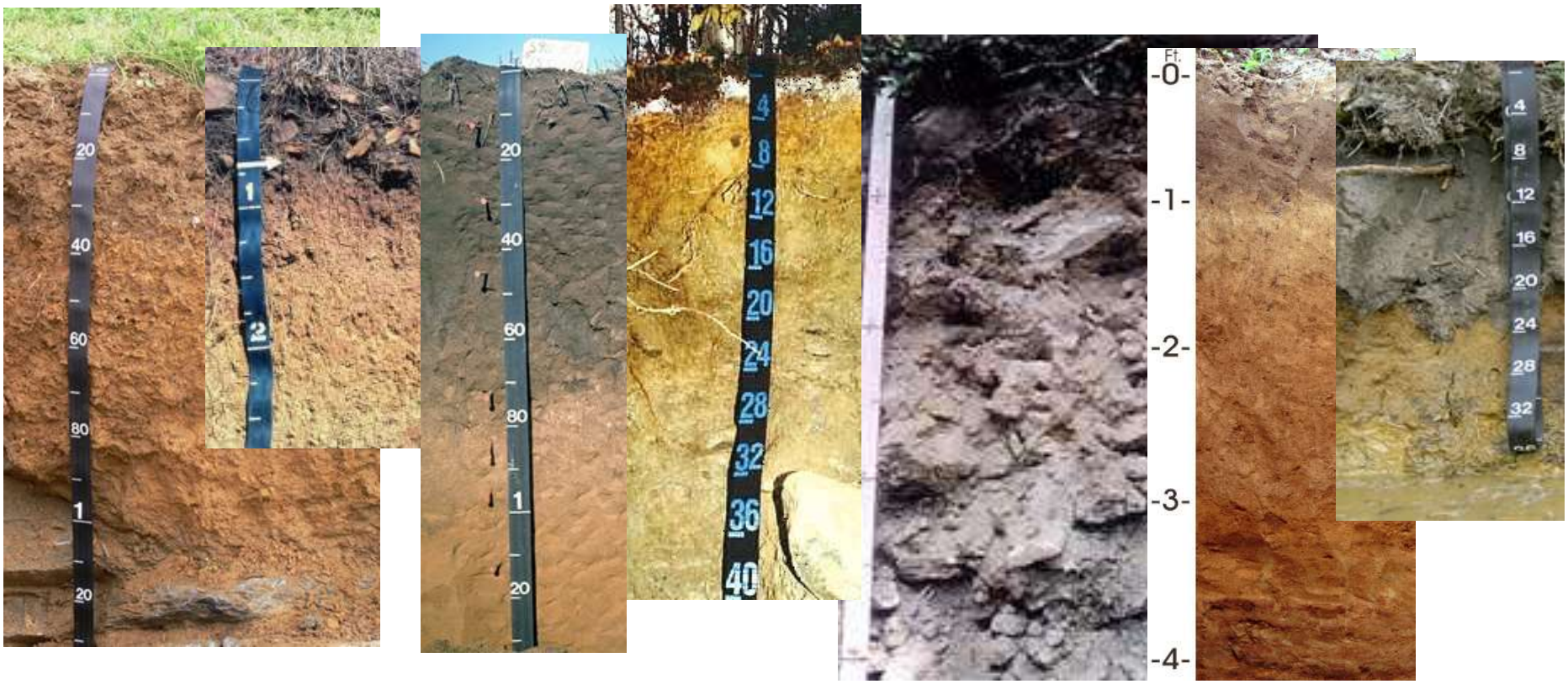
"Topsoil"



- The "top" of an undisturbed or cultivated "native" soil?
  - Depth ranges widely
  - Characteristics of native soils vary according to: parent material, climate, topography, vegetation and other organisms, and time (degree of aging)
  - Soil texture, organic matter content, pH, nutrients, structure (aggregation)

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Where does the "topsoil" come from?

- No legal definition:
  how do you know what you're getting?
- Much of the "topsoil" commercially available today for landscaping use is "manufactured".

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Rutgers Resources for Soil Evaluation

Rutgers Soil Testing Laboratory
http://njaes.rutgers.edu/soiltestinglab

- Basic fertility test
- Topsoil evaluation

NJAES Publications:
http://njaes.rutgers.edu/pubs
Fact Sheet 901

Recommended Topsoil Properties for Landscaping Use

pH: most : acid-loving	6.0 to 6.8 5.0 to 5.5
Organic content	1.5% to 10%
Sand	40% to 65%
Fines	5% to 20% clay

Topsoil Suitable for Landscape Use

Fact Sheet FS901

Cooperative Extension

Joseph R. Heckman, Ph.D., Extension Specialist in Soil Fertility

Construction activities often remove, bury or damage the existing soil. Bringing in new soil may appear to be the only practical way to establish landscape plantings and to garden on difficult sites. In many instances, however, it is easier and less ve the existing soil than to buy topsoil. A n be greatly improved by mixing in an f organic matter. This can be accomplished three inch layer of compost and using e to mix it with the existing soil.

y to bring in a topsoil, be sure to evaluate re having it transported and dumped at nportant soil qualities to consider are soil iter content, pH and soluble salts.

soils vary widely in quality. It should be o official or legal definition for what is to as topsoil.

n for topsoil is the top six to ten inches of hich the soil is plowed or cultivated. Topsoil the underlying soil by having higher ent, a darker color, better tilth, and higher n the form of earthworms, bacteria, and usually less compact than the underlying ly better for the growth of plants.

st reliable way to evaluate topsoil quality are low, fertilizers can be applied as is not easy to improve a soil with l properties. The physical condition of a soil depends largely on its soil texture. This refers to the percent sand, silt, and clay content. Topsoils with highly desirable textures have sand, silt and clay contents within the following ranges:

- Sand 40 to 65%
- Silt 25 to 60%
- Clay 5 to 20%

Examples of soil textural classes with desirable textures include: sandy loams, silt loams, and loams. Soil texture can be estimated by feel with trained hands or determined by submitting a sample to a soil testing laboratory for mechanical analysis. When soils of very different texture are layered one over the other, the movement of water through the soil profile can be restricted. Therefore, when adding topsoil of a different texture to an existing soil, mix the two for best results.

Soil organic matter content should be determined by a soil testing laboratory. Organic matter contents typical for sandy loam soils range from 1.25 to 3.0% and for silt loam or loam soils from 2.5 to 5.0. If soil organic matter content is low it can be enhanced by the addition of composted organic matter. An organic matter content up to 10% is suitable in an amended soil.

When buying topsoil, consider the desired pH range of the types of landscape plants to be grown. Certain acid loving plants will not grow well when the soil pH is greater than 6.0.

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Phone: 732.932.5000

Soil problems in sub/urban areas

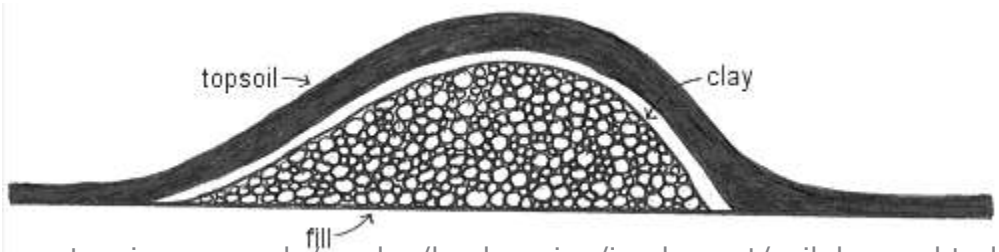
- Removal/disturbance/mixing of soil horizons
  - Amount of topsoil returned
  - *Quality* and *Quantity* matter!
  - Structural deterioration
- Fertility
- Water-holding capacity
- Compaction
- Erosion
- De-icing salt contamination (in cold climates)
- Underlying hydrology

120 cubic feet

500 cubic feet

1000 cubic feet

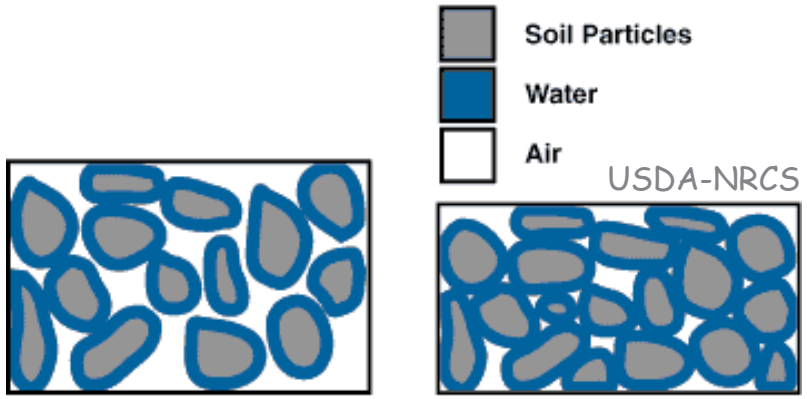
caseytrees.org



www.extension.umn.edu/garden/landscaping/implement/soil_berms.html

Compaction

- A change in soil structure due to pressure - resulting in decrease of total soil porespace volume
- Changes pore size distribution
- Degree of damage depends on load pressure, soil water content, soil texture



Foot traffic under grass

	Bulk Density	Porosity Total	Porosity Macro-	Infiltration
	g/cm3	%	%	in/h
None	1.09	58.9	33.1	3.0
Moderate	1.47	44.6	19.2	1.13
Heavy	1.80	27.9	3.0	0.28

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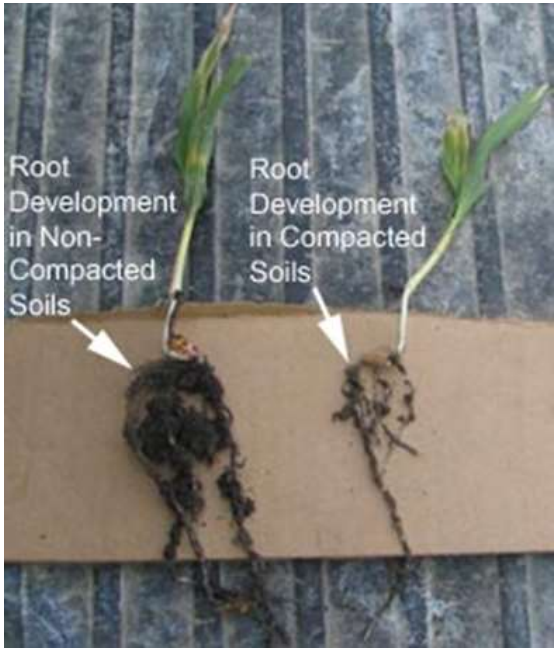
Consequences of compaction

- Reduced movement of air and water
- Greater retention of water
- Build-up of toxic gases
- Root growth may be limited, function & viability compromised
- Alters microbial population/activity



What's underneath matters!

- Be concerned about what the topsoil is going over – Compacted subsoil? Discontinuity of texture? Inhibiting water movement and root penetration
- Water-storage ability and drainage, groundwater recharge

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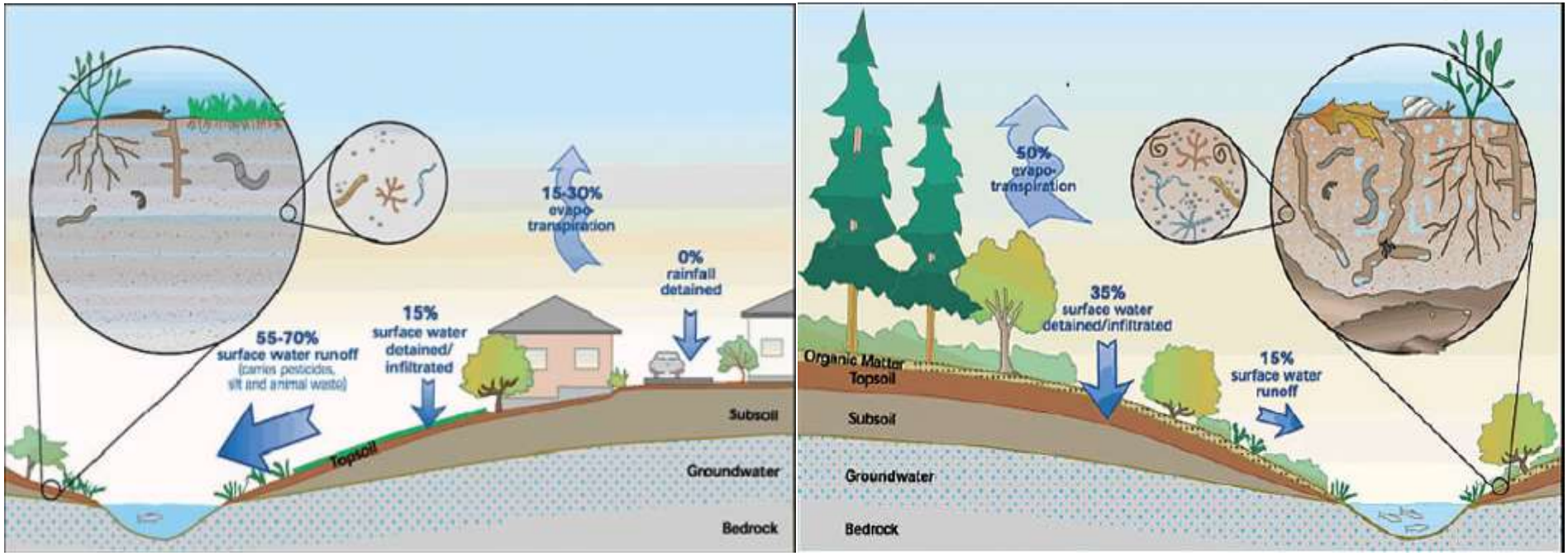
Developed vs. Natural Landscape

Compare:

- Topsoil
- Subsoil density
- Permeability
- Biological activity
- Water storage
- Suitability for roots



Diagrams: USDA-NRCS Urban Soil Primer

Sustainable

- using a resource in such a way that it is not depleted or permanently damaged
- Horticultural best management practices (BMPs) are operations which establish, maintain, or improve conditions for healthy vegetative growth and environmental quality
- Minimal input – at least in long term

green-gardener.org

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Maintain Good Soil Structure

- Prevent compaction
  - limit traffic and other loads, especially when soil is wet
  - Promote infiltration
- Prevent erosion to conserve soil and protect natural water bodies and stormwater management infrastructure
- Limited tillage
  - Coring to alleviate compaction, improve aeration & infiltration, and incorporate amendments
  - Deep ripping when necessary
- Promote biological activity
- Addition of organic matter

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Enhance soil organic matter and soil life

- Add organic amendments when starting low
- With adequate initial levels of OM, healthy vegetation will help maintain OM and sustain soil life
- Mulch clippings back into lawn
- A practice and a goal: "maintaining healthy crop" – plants initiate the soil food web

www.northernplains.org

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Maintain a healthy "crop"

- Maintain dense cover to protect soil surface
- Irrigate during establishment or drought
- Re-establish vegetation when necessary
- Deal with pest outbreaks when necessary
- Off-season care
  – avoid damage from snowplows, de-icing salts

Rutgers Plant Diagnostic Lab

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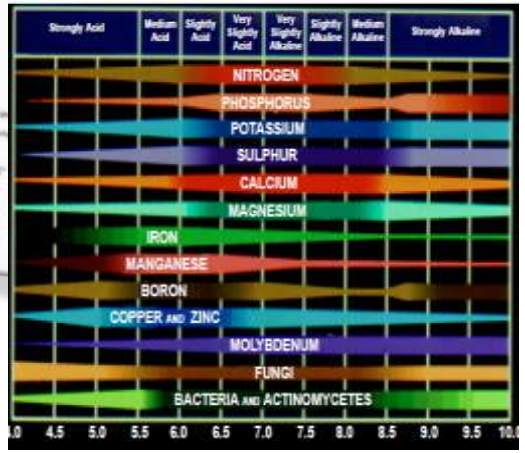
Soil Test!
To manage soil pH and nutrient levels



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Conclusions

- Stewardship of soils in sub/urban landscapes will avoid many problems and minimize costs in the long run
- Monitoring and measured management of soils will help develop and sustain successful landscapes
- BMPs often involve ***prevention*** of soil degradation: compaction, smearing, bare soil, crusting/sealing, fertility depletion, acidification, erosion – to minimize pollution risks of waterways and help maintain healthy landscapes!

2015 International Year of Soils

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