Soil Fertility

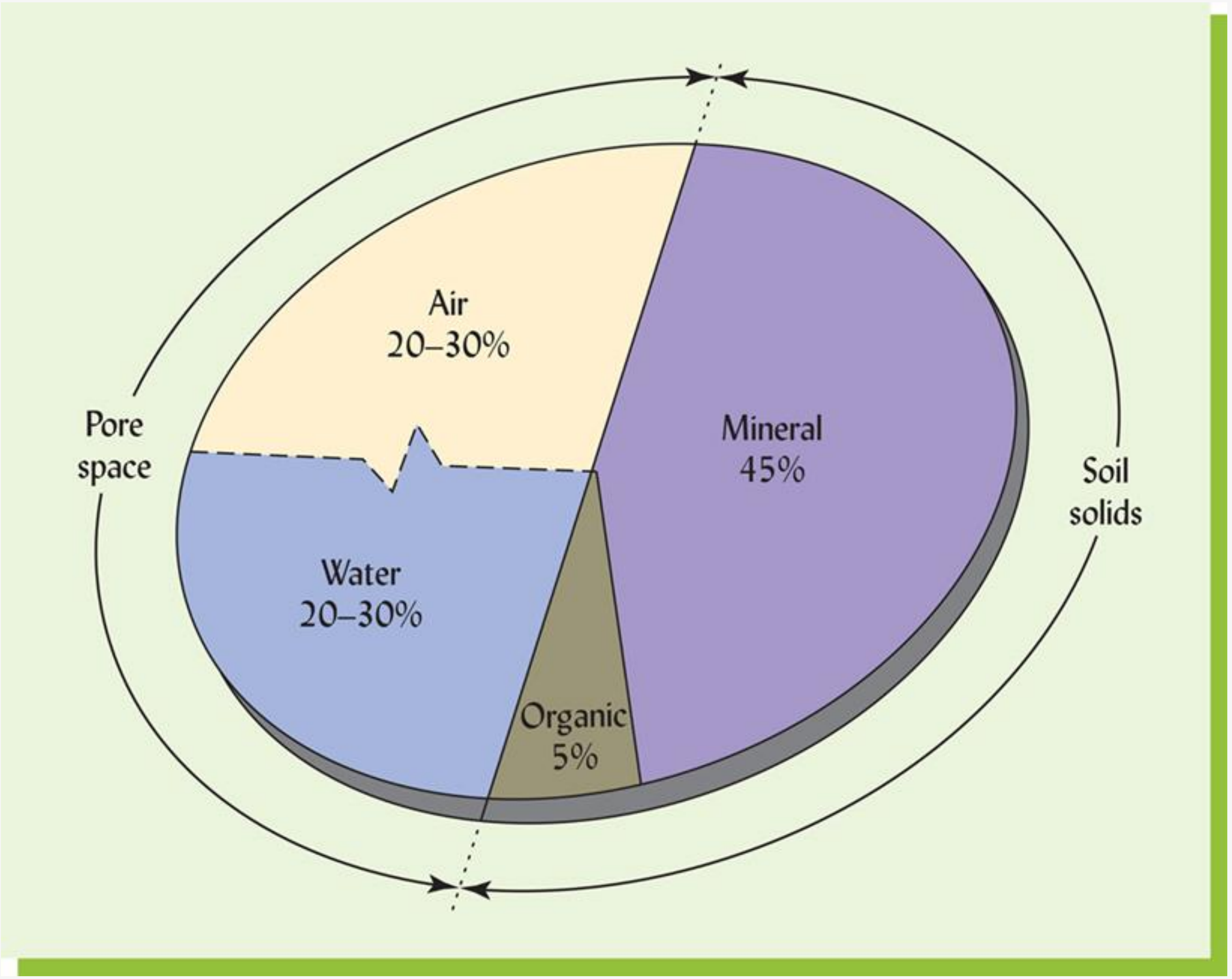
Mvskoke Gardeners

2025

Ode to Dirt

Dear dirt, I am sorry I slighted you,
I thought that you were only the background
for the leading characters—the plants
and animals and human animals.
It's as if I had loved only the stars
and not the sky which gave them space
in which to shine. Subtle, various,
sensitive, you are the skin of our terrain,
you're our democracy. When I understood
I had never honored you as a living
equal, I was ashamed of myself,
as if I had not recognized
a character who looked so different from me,
but now I can see us all, made of the
same basic materials—
cousins of that first exploding from nothing—
in our intricate equation together. O dirt,
help us find ways to serve your life,
you who have brought us forth, and fed us,
and who at the end will take us in
and rotate with us, and wobble, and orbit.

—Sharon Olds



What is soil?

- **SOIL** is defined as "a dynamic natural body composed of mineral and organic solids, gases, liquids, and living organisms which can serve as a medium for plant growth."

- **Dynamic natural body**
  - **45%** Mineral solids
  - **5%** Organic matter (OM)
  - **25%** Gases (soil air)
  - **25%** Water + chemicals (soil solution)
  - Living organisms
    - Including plants

What is soil?

45% Mineral Solids

- Inorganic soil components aka **nonliving and have never been 'alive'**
  - **Contains NO carbon (C)**

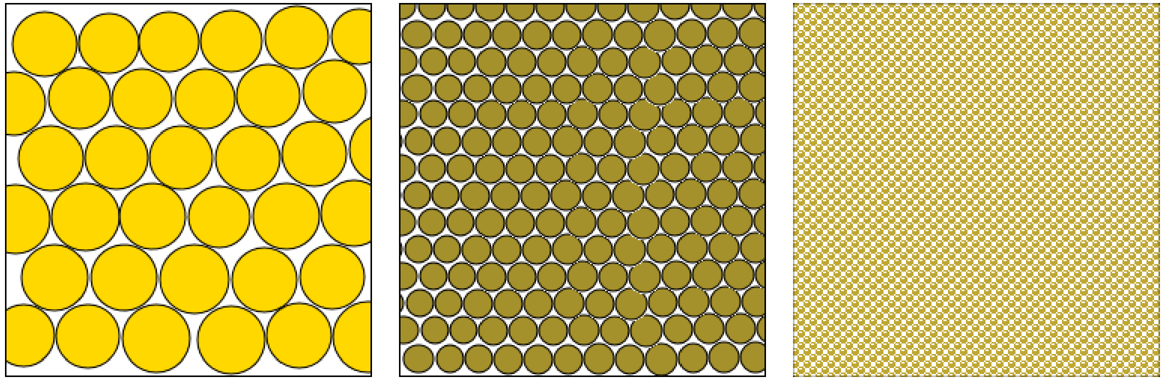
- Soil is composed of **sand, silt, and clay** textures.
  - Soil texture affects suitability of soil for most uses (farming vs building)
  - Sandy soils vs. Clay soils

Table 1.2

Some General Properties of the Three Major Size Classes of Inorganic Soil Particles

	Property	Sand	Silt	Clay
1.	Range of particle diameters in millimeters	2.0–0.05	0.05–0.002	Smaller than 0.002
2.	Means of observation	Naked eye	Microscope	Electron microscope
3.	Dominant minerals	Primary	Primary and secondary	Secondary
4.	Attraction of particles for each other	Low	Medium	High
5.	Attraction of particles for water	Low	Medium	High
6.	Ability to hold chemicals and nutrients in plant-available form	Very low	Low	High
7.	Consistency when wet	Loose, gritty	Smooth	Sticky, malleable
8.	Consistency when dry	Very loose, gritty	Powdery, some clods	Hard clods

Sand | Silt | Clay



Large particles and pore size (air spaces)

Medium particles and pore size (air spaces)

Small particles tightly packed with very little space between them

Table 4.1
Generalized Influence of Soil Separates on Some Properties and Behavior of Soils[a]

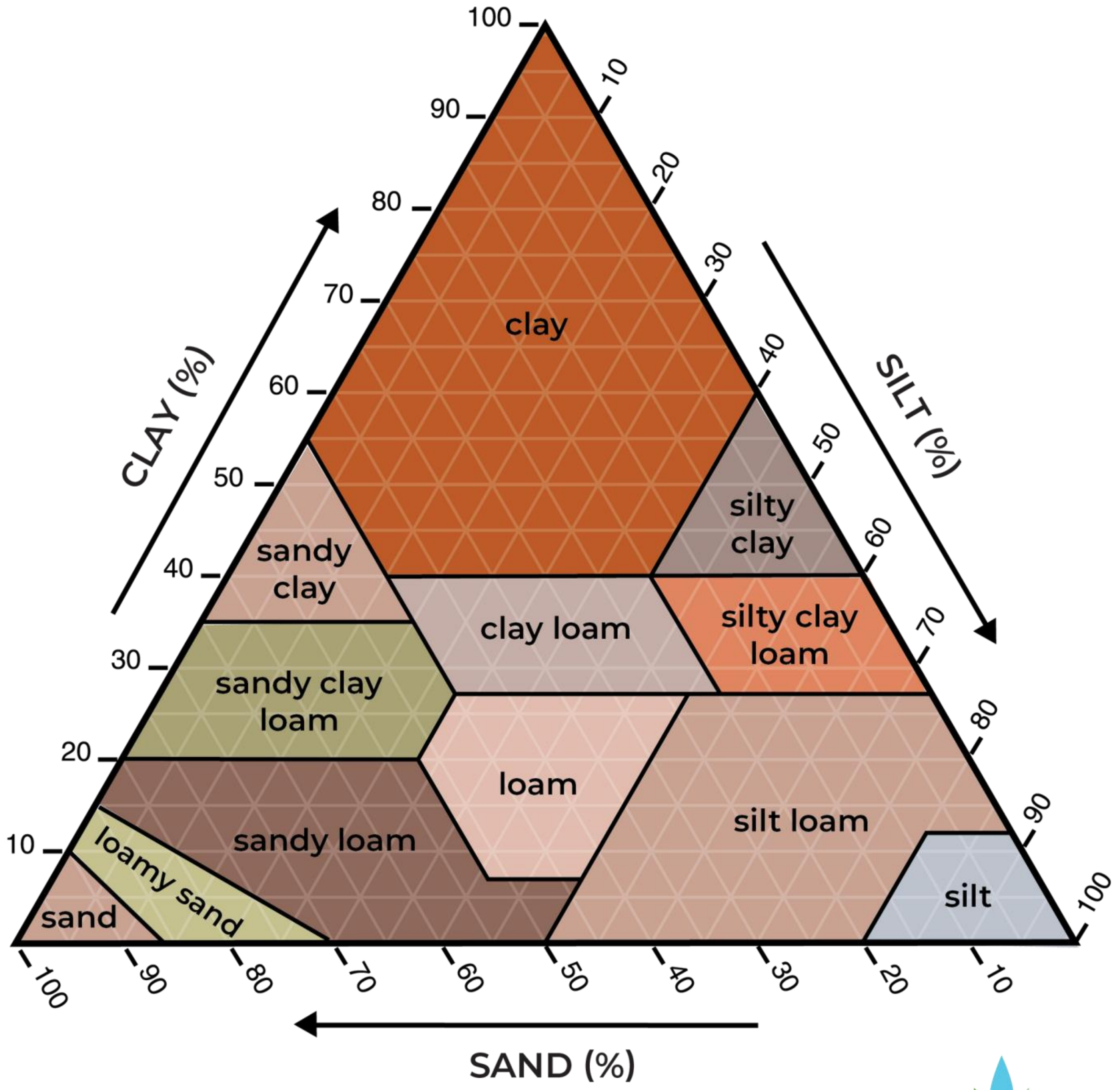
Property/behavior	Rating associated with soil separates		
	Sand	Silt	Clay
Water-holding capacity	Low	Medium to high	High
Aeration	Good	Medium	Poor
Drainage rate	High	Slow to medium	Very slow
Soil organic matter level	Low	Medium to high	High to medium
Decomposition of organic matter	Rapid	Moderate	Slow
Warm-up in spring	Rapid	Moderate	Slow
Compactability	Low	Medium	High
Susceptibility to wind erosion	Moderate (high if fine sand)	High	Low
Susceptibility to water erosion	Low (unless fine sand)	High	Low if aggregated, high if not
Shrink–swell potential	Very low	Low	Moderate to very high
Sealing of ponds, dams, and landfills	Poor	Poor	Good
Suitability for tillage after rain	Good	Medium	Poor
Pollutant leaching potential	High	Medium	Low (unless cracked)
Ability to store plant nutrients	Poor	Medium to high	High
Resistance to pH change	Low	Medium	High

[a]Exceptions to these generalizations do occur, especially as a result of soil structure and clay mineralogy.

What is soil?

45% Mineral Solids

- Within sandy, silty, clayey soils there are classes
  - Classes are more detailed on the ratio of soil particles
- Most soils are a type of **loam**.
  - Mix of sand silt clay particles, not always present in equal amounts.
  - Loams exhibit properties of each soil separate.
  - Clay is only needed in small amounts to influence soil.



USDA soil textural triangle

Source: National Agronomy Manual, USDA

BOX 4.2

A METHOD FOR DETERMINING TEXTURE BY FEEL

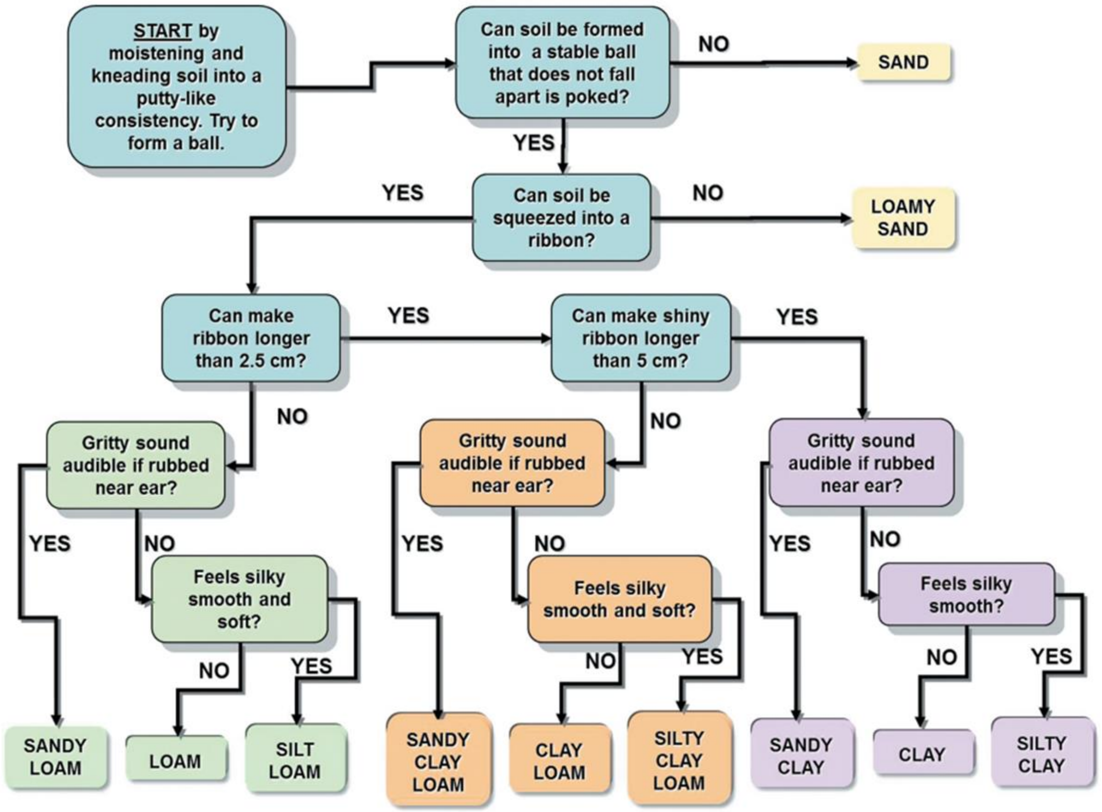
The first, and most critical, step in the texture-by-feel method is to knead a walnut-sized sample of moist soil into a uniform puttylike consistency, slowly adding water if necessary. This step may take a few minutes, but a premature determination is likely to be in error as hard clumps of clay and silt may feel like sand grains. The soil should be moist, but not quite glistening. Try to do this with only one hand so as to keep your other hand clean for writing in a field notebook (and shaking hands with your client).

While squeezing and kneading the sample, note its malleability, stickiness, and stiffness, all properties associated with the clay content. A high silt content makes a sample feel smooth and silky, with little stickiness or resistance to deformation. A soil with a significant content of sand feels rough and gritty, and makes a grinding noise when rubbed near one's ear.

Get a feel for the amount of clay by attempting to squeeze a ball of properly moistened soil between your thumb and the side of your forefinger, making a ribbon of soil. Squeeze out the ribbon little by little, making it as long as possible until it breaks from its own weight (see Figure 4.15). Interpret your observations as indicated in Figure 4.16.

A more precise estimate of sand content (and hence more accurate placement in the horizontal dimension of the textural class triangle) can be made by wetting a pea-sized clump of soil in the palm of your hand and smearing it around with your finger until your palm becomes coated with a souplike suspension of soil. The sand grains will stand out visibly and their volume as compared to the original "pea" can be estimated, as can their relative size (fine, medium, coarse, etc.).

Figure 4.16 Flow chart for determining textural class by feel. To use the chart, to determine the texture of a soil, begin at the top left corner.
[Diagram Weil (2009)]



Altering Soil Texture

- Altering soil texture is difficult and expensive
- Requires mixing current soil with another soil form a different texture class
  - Preferably one that occurs naturally
  - Imported from another region
- Simply adding clay to a sandy soil or sand to a clayey soil is not advised because proper particle sizes and amounts vary by location.
  - Coarse sand vs fine sand
  - Nearly impossible to determine exact quantities for an entire area.

What is soil?

5% Organic Matter (OM)

- OM consists of anything that is **alive or was once living**.
  - **All living or once living organisms (organics) contain carbon (c)**
  - Includes: Living organisms, carbon remains of once living organisms, organic compounds produced by breakdown of OM
- **Binds** mineral (sand, silt, clay) particles together, making soils more productive
- Increases water holding capacity
- Excellent source of nutrients for plants
- Food supply for many soil microbes
- Comprises 1-6% of topsoil
- **Humus** – collection of organic compounds that accumulate in soils.
  - Dark color – almost black
  - High water holding capacity

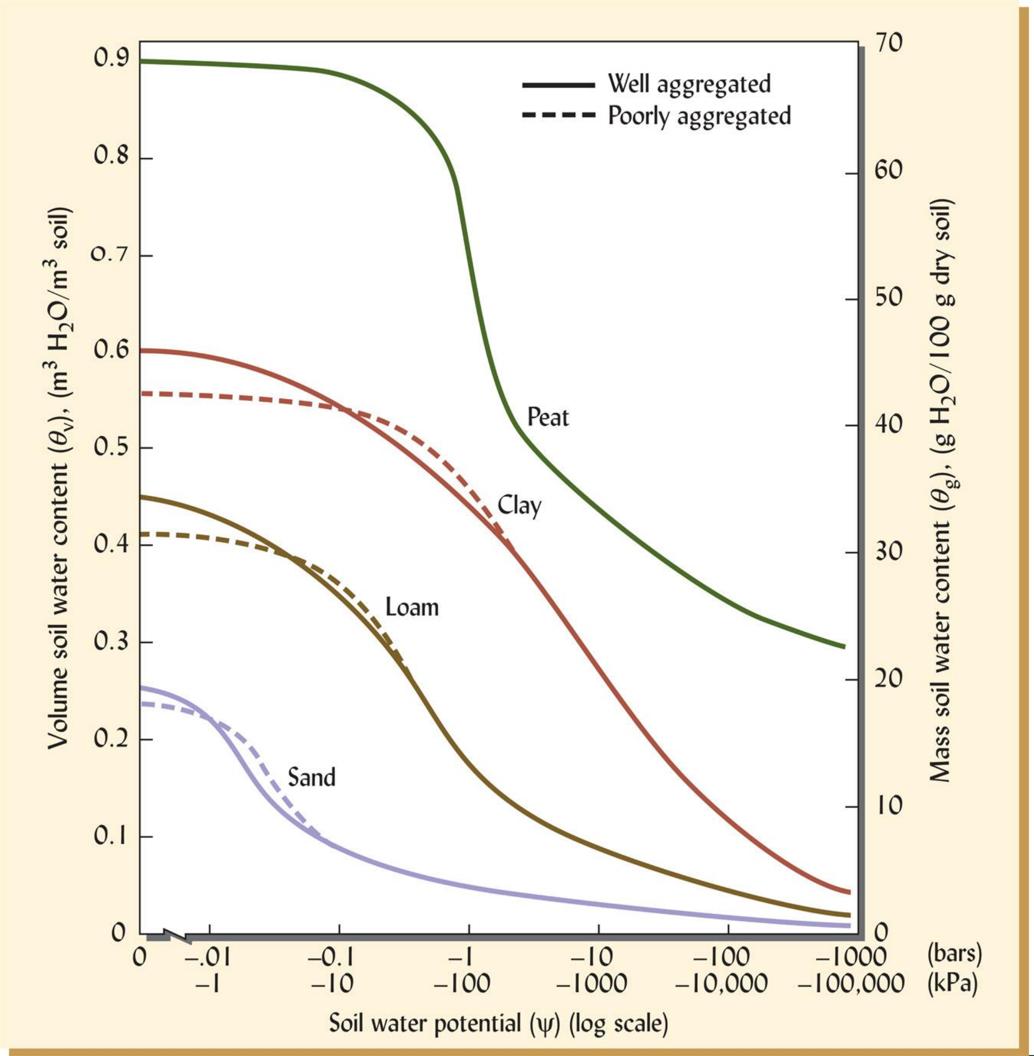
What is soil?

25% Water

- Soil water is best described as a **soil solution** because it contains more than just water (H_2O)
  - Also contains nutrients from OM breakdown
- **When water meets a soil surface, it has two fates:**
  - **Infiltrate and become part of the soil solution**
  - **Stay at soil surface and become runoff**
- Water moves throughout soil in the macropores (gravity) and micropores (chemical bonding).
- Plants obtain nutrients only from the soil solution by exchanging one nutrient for another.

Figure 5.12 Soil water potential curves for three representative mineral soils and an organic peat. The curves show the relationship obtained by slowly drying completely saturated soils. The dashed lines show the effect of compaction or poor aggregation in mineral soils. Note that the soil water potential ψ (which is negative) is plotted on a log scale in units of bars (upper scale) and kilopascals (kPa) (lower scale). Soil water content is plotted on the vertical scale on a volumetric basis (left axis). The curves do not account for possible soil volume changes (shrinkage) and are generally representative of data in Rawls et al. (1982, 2004) and Schw.rzel et al. (2002).

How tight water is held by different soil textures



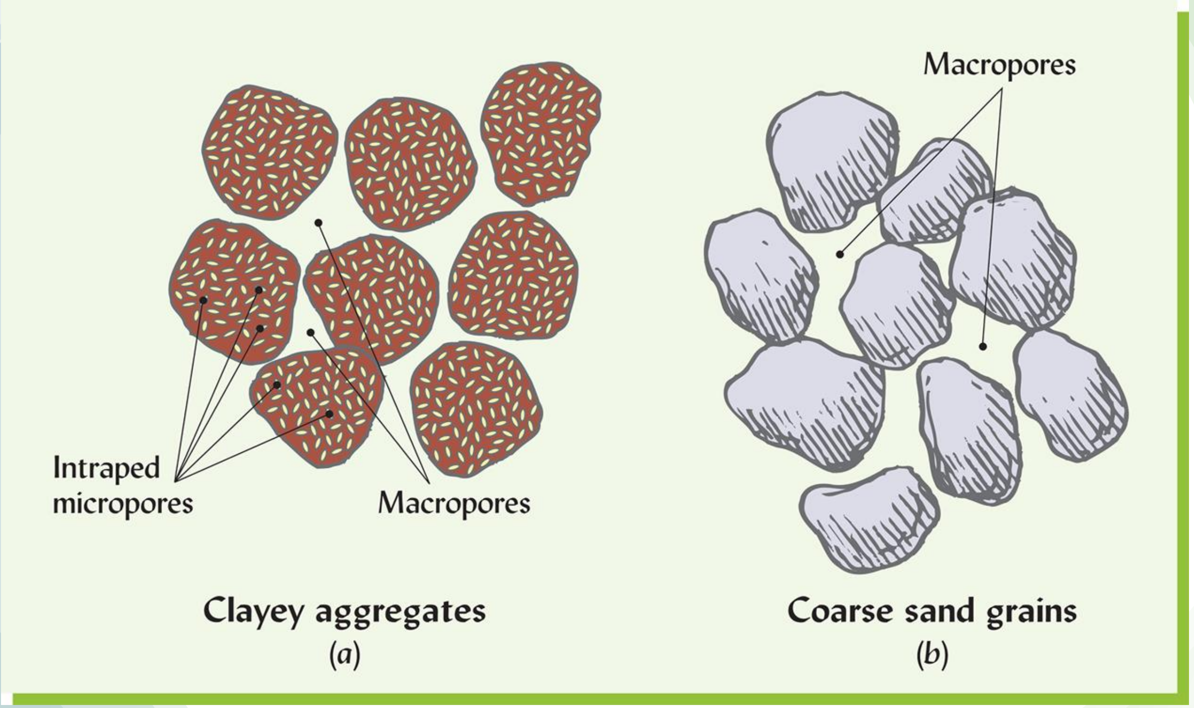
What is soil?

25% Air

- **Soil pores are the ventilation system of soil**

- Air content inversely related to water content

- Soil aeration is important for plant growth and microbial activity.
  - Plant growth and microbial activity becomes severely inhibited when air filled pores falls below **10%.**



What is soil?
25% Air

- **Soil color is influenced by air flow.**
  - Reddish/yellow/orange colors in soil indicate good airflow.
  - Grey/blue colors in soil indicate poor airflow.
    - Lack of oxygen
  - *Remember dark brown/black colors come from OM*

ROCKS IN THE BOTTOM OF PLANT POTS

MYTH BUSTED: You do **not** need to put gravel in the bottom of plant pots!

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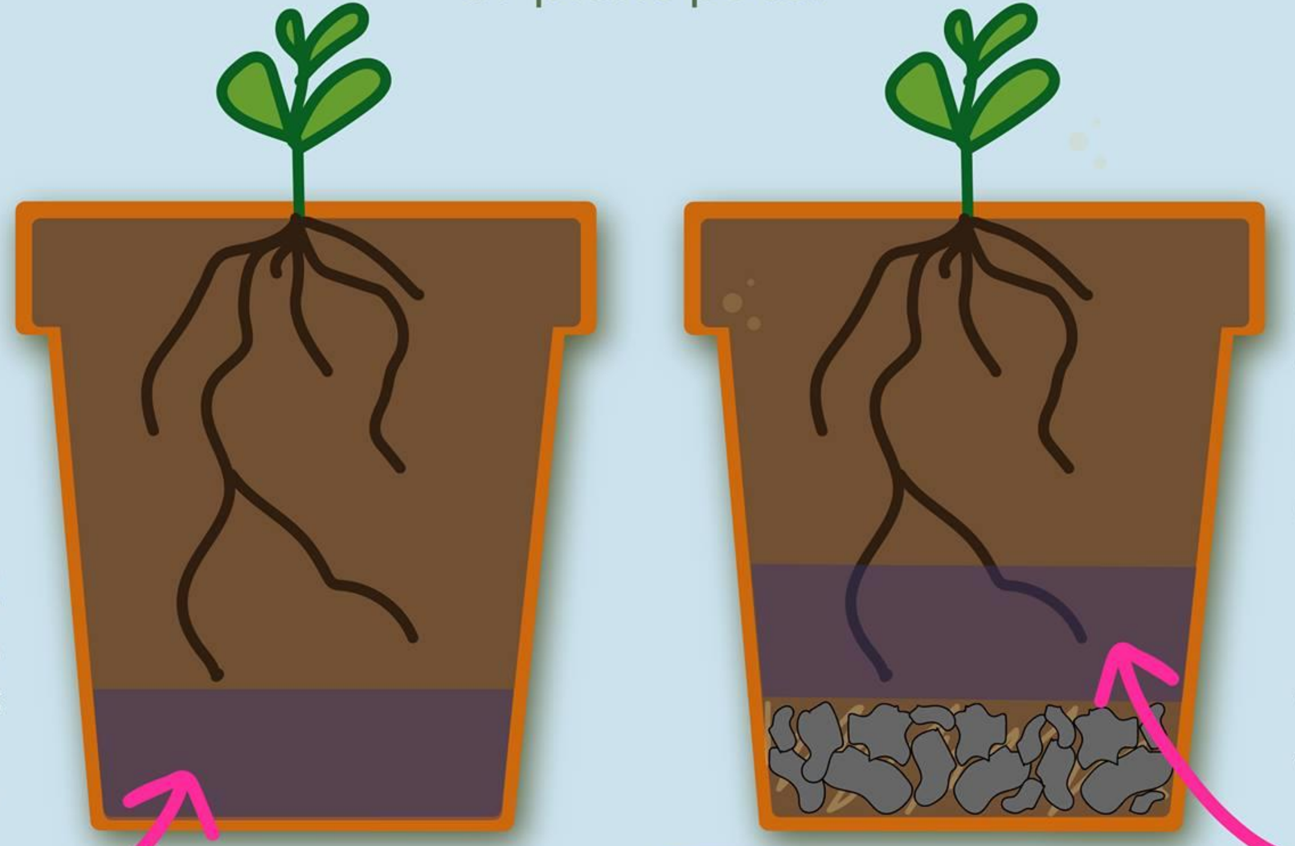
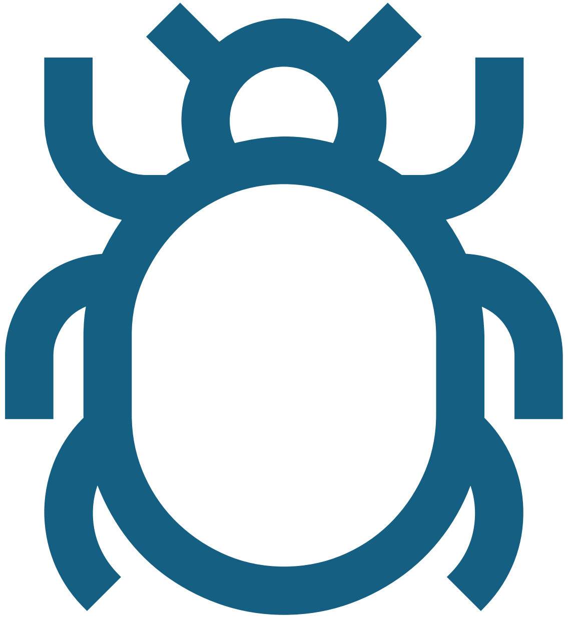


✓ The wettest soil is at the **bottom** of the pot.

✗ Gravel moves the **wettest soil up** in the pot, closer to the roots, which can lead to rot, which is bad for your plants.

Soil Living Organisms

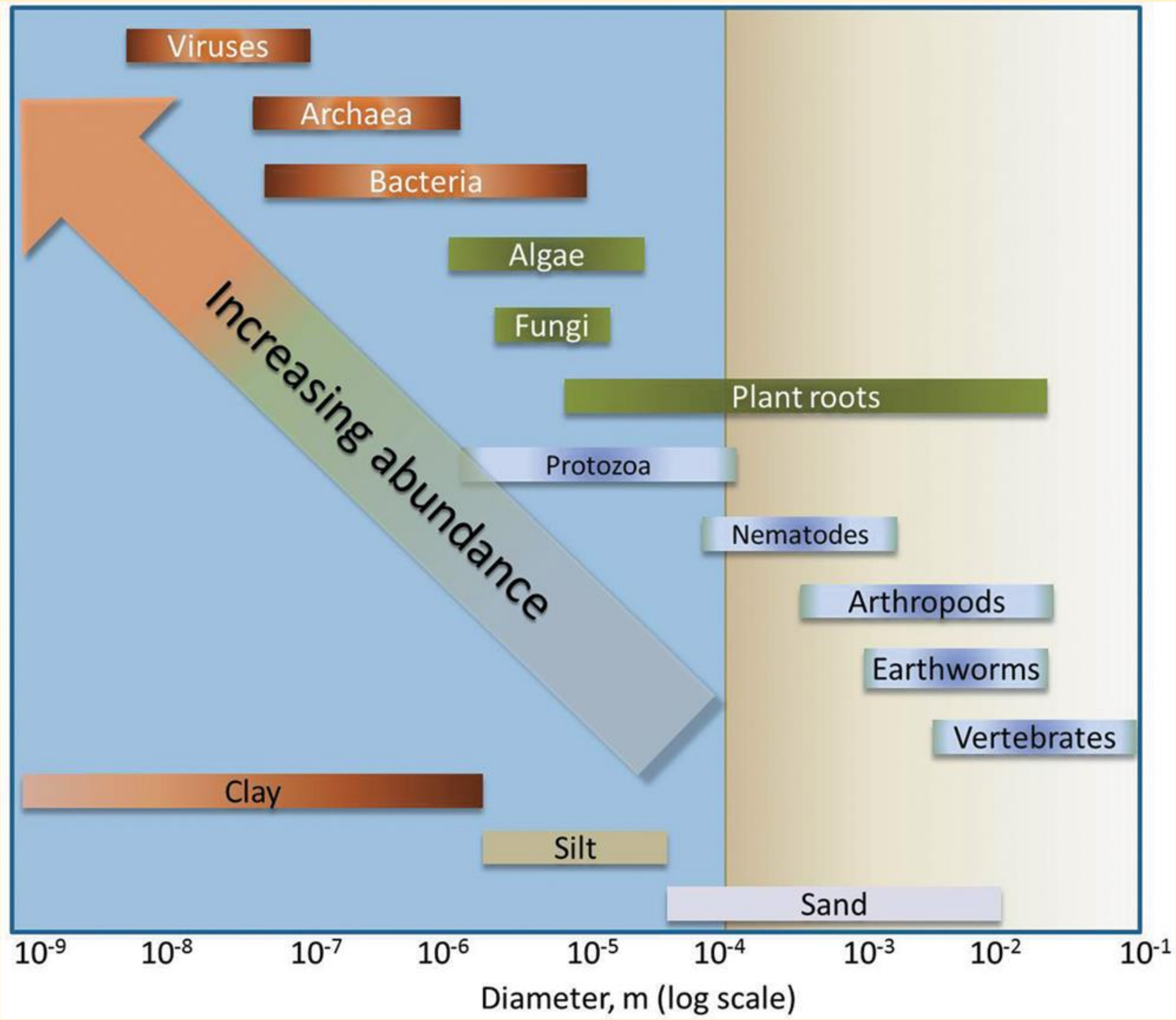
- 1 handful of soil contains billions of organisms. Most are microscopic.
- A typical, healthy soil contains
  - 3-4 species of **vertebrae animals** (mice, gophers, snakes)
  - 6+ species of **earthworms**
  - 50 species of **arthropods** (mites, beetles, ants, etc.)
  - 100+ species of **nematodes**
  - 100+ species of **fungi**
  - 1000+ bacteria species
- **High species diversity = high functional diversity**
- Plant roots also considered living organism in soil and occupy 1% of most soil volume.



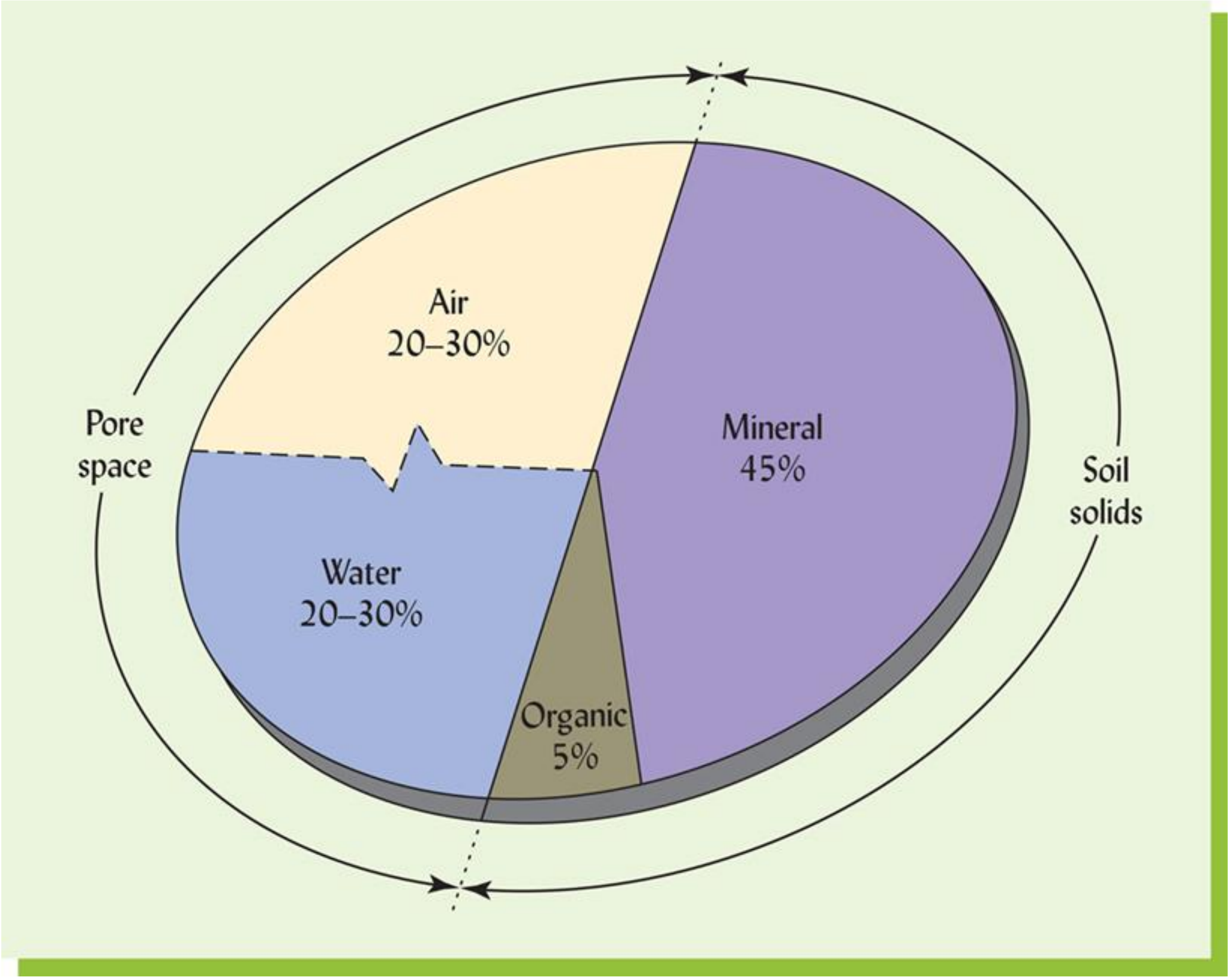
Soil Living Organisms

- Factors that influence the presence of living organisms in soil include:
  - OM (feeds microbes)
  - Oxygen (microbes require airflow)
  - Temperatures (prefer warm 68°F +)
  - Soil pH
- **Microbial activity is largely responsible for nutrient availability in soil.**
  - Microbes eat OM, poop smaller forms of OM out.
    - Another microbe eats that poop, and poops even smaller forms of the OM out.
    - As this continues, nutrients are released from OM and dissolved into the soil solution.

Soil Living Organisms



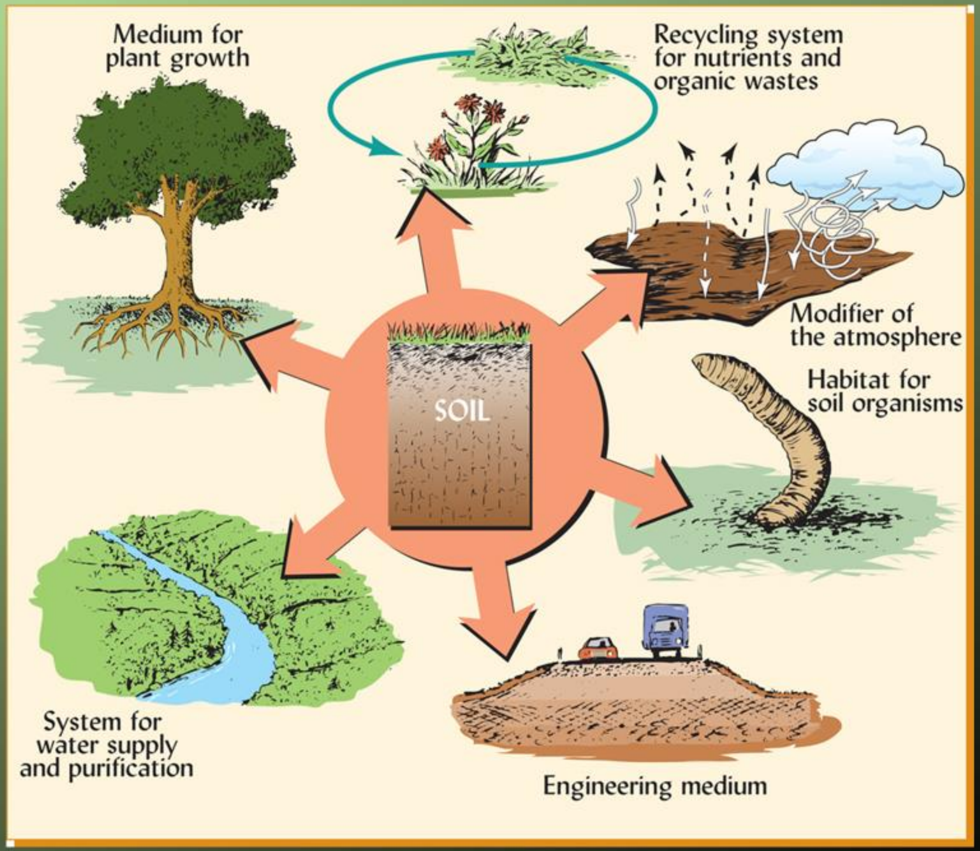
What is soil?


Air
20–30%
Pore
space
Mineral
45%
Soil
solids
Water
20–30%
Organic
5%

Why is soil important?

Roles of Soil

1. Supporting plant growth
2. Regulating water supplies
3. Recycling waste products (dead and decaying products into nutrients)
4. Atmosphere modification
5. Providing habitats for soil organisms
6. Engineering material and foundation



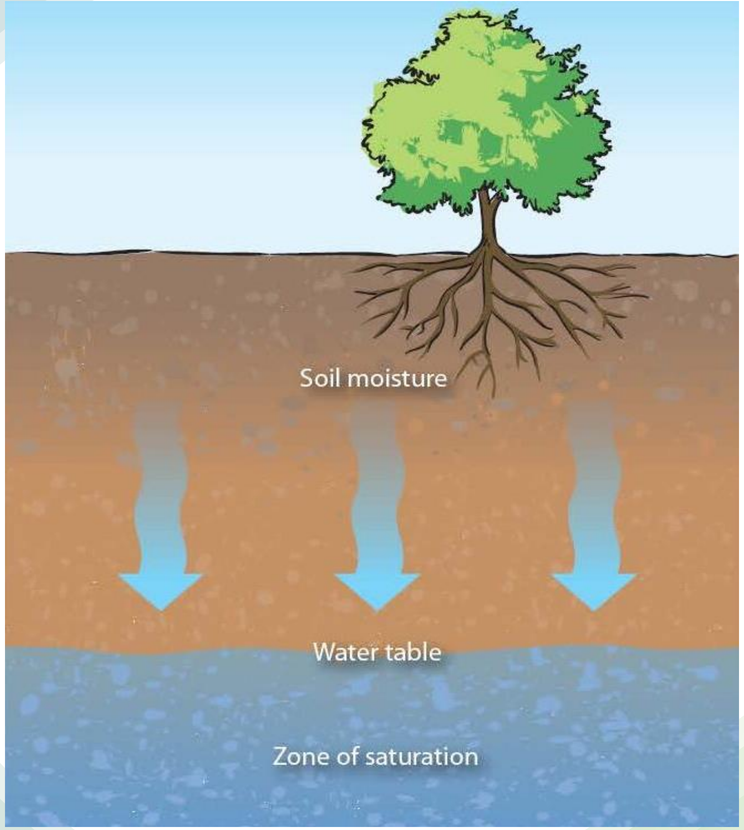
How Soils Support Plant Growth

1. **Physical Support**
   - Anchors root system
2. **Ventilation for Plant Roots**
3. **Water**
   - Soil's water-holding capacity is crucial for plant survival.
4. **Temperature Moderation**
   - Soil's insulating properties protect roots from hot/cold extremes that occur at the soil surface.
5. **Protection from Toxic Substances**
   - Soil protects plants from such substances by decomposing, adsorbing, ventilating, or suppressing toxin-producing organisms.
6. **NUTRIENTS**
   - A fertile soil will continuously supply dissolved nutrients to plant roots. (soil solution)

How Soils Regulate Water Supplies

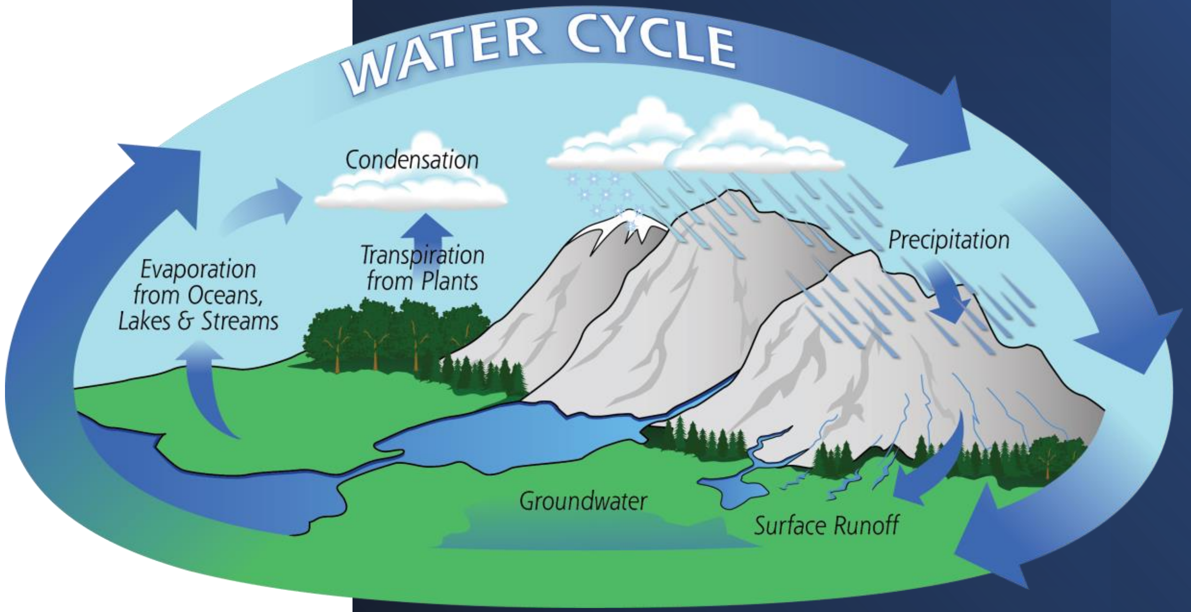
- Nearly every drop of water in rivers, lakes, estuaries, etc. has travelled through or over soils.
- **When water meets a soil surface, it has two fates:**
  - **Infiltrate and become part of the soil solution**
  - **Stay at soil surface and become runoff**
- Infiltrated water is either stored in soil pores, used by plants, or slowly trickles down into groundwater.
  - As water slowly moves down through soil layers, it is cleansed and purified.
- Runoff water detaches soil particles and carries it away into rivers and streams.
  - No purification process
  - Soil is shallow or impermeable

- Soil plays a central role in the Earth's water cycling.
  - ~65% of water that infiltrates soil is kept as soil moisture and eventually used by plants or drained into groundwater.
  - The rest is returned to atmosphere via evapotranspiration.
- As water moves down deeper into soil, it eventually encounters a zone where all pores are saturated (filled with water).
  - This zone is the **water table – where soil meets the groundwater storage.**
  - As water moves down deeper into soil, it is slowly filtered/purified.
  - Groundwater either
    - Slowly moves laterally into streams and lakes
    - Slowly percolates upward towards plant roots as needed (drought)
    - Is pumped out and used by humans (20% of US water is sourced from groundwater)



Global Hydrologic Cycle

- Global stocks of water:
  - 97% of earth's water in oceans
  - 1.7% of earth's water in glaciers and ice caps
  - **1.7% in groundwater up to 750 m underground**
- Water in shallow groundwater, in streams and rivers, in the atmosphere, and in the soil is very active in hydrologic cycle.
- Water typically resides in one location for
  - ~10 days in the atmosphere
  - ~20 days in rivers
  - ~30 days in soil



How Soils Recycle Waste

- Soil has the capacity to breakdown large quantities of organic waste into forms that can be used by plants.
- Without soils, the planet would likely be covered in plant and animal waste, and we would have run out of nourishment a long time ago.

How Soils Modify the Atmosphere

- Gas exchanges between the soil and the atmosphere influence atmosphere composition and global climate change.
- **Soil's store lots of carbon because of the high OM content.**
- Evaporation of soil moisture is a major source of water vapor in the atmosphere which alters air temperature and weather patterns.
- In dry areas, soil picked up by wind can impact air quality and negatively effect human respiratory health.

- The atmosphere above the soil contains approximately:
  - 78% Nitrogen
  - 21% Oxygen
  - **0.0035% Carbon Dioxide CO2**
- Soil air contains approximately:
  - 78% Nitrogen
  - <20% Oxygen in upper layers
  - <5% Oxygen in deeper layers or on anaerobic soils
  - **0.35% Carbon Dioxide CO2 ***
    - 10% CO2 becomes damaging to plants
- There are also other gases present in both atmospheres, like methane and ethylene.

Habitat for Soil Organisms

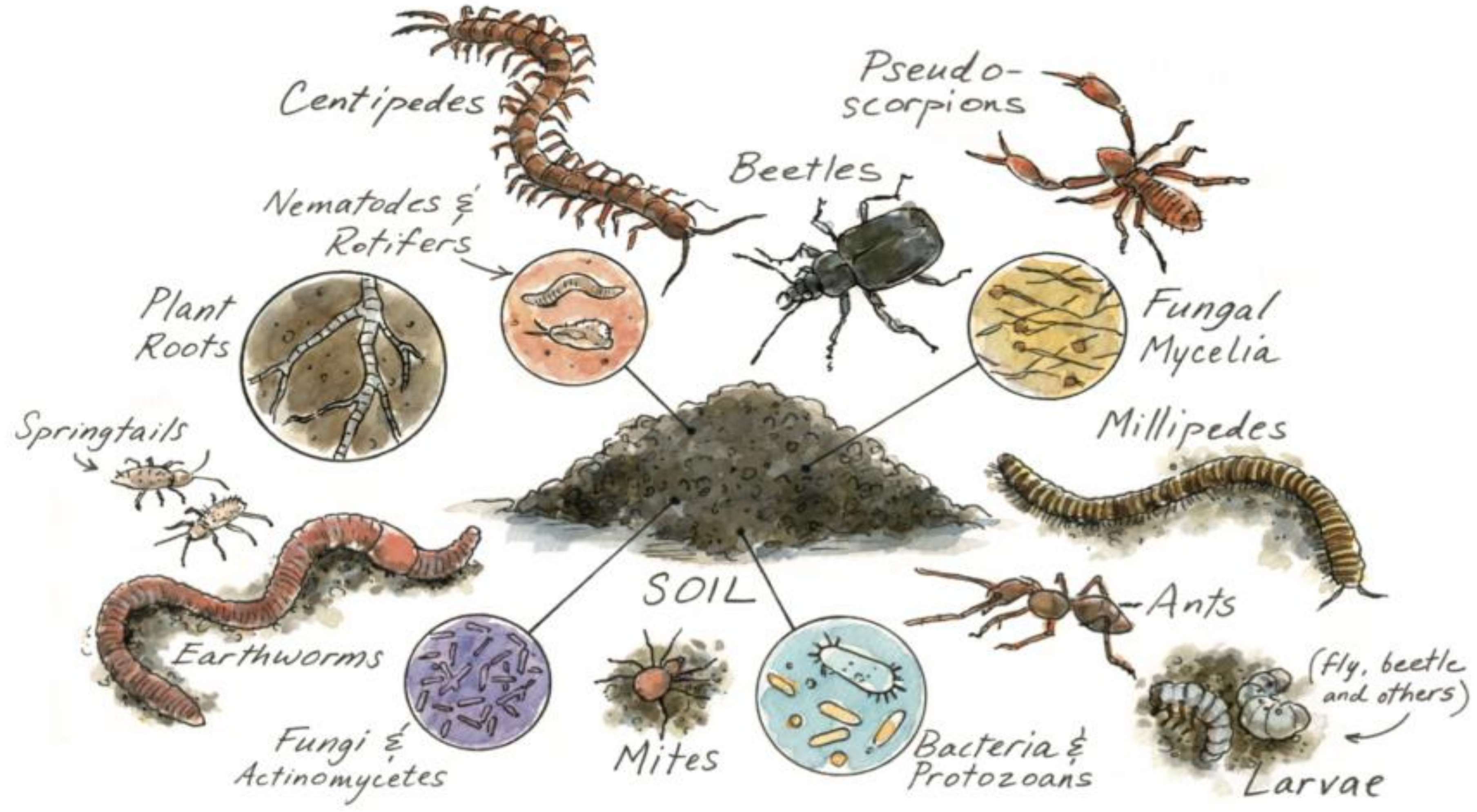
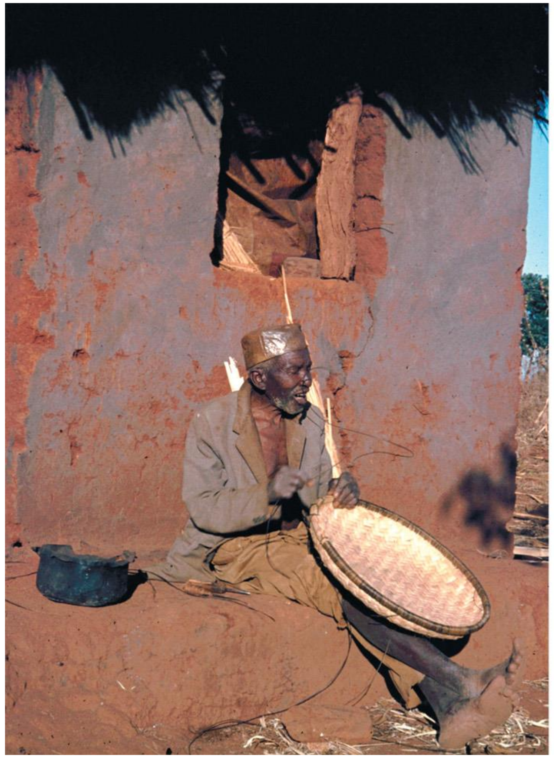


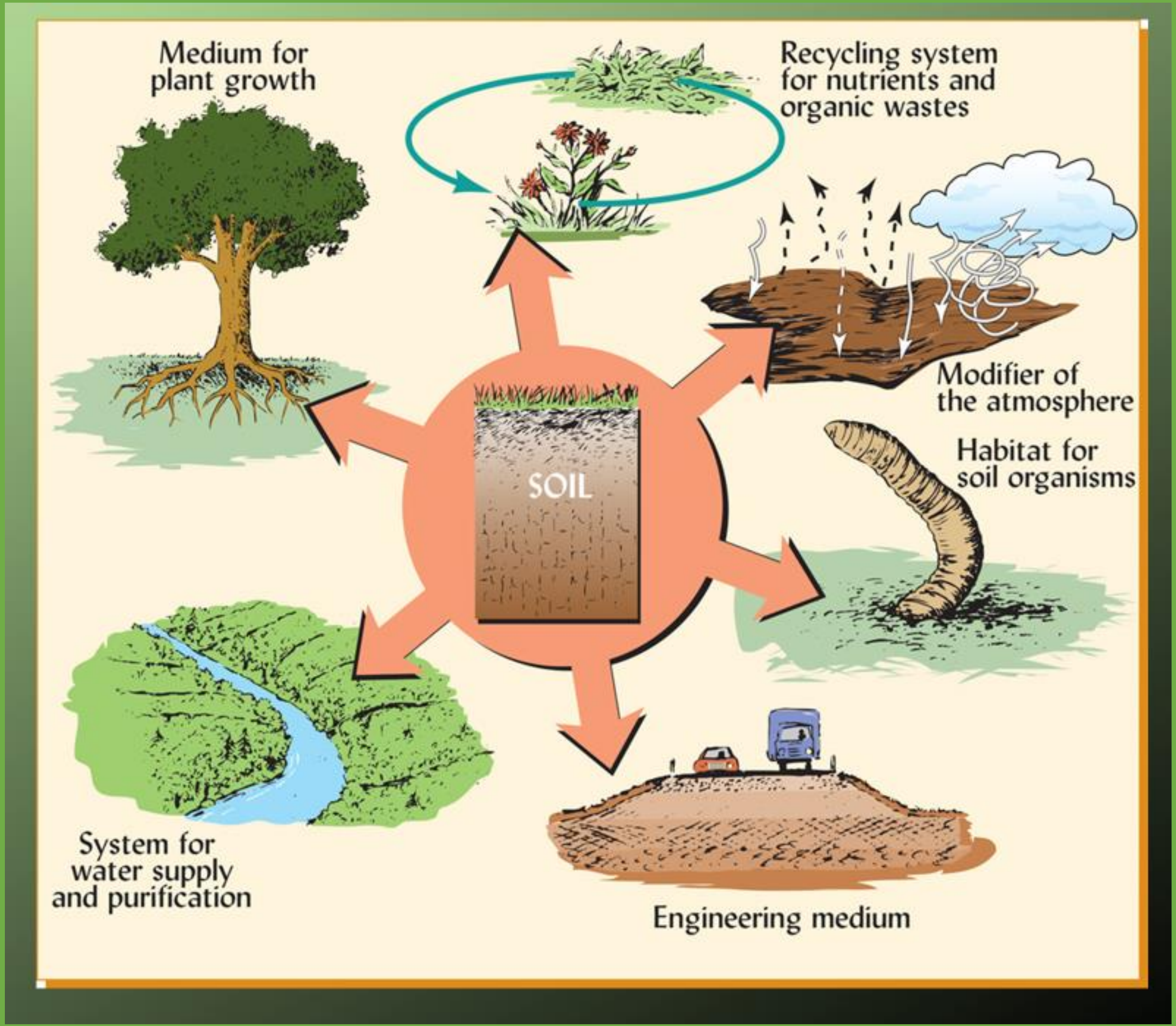
FIGURE 4.1. A few examples of the inhabitants that live in soil. *Illustration by Elara Tanguy.*

Soil as an Engineering Medium

Figure 1.10 Soil is among the oldest and most common of building materials, with half the world's people living in homes made of soil. (left) An elderly African villager weaves a basket outside his house made from red and black clay soil reinforced with small tree branches (a technique termed wattle and daub). (right) Several round Tulou apartment buildings housing up to 80 families each in Fu-Jian, China. These buildings have 2-m-thick walls made thousands of years ago from compacted yellowish soil mixed with bamboo and stones. These massive "rammed earth" walls make the buildings warm in winter but cool in summer (see Chapter 7) and resistant to damage from earthquakes.
(Left photo courtesy of Ray R. Weil; right photo courtesy of Lu Zhang, Zhejiang, China)



Roles of Soil



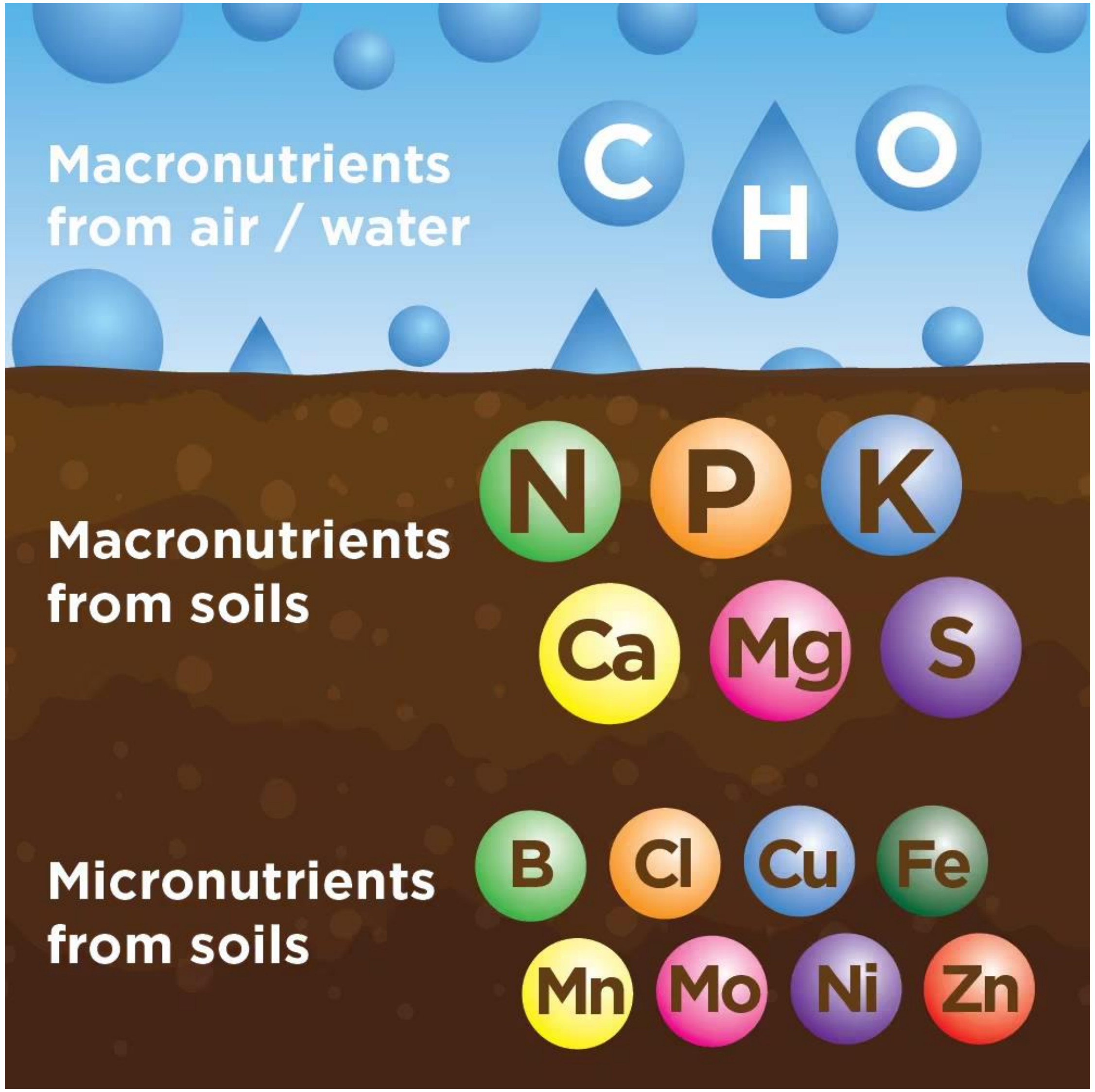
Soil Health

- Soil is not just dirt for plants, but a whole living resource.
- Maximize soil health by maximizing:
  - Plant roots
  - Soil covers/**OM**
  - MINIMIZING disturbance

Plant Nutrients

- Soil is loaded with different elements but only **17** are necessary for plant growth and development.

- Macronutrients are nutrients needed in larger quantities for plant health, most come from the soil.
  - Carbon, Hydrogen, and Oxygen come from the air and/or water
  - Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulphur (S) come from soil/nutrient solution.
- Micronutrients are nutrients needed in smaller quantities for plant health, most come from the soil
  - Boron (B), Chlorine (Cl), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Zinc (Zn)



Nitrogen (N)

- Roles in Plants:
  - Essential for chlorophyll development
  - Dark green leaves indicate adequate N
- Deficiencies look like:
  - Yellow/pale **older leaves**
- **N is very mobile in plants and soil**
- Oversupply of N:
  - Excess vegetative growth, no flowering
  - Delays in plant maturity
  - Water pollution

Managing N in Soil

- Maintenance of OM to ensure long term source of N in soil
- Regulation of N fertilizers
  - Minimizing N loss through leaching
- **Legumes (beans) in crop rotations**
- Ideal soil pH 5.5 – 6.5

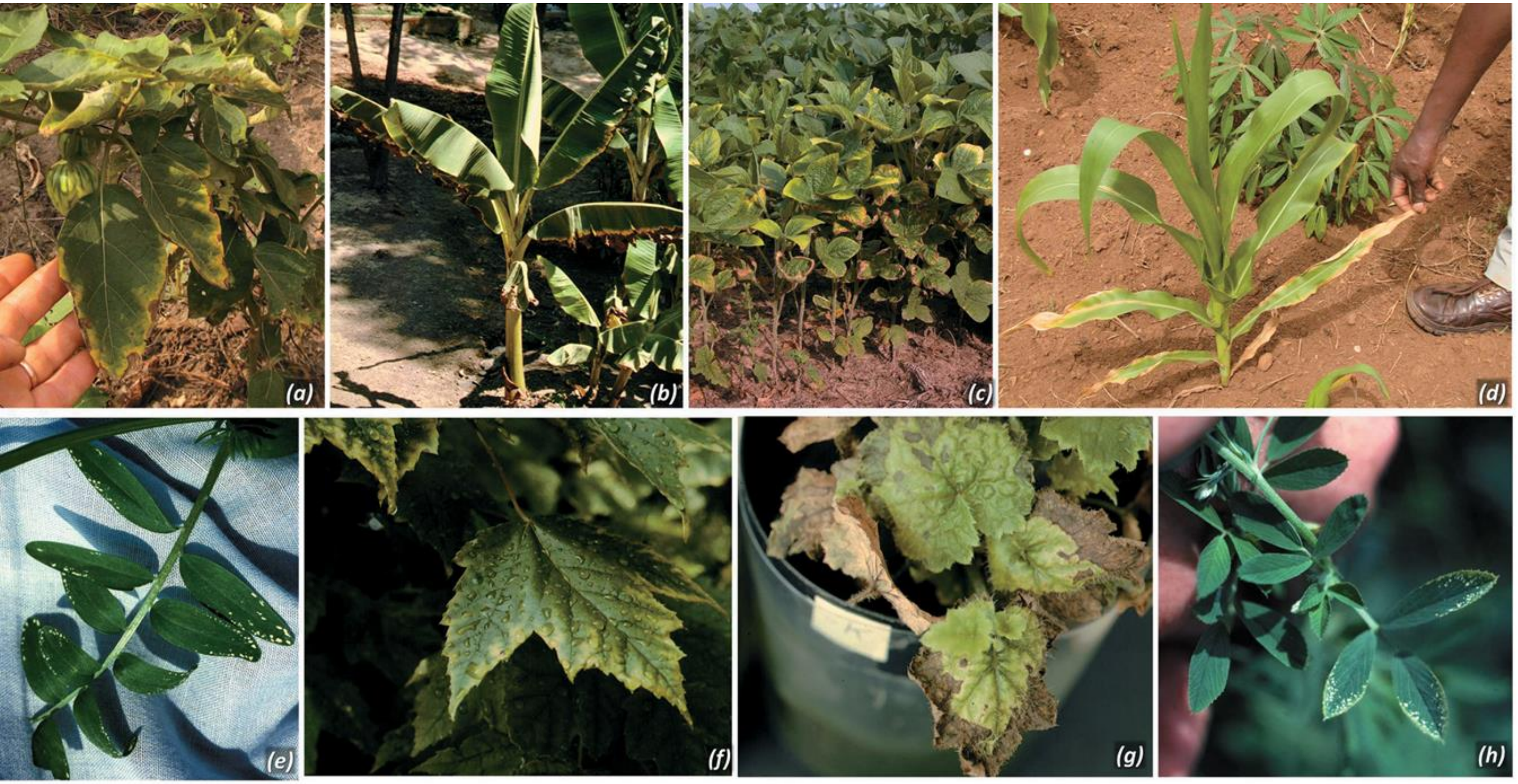
Phosphorus (P)

- Roles in Plants:
  - Enhances flowering, fruiting, seed development
    - Essential for plant **maturation**
  - Encourages **root growth**
- Deficiencies:
  - Delayed maturity
  - Sparce flowering
  - Poor seed quality
  - **Purple leaves and stems**
    - First shows in older leaves, P is very mobile in plants

Managing P

- Challenge is to add enough P to soils so that plants can efficiently uptake, but to avoid adding too much/wasting P
  - P fertilizers are only available to plant roots for a short time before turning into a different, less soluble form of P after awhile in the soil.
- Enhancing roots with **mycorrhizae** aids in P uptake
- Localized placement of P fertilizers aids in plant uptake and reduces waste/leaching
- Control soil pH
  - 6.0 to 7.0
- Add OM to soils
- Minimize runoff and erosion

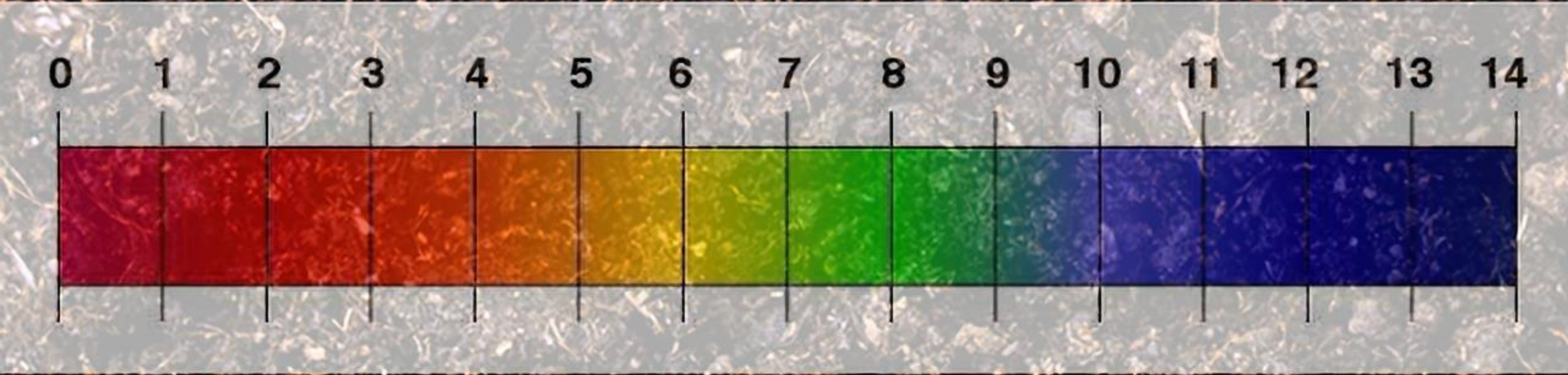
Potassium (K)



- Roles in Plants:
  - **Helps plants respond to stress**
    - Good K levels help plants withstand drought, temperature changes, and pests and diseases.
- Deficiencies:
  - **Yellow/brown crunchy leaf tips and margins**
  - Small, white, necrotic spots on leaves
  - Mobile in plants, deficiencies seen first in older leaves

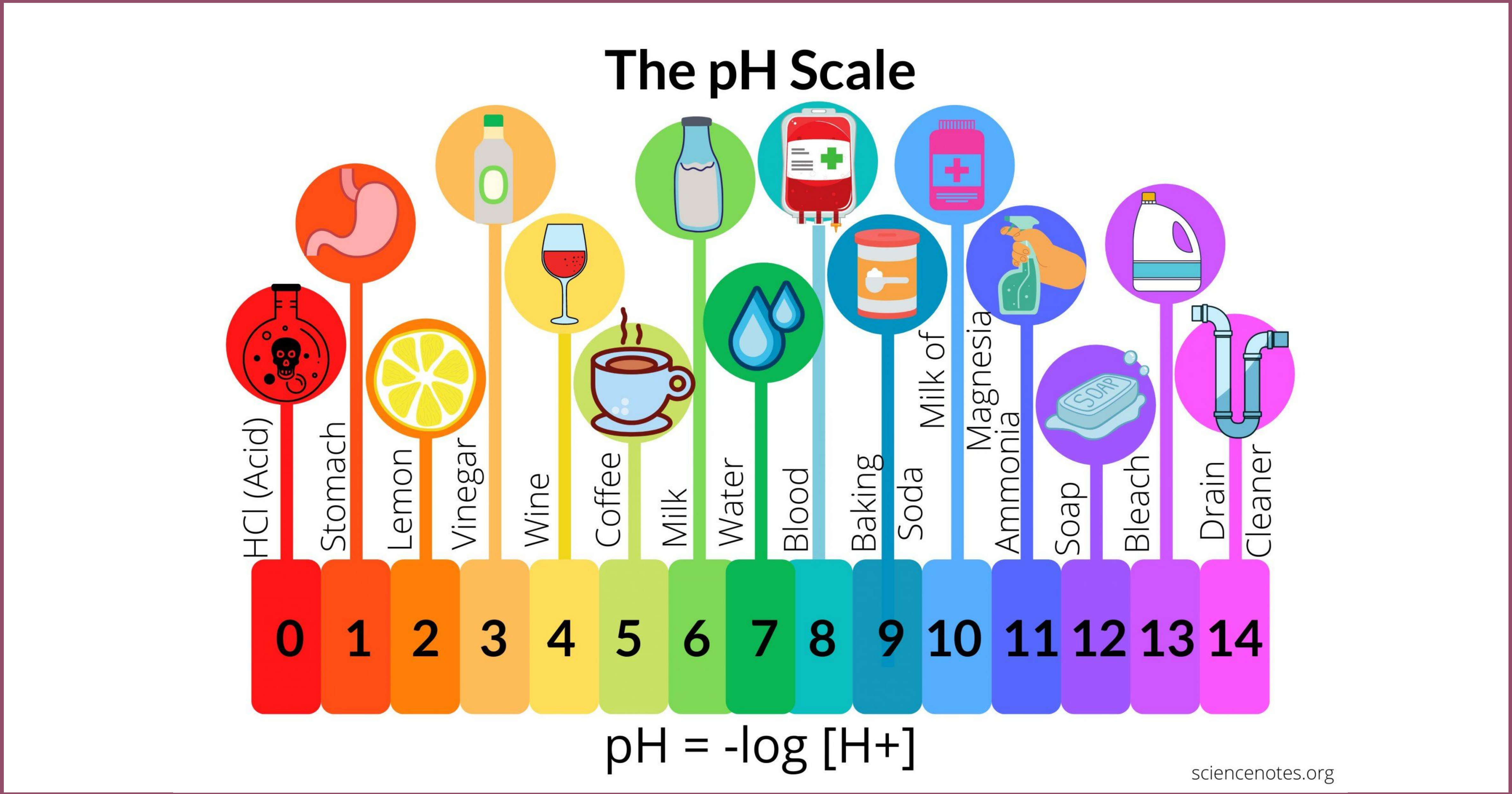
Potassium (K)

- Found in large quantities in most soils
  - Moderately available to plants
    - 1-2% of K in soil is available to plants
- Managing K in soils:
  - Frequent, light K fertilization helps keep plant available forms in the soil
  - Adding OM + microbes
  - Reduce leaching
  - Ideal soil pH 5.5 – 6.5



Soil pH

- Soil pH affects the mobility of chemicals in the soil and influences their breakdown, their solubility, and their adsorption to colloids.
- Soil pH determines what types of plants and soil microbes dominate the landscape under natural conditions.


The pH Scale
HCl (Acid)
Stomach
Lemon
Vinegar
Wine
Coffee
Milk
Water
Blood
Baking Soda
Milk of Magnesia
Ammonia
Soap
Bleach
Drain Cleaner
SOAP
0
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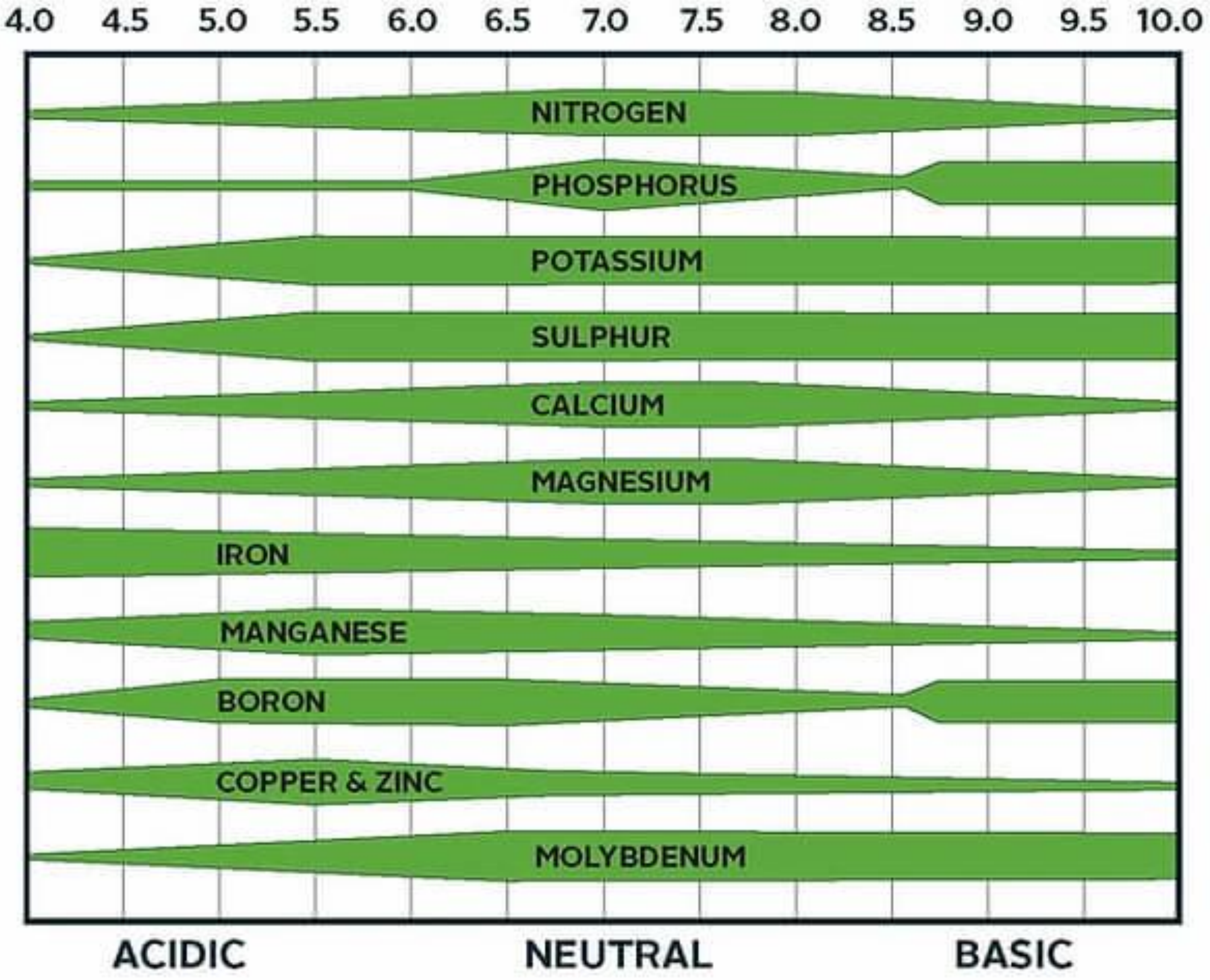
11
12
13
14
pH = -log [H+]
sciencenotes.org

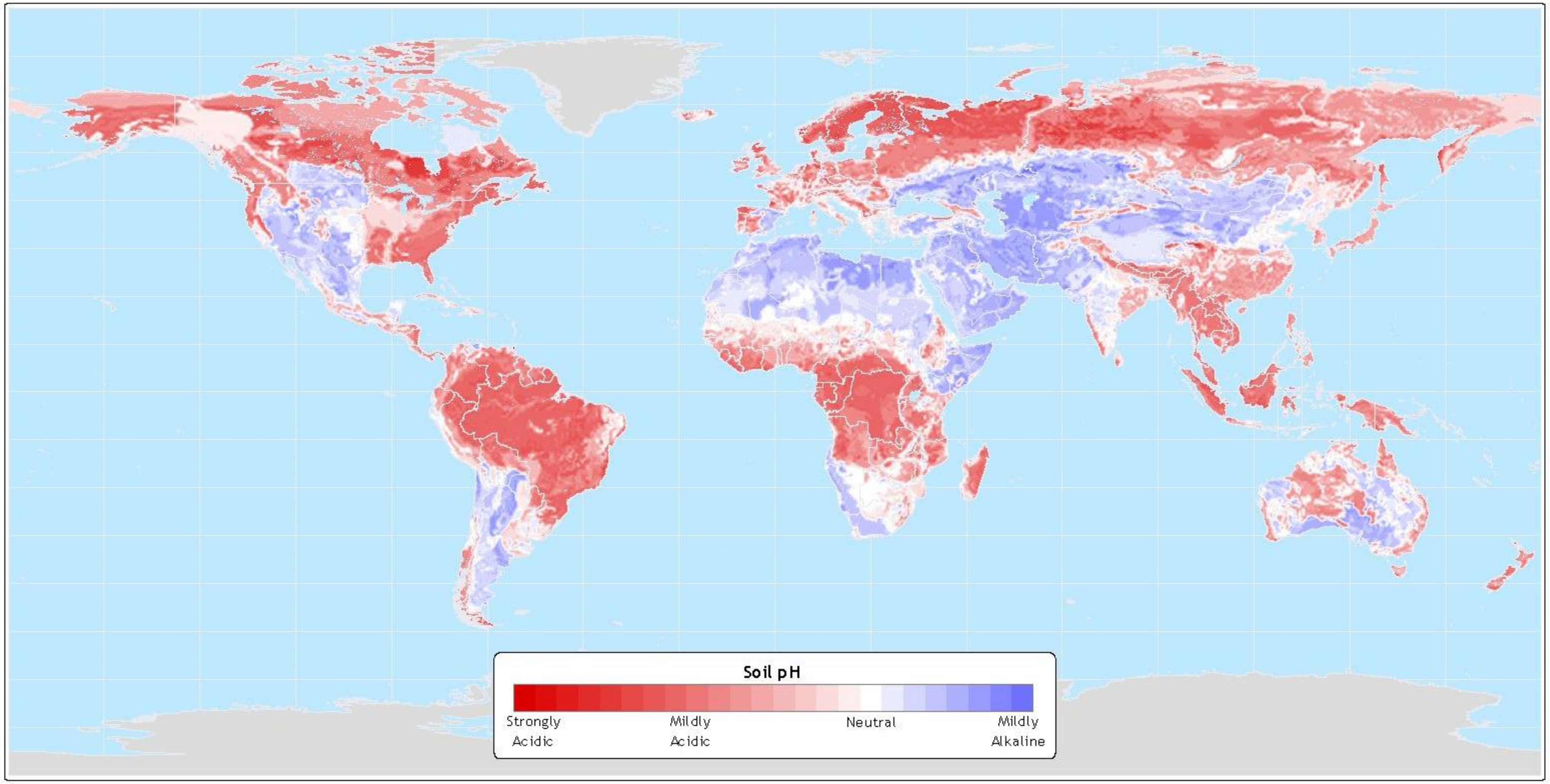


Most plant nutrients are available in 5.5 to 7.0 range

Soil Acidity

- Whether a soil is acidic (low pH), alkaline (high pH), or neutral (in the middle) is determined by how many **H+** ions are in the soil.
- **As pH increases, H+ decreases**

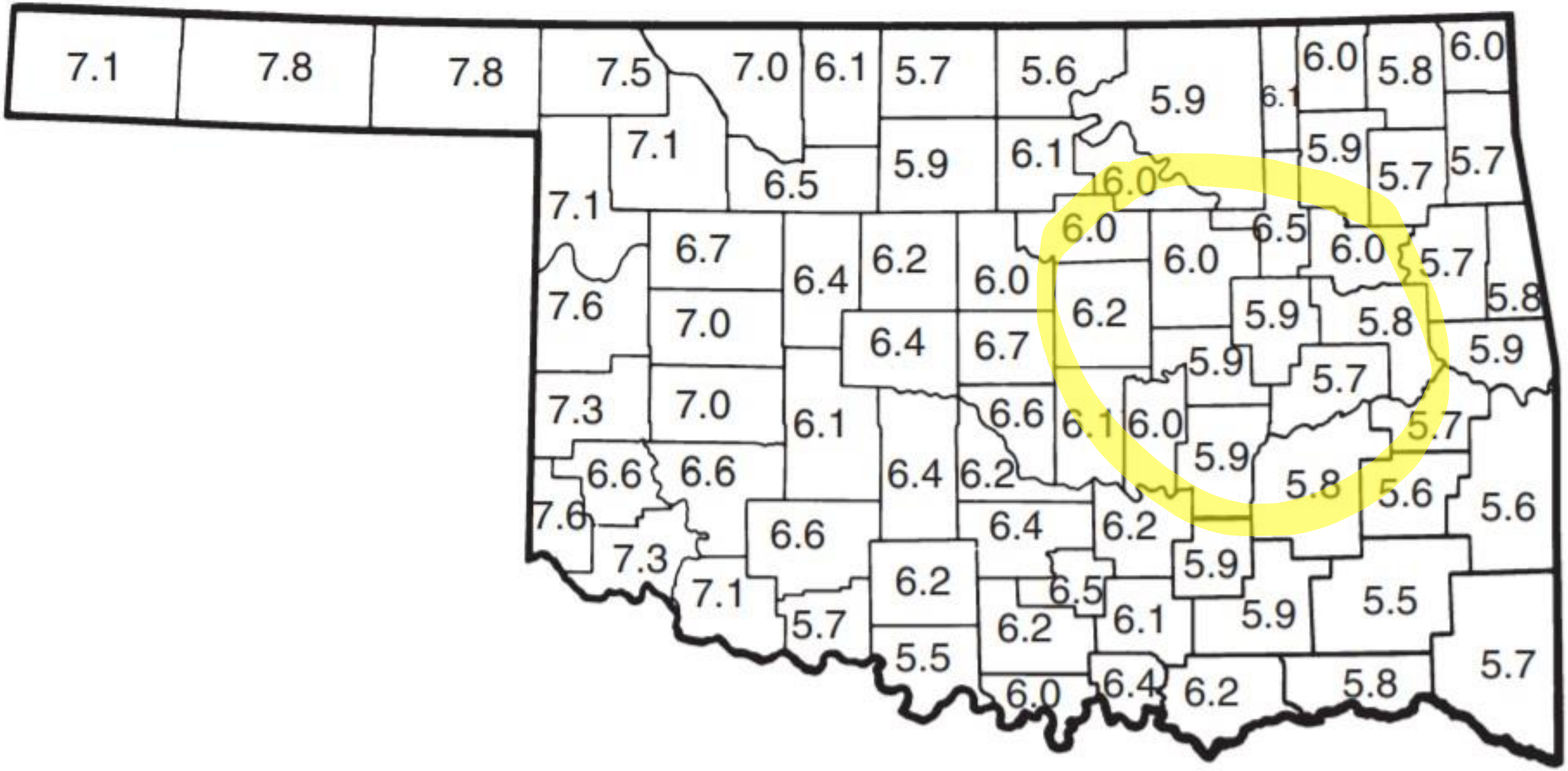
Soil pH



Data taken from: IGBP-DIS Global Soils Dataset (1998)

Atlas of the Biosphere

Center for Sustainability and the Global Environment
University of Wisconsin - Madison



7.1
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7.1
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6.5
5.9
5.7
6.2
6.1
5.9
5.5
5.5
5.7
6.0
6.4
6.2
5.8

- **<u>Aluminum (Al) Toxicity</u>**:
  - Most common problem associated with acidic soils
  - Affects soils with a pH below 5.2
  - **Aluminum is not a plant nutrient**
  - Aluminum is very soluble at low pH
  - When aluminum is taken up by a plant, it remains in the root and does not translocate throughout the plant.
    - Aluminum damages root cells by inhibiting calcium uptake.
  - **Causes visually stunted root growth**
  - **Can be reduced with high OM**
    - **OM has charge sites that tightly hold on to aluminum**

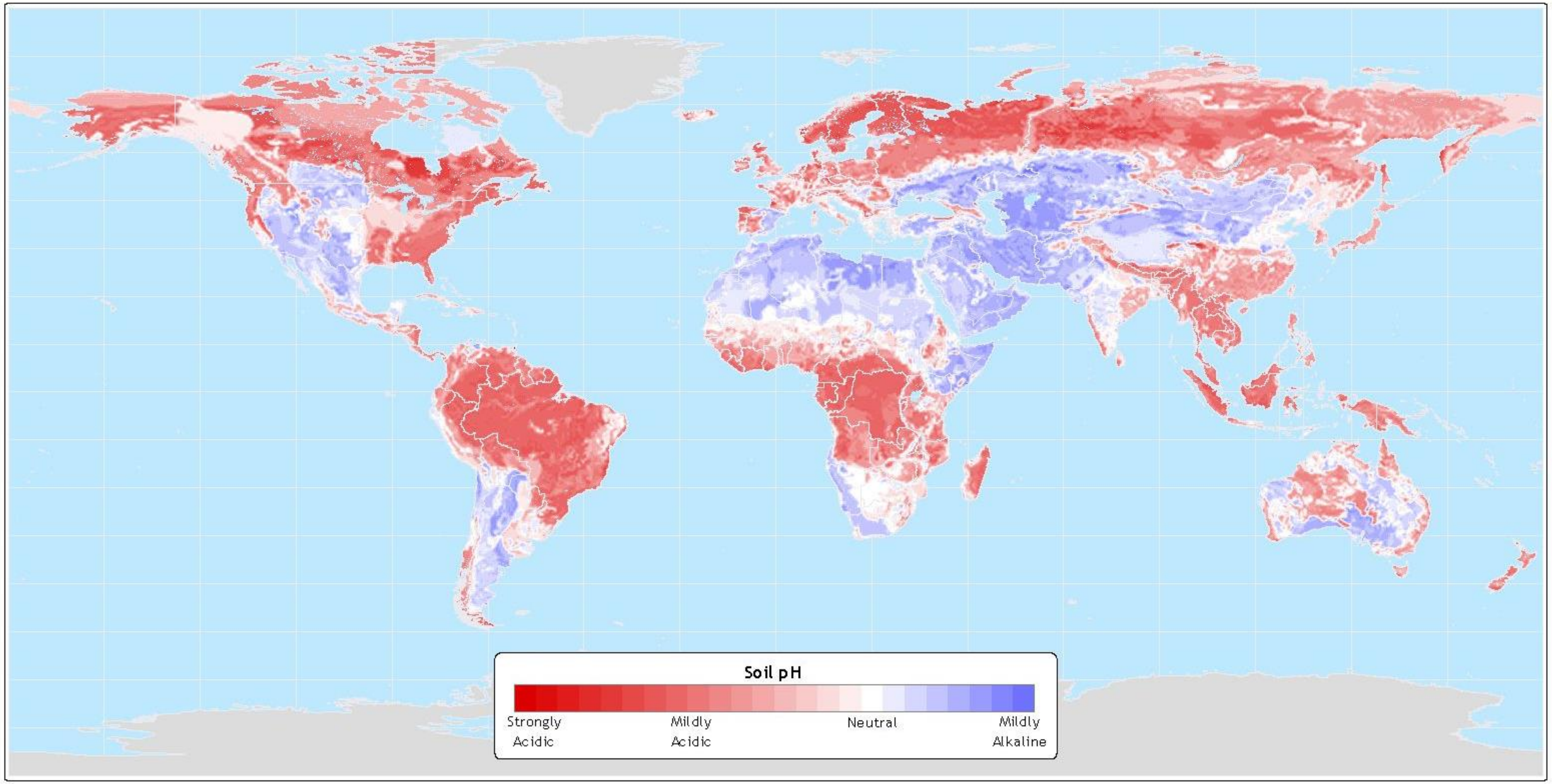
Raising pH by Liming

- Soil pH can be raised by liming.
- **Agricultural limes** – Calcium (Ca) and Magnesium (Mg) amendments are added to soil to raise pH.
- Must be added in large quantities to influence soil pH.
- Liming materials slowly react with soil acidity, gradually raising soil pH over time
  - 3 weeks to 1 year
- Over liming can cause nutrient deficiencies.
- https://youtu.be/bF8icIrJoSI?si=F4FdN3vAhfwDp3b8

Alkaline Soils

- In dry regions, soils are more **alkaline** (pH greater than 7.0)
- In dry regions, reduced precipitation = less H+ ions.
  - As a result, minerals released by weathering accumulate in the soil instead of being washed away.
  - Many arid regions accumulate detrimental levels of salts and sodium (Na) ions.

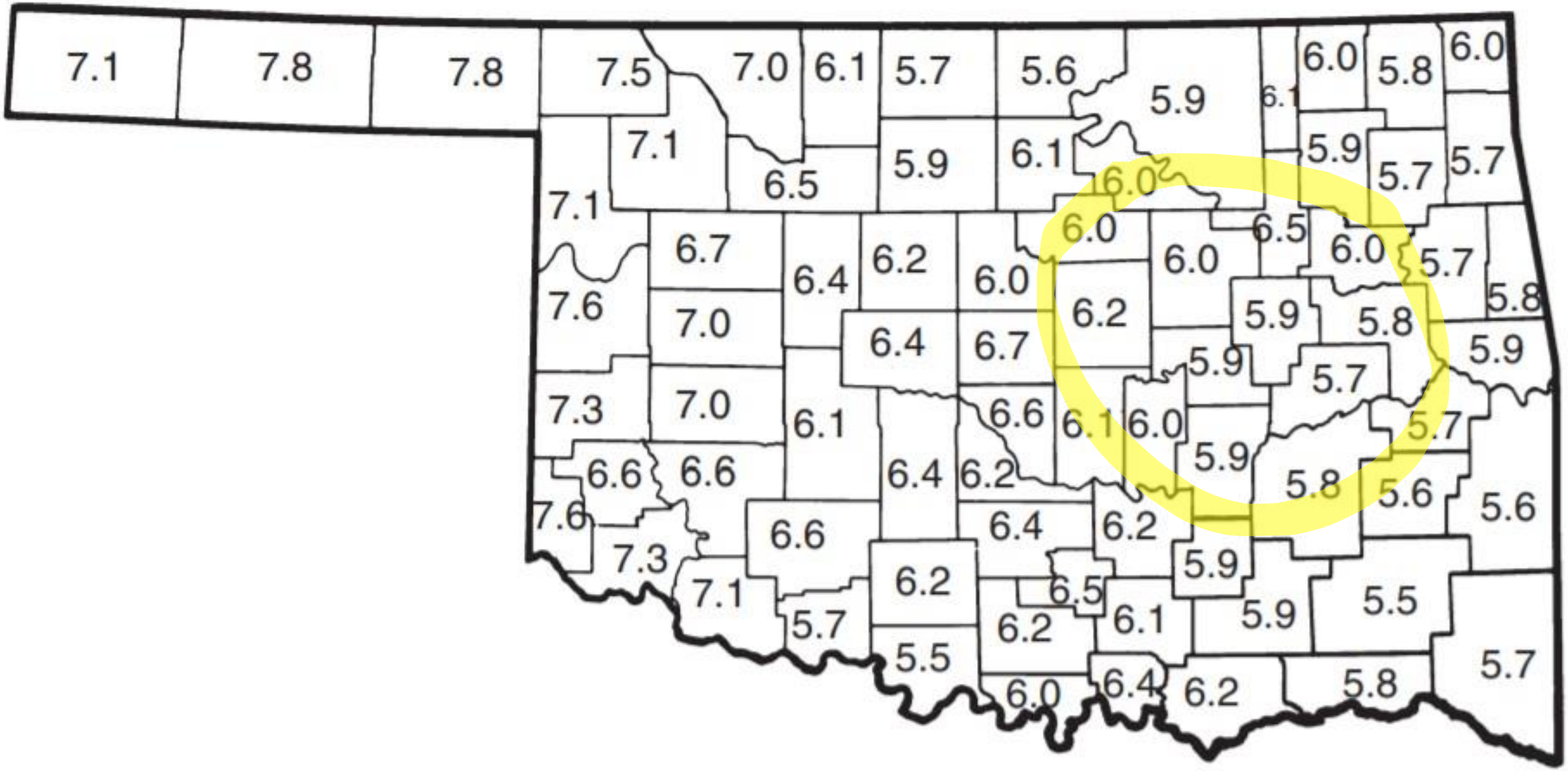
Soil pH



Data taken from: IGBP-DIS Global Soils Dataset (1998)

Atlas of the Biosphere

Center for Sustainability and the Global Environment
University of Wisconsin - Madison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Irrigation Induced Saltiness

- Irrigation + Fertilization (Fertigation) alters the water balance in soil by bringing in more water and more salts.
    - Even the best quality groundwater contains at least some dissolved salts.
- The amount of salts brought in per irrigation is very small, but it accumulates over time.
- While irrigation is necessary for food production, it does contribute to salt accumulation in soils, **especially if there is poor drainage**.

Classes of Salty Soils

- **<u>Saline Soils</u>**:
    - **Calcium (Ca) and Magnesium (Mg) accumulations**
    - pH usually below 8.5
    - May or may not impact plant growth
    - White salty crust on soil surface caused by evaporation

Classes of Salty Soils

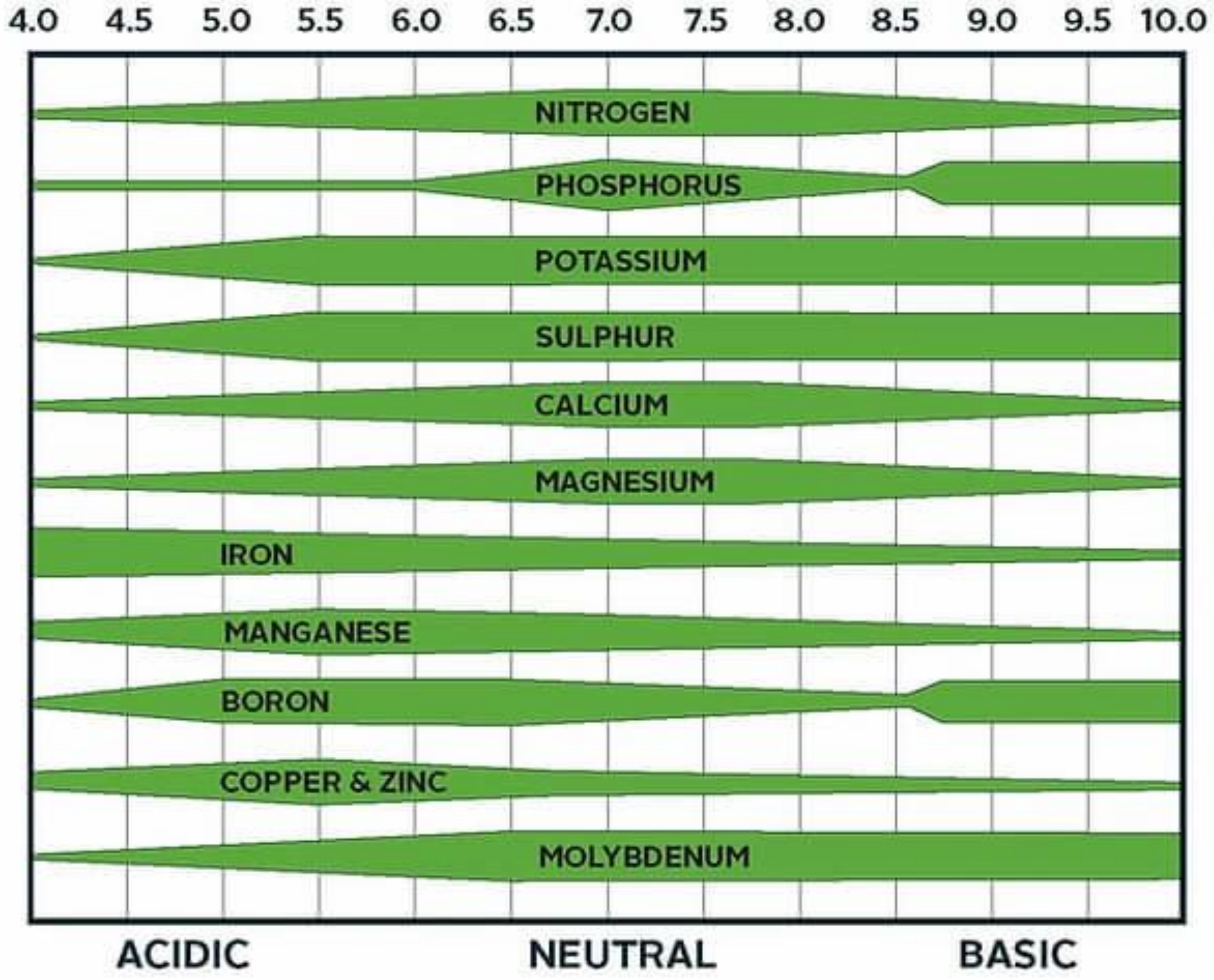
- **<u>Sodic Soils</u>**:
  - Most troublesome of salty soils.
  - **HIGH levels of sodium (Na)**
  - Some sodic soils have a thin topsoil horizon above a sodium layer.
  - pH 8.5 to 10.0+
  - Constrained plant growth – may even be barren.

Impacts of Salty Soils

- High sodium (Na) restricts water infiltration and causes water to puddle at soil surface.
- High sodium (Na) causes shrink/swell types of clay to swell even more.
- Soluble salts make it more difficult for roots to uptake water from the soil.
- Salinity delays or prevents seed germination.
- Increased levels of sodium (Na) in soil can cause potassium (K) deficiencies in plants.
- High salinity can cause necrosis of leaf margins
  - More severely on older leaves because they’ve been accumulating salts longer.

Repairing Salty Soils

- Relies on **effective drainage** and the quality of irrigation water, so salts can be leached from the soil.
- Plant salt-tolerant varieties
- Gypsum
  - Calcium (Ca) and hydrogen (H+) ions in gypsum help turn sodium (Na) ions into a from that leaches away easily.
- Sulfur/Sulfuric Acid repairs sodic soils by participating in chemical reactions that change sodium (Na) into a more soluble, leachable form.
  - **Also lowers pH**
  - Very effective at repairing sodic soils



Most plant nutrients are available in 5.5 to 7.0 range

Soil Diversity

- Species that inhabit the soil very between environments.
  - Deserts vs Rainforests
  - Undisturbed vs Farmland
- Almost all soils everywhere contain the same species of bacteria and fungi.
- **High species diversity = high functional diversity**
- Diversity creates <u>stability</u> and <u>resilience</u> in soils.
  - No single species is likely to become dominant
  - Loss of 1 species will not cripple entire soil system
- Cultivated farms are usually less diverse than undisturbed areas.

Earthworms

- Ecosystem engineers – make alterations to the soil that influence other organisms.
- Eat waste and OM in many forms
- Do not eat living plants or roots
- 7000+ species worldwide
- Ideal worm pH 5.5 – 8.5
- Earthworms require airflow so they do not live in anaerobic conditions.

How Earthworms Impact Soil

- **Burrowing** – earthworm burrows create extensive channels in the soil.
  - "Nature's tillers"
  - Helps with root penetration
- **Casts** – earthworms ingest 20-30x their weight in soil, this excess soil is expelled in globs/casts.
  - Sign of earthworm activity in soil
- **Nutrients** – earthworms are important for nutrient cycling and nutrient availability for plants.

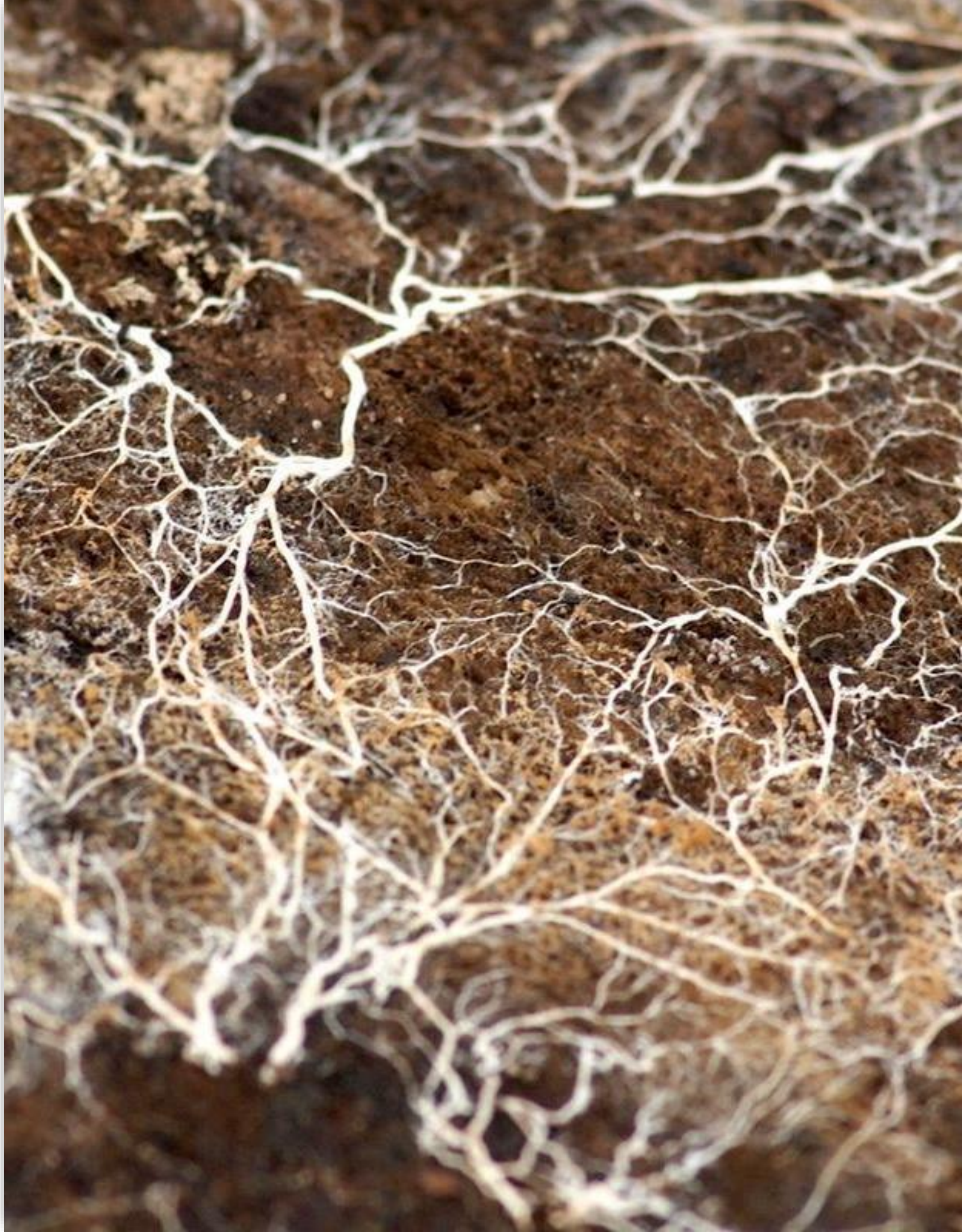
Figure 11.10 Anecic earthworm species such as these Lumbricus terrestris (a) come to the surface to feed on litter (c), excrete soil casts (a, arrows), and reproduce (b). They incorporate large amounts of plant litter into the soil and gather plant debris into piles called middens to cover their burrow entrances (d, 10 cm scale markings). Earthworms are perhaps the most significant macroorganism in soils of humid temperate regions, particularly in relation to their effects on the physical conditions of soils.
(Photos (a) and (d) courtesy of Ray R. Weil; photos (b) and (c) courtesy of Steve Groff)

Nematodes

- Predatory nematodes:
  - Eat insect larvae (fungus gnats)
  - Sold as beneficials to kill insect larvae as an alternative to pesticides
- Parasitic nematodes:
  - Pierce root cells
  - Wounds leave roots exposed to pathogens and infections
  - Infestations can kill a plant
- <u>Controlling parasitic nematodes in soil</u>:
  - Crop rotations with resistant varieties
  - Companion planting with marigolds
    - Marigold roots exude a natural nematicide
  - Soil fumigation
    - Uncommon
    - Negatively impacts environment

Fungi

- 2500+ species present in a single location
- 3 groups:
  - Yeasts are found in anaerobic soils
  - Molds are long, threadlike
  - Mushrooms are also long, threadlike
- Individual fungi strands are **hyphae**
- Group of fungi strands are **mycelia**



Mycorrhizae

- Mushroom type of fungi
- **Symbiotic relationship** between fungi and plant roots
  - “Fungus root”
- In natural ecosystems, plant roots rely on mycorrhizae for survival.
- Fungi obtains sugars from plant roots
- Fungi infects plant roots and acts as an extension of roots
  - Helps plants obtain nutrients 10x more than an uninfected plant
  - Helps cure nutrient deficiencies
  - Helps plants obtain micronutrients
  - Helps reach into nanopores
  - Reduces drought stress
  - Protects from nematodes

Conditions Affecting Microbial Growth and Activity

- **Organic Matter**
  - Microbe food
  - Stimulates microbial growth and activity
- **Oxygen**
  - Most microbes are aerobic
- **Moisture and Temperature**
  - Greatest microbial activity 68°F - 100°F
  - Still active but much slower at cold temperatures
- **Calcium (Ca) and pH**
  - High Ca + 7.0 pH = very diverse bacteria
  - Fungi dominate in low pH, but are present at all pH

Managing Soil for Organism Diversity

- Crop Rotations
- No till
    - Tilling exposes microbes
- Proper nutrition for healthy and strong plants
- Proper soil pH (5.2 – 7.0)

Good Farming Practices

Land Preparation

- Conventional Tillage
  - Practiced by farmers for over 100 years
  - Uses heavy machinery – often takes many passes over land
  - Temporarily loosens topsoil and creates a good bed for seed sowing
  - Damaging to soil if carried out every growing season over time
    - Contributes to soil erosion and compaction

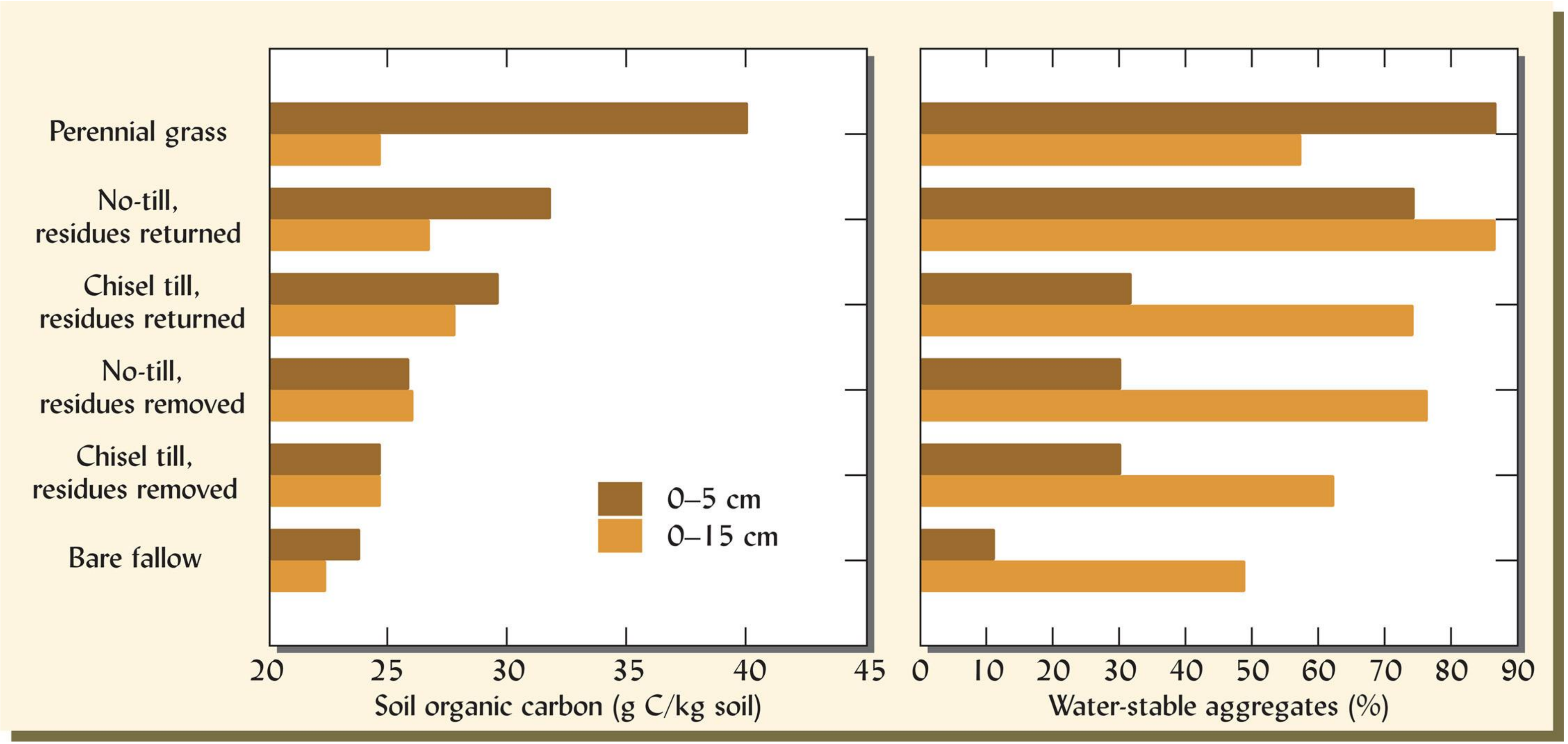
Conventional Tillage

Land Preparation

- Conservation Tillage
  - **30%** or more of crop residue left on soil surface.
  - Crop residues help protect soil from erosion, enhance soil quality, restore degraded soils, improve nutrient levels, suppress weeds, increase water retention and reduce runoff.
  - **Strip Tillage or Zone Tillage**
    - Only disturbs row or zone where crop will be planted. Space between rows is left undisturbed/crop residues left there.
  - **No till**
    - Soil undisturbed by tillage, crop residues left on surface
    - Relies on crop rotation and OM to improve soil conditions and create seedbeds
    - No till farmer
  - Conventional vs No till

- **Conservation Tillage**:
  1. Less soil erosion, less surface runoff
  2. Greater pore development
  3. Better water infiltration
  4. Increased water holding capacity
  5. Increased nutrient holding
  6. Positive changes most noticeable in surface horizon (O and A)
  7. Increased soil organisms
     - Especially worms and fungi
  8. Stays cool in summer
     - Slow to thaw and warm up in spring

Figure 12.31 Effects of agricultural disturbance intensity and plant residue removal on organic carbon and aggregate stability at two depths of Waukegan silt loam soil (Typic Hapludoll) from east-central Minnesota. The study was designed to understand how the harvest of corn stover for cellulosic biofuel production might affect soil quality, depending on how such land was managed. Experimental treatments applied for 19 years prior to the data collection ranged from maximum positive C balance with untilled perennial grass to maximum negative balance with soil kept continuously bare. There were also several corn production systems with intermediate C balances that depended on various combinations of tillage (chisel or no-till) and residue removal (all returned or 90% removed as for biofuel feedstock).
[Graphed from data in Laird and Chang (2013)]



Crop Selection

- Selecting crops depends on farmer's goals
  - N fixation? Reduce compaction? Attract/Repel certain insects? Combination?? Etc.
- **Crop Rotation** - growing different crops in a particular area every season.
  - Crop rotation is required in certified organic farming.
  - Crop rotating means that crops are not followed by a member of the same crop family. (ex. Planting corn then sorghum is not ideal)
  - Improves OM content, helps with pest management (insects and weeds), manages nutrition levels, provides erosion control.
- **Cover Crops** – grown during "off seasons".
  - Primarily used to slow soil erosion and improve soil health.
  - Cover crops provide vegetative covers between trees, shrubs, and crop rows, or on fields between cropping seasons.
  - Prevents soil erosion, provides food for microbes, provides habitat for organisms, reduces insects and diseases, legumes fix nitrogen.

Crop Selection

General Principles to Guide Crop Rotations:

Adapted from Building Soils for Better Crops (2000; Fred Magdoff and Harold van Es), chapter 11, "Crop Rotation," pp. 102–3:

1. Follow a legume crop…with a high-nitrogen-demanding crop.
2. Grow less-nitrogen-demanding crops…in the second or third year after a legume sod.
3. Grow annual crops for only one year in a particular location…
4. Don't follow one crop with another closely related species…
5. Use crop sequences that promote healthier crops.
6. Use crop sequences that aid in controlling weeds.
7. Use longer periods of perennial crops on sloping land.
8. Try to grow a deep-rooted crop…as part of the rotation.
9. Grow some crops that will leave a significant amount of residue.
10. When growing a wide mix of crops…try grouping into blocks according to plant family, timing of crops, (all early season crops together, for example), type of crop (root vs. fruit vs. leaf), nutrient needs, or crops with similar cultural practices.

Common Plant Families of Crops

Plant Family	Crops in Plant Family
Grasses	Corn, barley, wheat, oats, millet, spelt, rye, sorghum, sudex
Legumes	Peas, beans, vetch, clover, alfalfa
Mustards/Brassicas	Broccoli, cauliflower, Brussels sprouts, collards, kale, kohlrabi, cabbage, Chinese cabbage, turnips, mustard greens, canola, radish, various mustard cover crops, sweet alyssum, arugula
Alliums	Garlic, leeks, onions, chives, shallots
Cucurbits	Squash, pumpkin, cucumbers, gourds, melons
Solanaceae/Nightshade	Tomato, potato, eggplant, peppers, Goji berries, tobacco
Lettuce/Asteraceae	Lettuce, endive, artichokes, safflower, sunflower
Beets/Chenopodiaceae	Beets, spinach, Swiss chard, chard
Carrot/Apiaceae	Anise, arracacha, asafoetida, caraway, carrot, celery, coriander (cilantro), cumin, dill, fennel, hemlock, parsley, parsnip
Rosacea	Strawberries




Legumes and Nitrogen

- Fabaceae / Legume / Bean family is known for its ability to provide biological source of N in soils.
- They do this with rhizobial (root) bacteria.
  - Symbiotic (mutually beneficial) relationship.
  - Roots give bacteria energy, and bacteria gives roots N.
  - Bacteria “infects” root hairs and causes nodule growth.
    - These nodules are the sites of N fixation
- Sunn hemp, clovers, vetch, beans and peas.

Crop Selection

- **<u>Companion Planting:</u>** growing several crops near one another to enhance production.
  - Plants with known positive relationships are planted together
  - Helps reduce insect and weed infestation
  - **Three Sisters** is a popular companion planting method.
    - Corn, beans, squash
    - Video

  - Planting root vegetables with large taproots (carrots) with deep rooted plants (melons) in a compacted soil
  - Planting herbs to repel pests
  - Planting marigolds to attract ladybugs – ladybug larvae eat aphids
  - Planting flowers with vegetable crops to attract pollinators

Agroforestry

- Integration of trees and shrubs into crop and animal farming systems.
- 5 types:
  - <u>Alley cropping</u>: planting crops between rows of trees to provide food while trees mature
  - <u>Forest farming</u>: Growing crops under forest canopy – also called multi-story cropping
  - <u>Silvopasture</u>: trees, livestock, and forage grown together. Trees provide fruit and nuts and shade for cattle.
  - <u>Forest buffers</u>: Natural or restablished areas along rivers and streams made up of trees and shrubs. Helps filter runoff, prevent erosion, and supports wildlife.
  - <u>Windbreaks</u>: shelter crops, animals, and buildings against wind and dust.

Alley Cropping

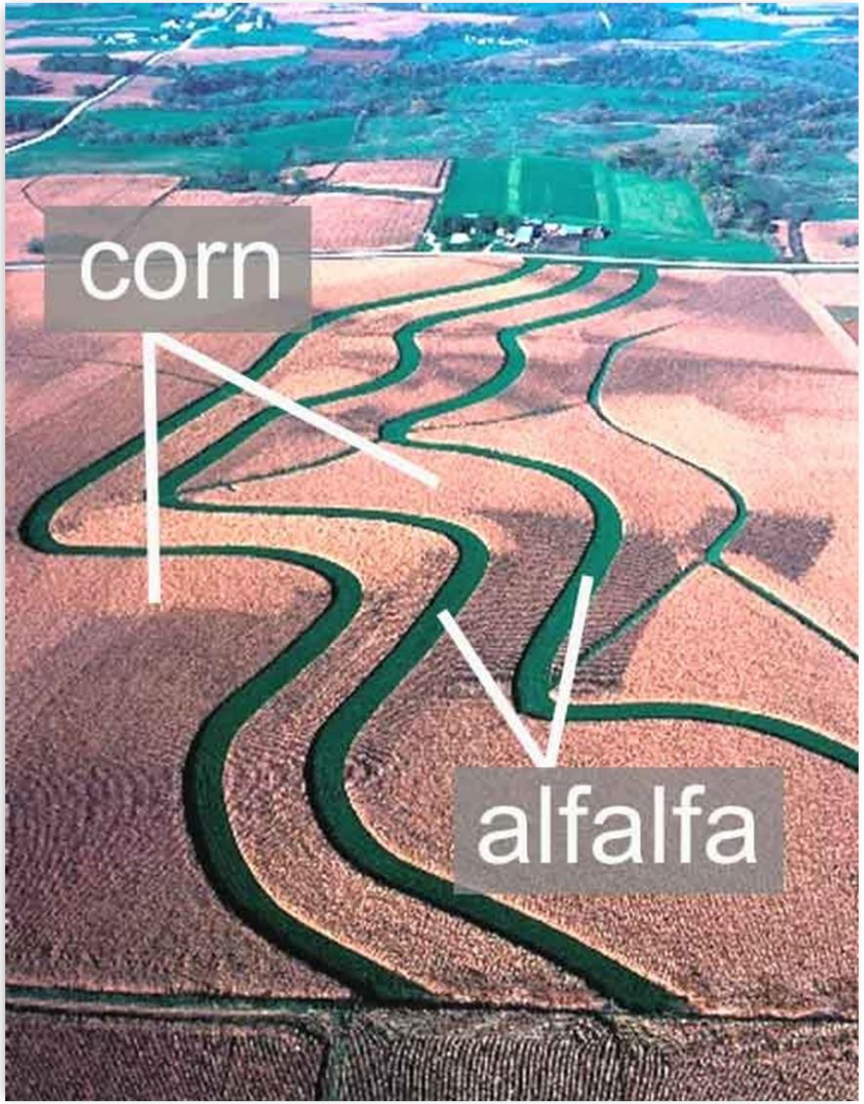
Silvopasture

Forest Buffer

Windbreak

Good Farming Practices

- **Organic mulches** provide many of the same benefits as cover crops, especially in preventing soil erosion.
  - **Straw, leaves, pine needles, wood chips are all effective mulches.**
  - Mulch layer does not have to be very thick to contribute to soil conservation.
- Contour farming across a land's contour lines slows water runoff and reduces erosion.
  - Rows of plants slow the flow of runoff water if they follow land contours across the slope.
- **Strip farming** alternates strips of different crops to prevent erosion and improve soil fertility.
  - Perennial crops alternate with annual crops
  - Cover crops alternate with row crops
  - 20m – 120m wide strips are common
- Contour Farming + Strip Cropping = **Contour Strip Cropping**



Good Farming Practices

- **Vegetative Barriers**:
  - Narrow strips of permeant vegetation (usually grass or shrubs) slow runoff.
  - Eventually forms into a natural / living terrace.
  - Elephant grass or other deep-rooted grasses are good vegetative barriers.
  - Combining grasses and trees provides erosion control and benefits like fruit, firewood, mulch, etc.

Composting

- Controlled, aerobic (requires oxygen) process that converts OM into a nutrient rich soil amendment through natural decomposition.
- Can be done using food scraps, grass clippings, woody materials, even paper shreds.
- **Helps build a healthy soil by transforming waste into valuable soil amendments.**
- Adding compost to soil:
  - Improves soil structure
  - Retains soil moisture and nutrients
  - Adds beneficial organisms to soil
  - Sequesters carbon

Integrated Pest Management (IPM)

- IPM is an approach to pest management that relies on a combination of practices.
- Takes advantage of all pest management options – including pesticide sprays.
    - Organic farming requires naturally derived sprays
- 3 General Practices:
    - Monitoring – walking garden everyday and scouting for bugs/damage
    - Prevention – companion planting, planting resistant varieties, etc.
    - Control – pesticides, beneficial insects, etc.
- Widespread pesticide use in agricultural and urban landscapes has led to contamination of soil and water.
- Most pesticides are not applied directly to the soil, but they reach the soil inadvertently.
- When pesticides are applied to a field, only
    - 1% reaches targeted pest
    - 25% reaches plant foliage
    - 30% reaches soil
    - Remainder lost to atmosphere or as runoff

Managing OM

- A continuous supply of plant residues, animal manures, composts, and other materials must be added to soil to maintain good OM levels.
- It is always preferable for soil to be vegetated rather than bare.
- Moderate nutrient applications may be necessary to help free plants from growth constraints like nutrient deficiencies and toxicities.
- Incorporate legumes (beans) and animal manures for adequate N
- **Limit or eliminate tillage to reduce surface OM loss**
- Encourage perennial vegetation, especially in natural ecosystems.

Soil Testing

- Soil should be tested to keep your farm and garden healthy and productive.
- Soil tests help farmers and gardeners determine soil nutrient and pH levels.
  - Efficient fertilizer use
  - Optimizing soil pH
  - Reduced off-site environmental pollution
  - Potential increase in crop yields
- Soil test should be performed every 3-5 years
  - Test just before your growing season (early spring)
  - Test when dormant/plants are not actively growing

Soil Testing

- Collecting a soil sample
  1. Find lab (ex. OSU)
  2. Tools needed – soil probe, soil knife, auger, or hand shovel, plastic bag, mallet may be needed.
  3. Sampling should be done at a depth of 6in-8in for gardens and farms.
     - 15-20 samples should be collected per area
     - Scattered sampling for best representation
     - OSU How to
- https://www.nrcs.usda.gov/sites/default/files/2022-09/stelprdb1167377-soil-testing.pdf

Questions??

Courtney Natseway

cnatseway@cmn.edu

918-549-2862

MVTO!!

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