soil analysis

soils in environmental science

why soil?

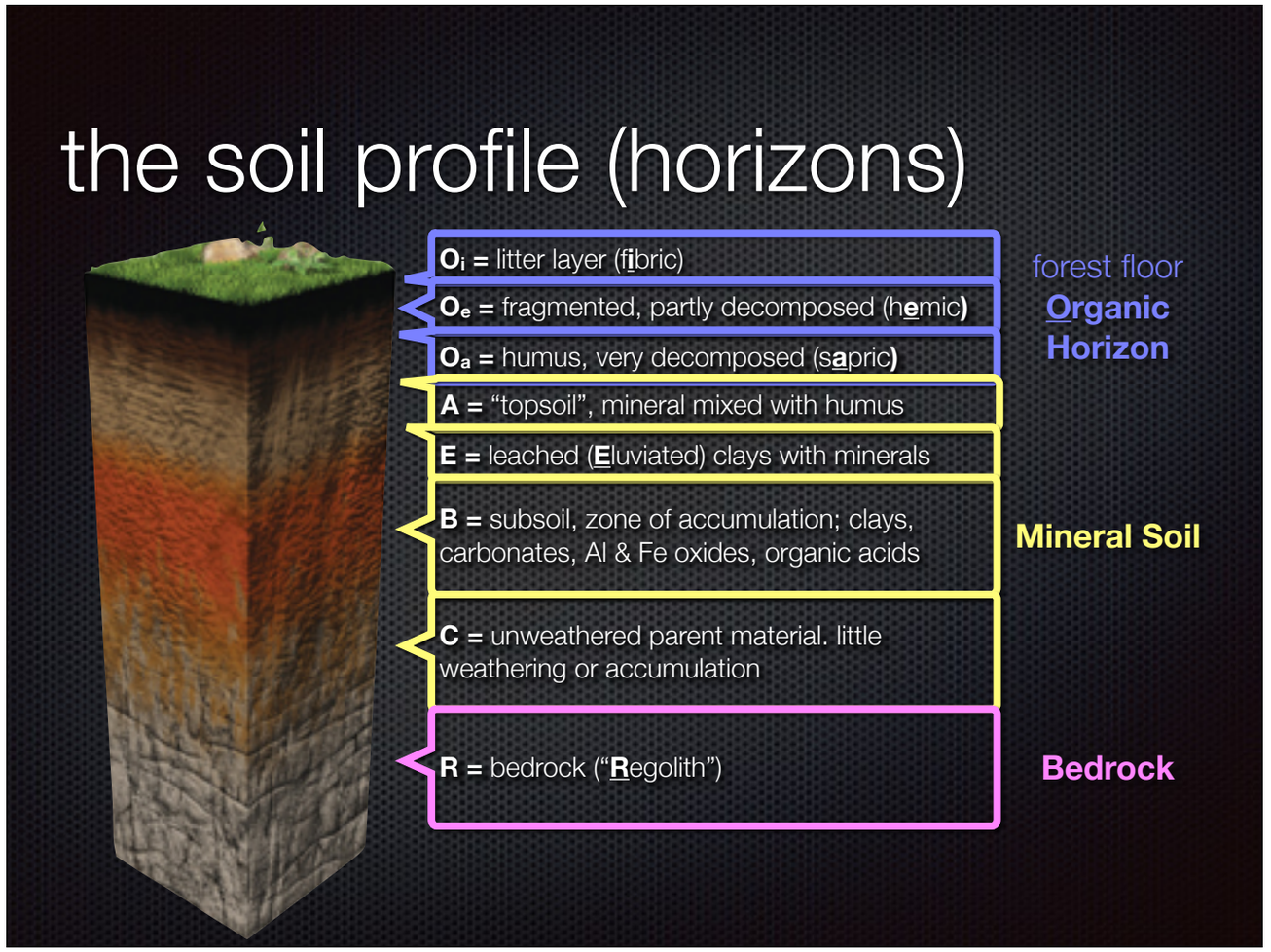
- food security
- pollution mitigation
- water filtration
- carbon storage
- non-renewable

a key ecosystem factor

- bedrock type & composition
- materials from elsewhere
- affect soil texture, chemistry, and nutrient supply rate
- **often drives variation in ecosystem processes**

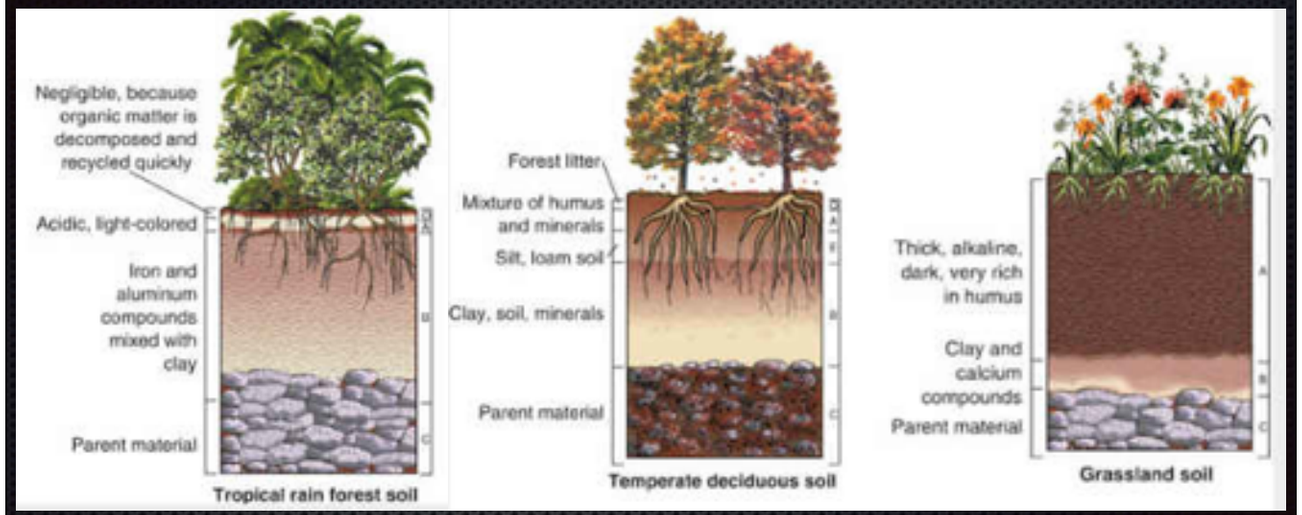
environmental soil science

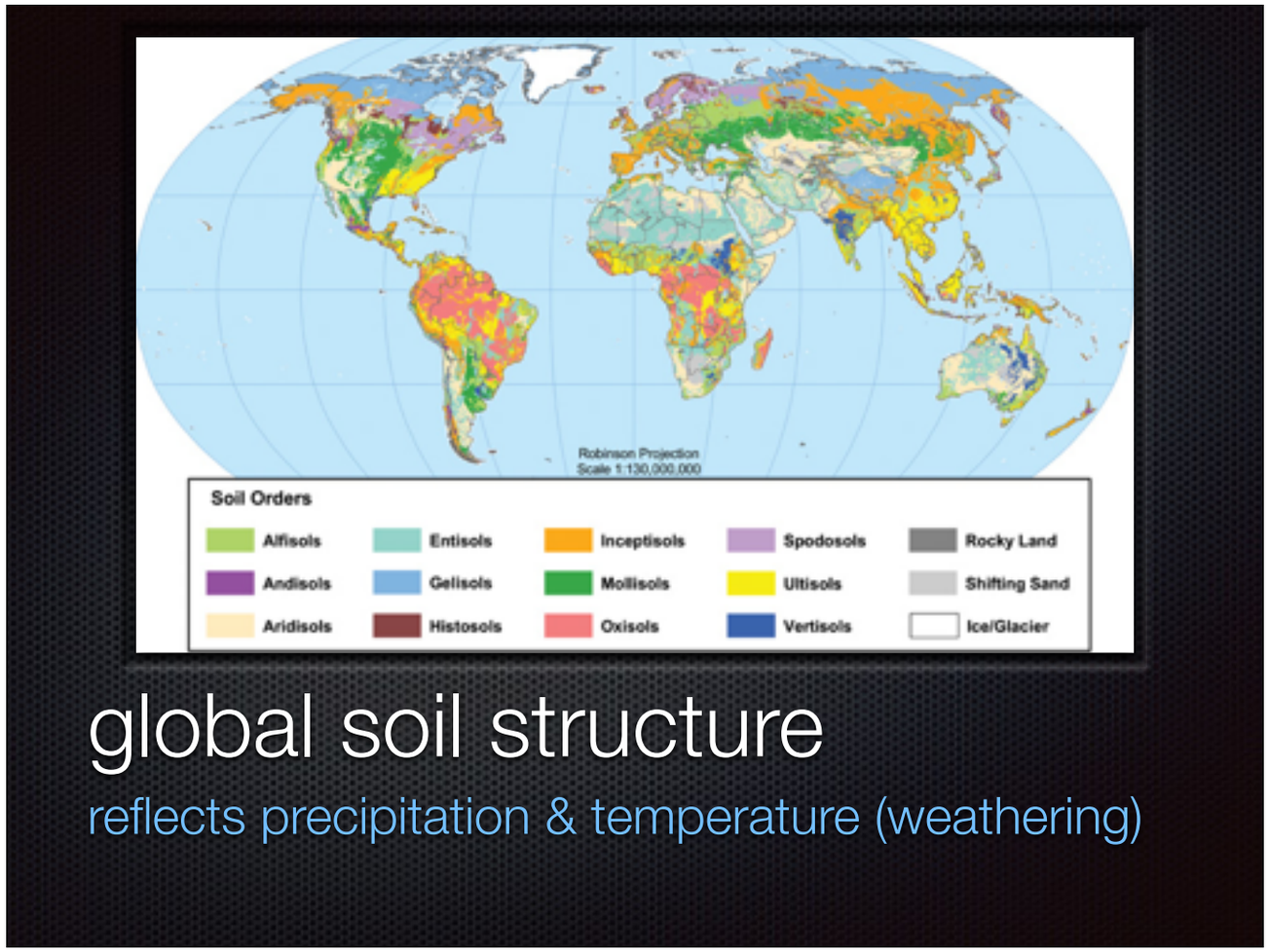
- water quality, wastewater, stormwater, erosion control, metal and pesticide contamination, wetland restoration, soil degradation, nutrient management, microbial ecology, bioremediation, genetic engineering of pollution-degrading plants and microbes, land use change, global warming, acid rain...etc.



Soil horizons are useful information for characterizing a biome. The presence/absence or the depth and thickness of a soil horizon varies greatly with local climate, disturbance, and vegetation.

common soil profiles



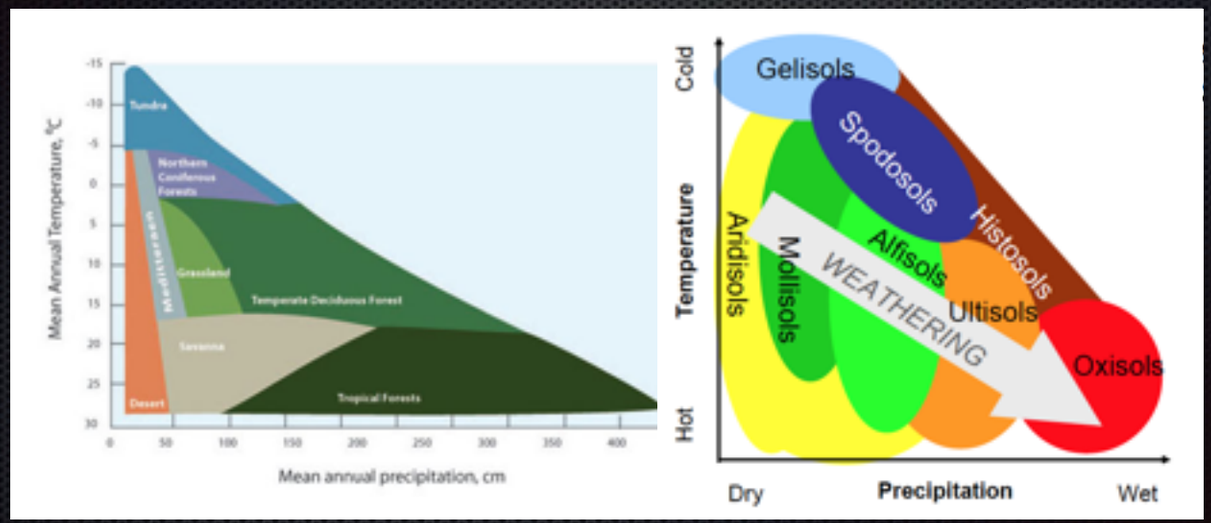


global soil structure

reflects precipitation & temperature (weathering)

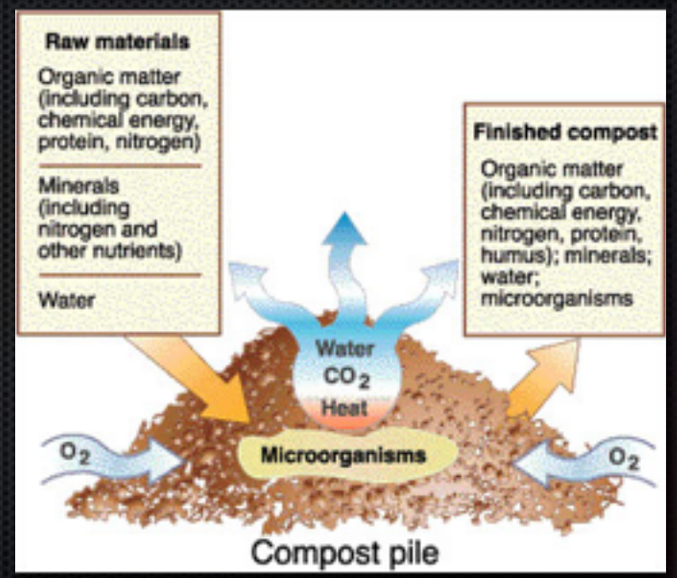
Global distribution of Soil Orders in the USDA soil taxonomy system.

soils vary with biomes



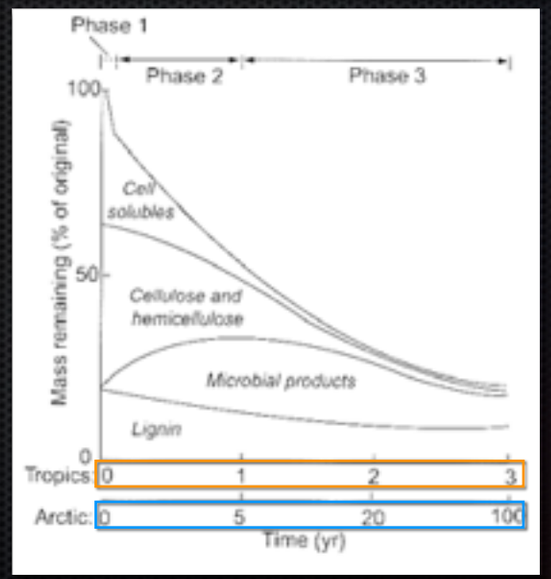
decomposition - organic

- evident in composting
- OM is respired
- CO_2, H_2O & Heat
- More decomposition = higher C:N ratio
- bacteria, fungi, inverts



decomposition rate increases with temperature

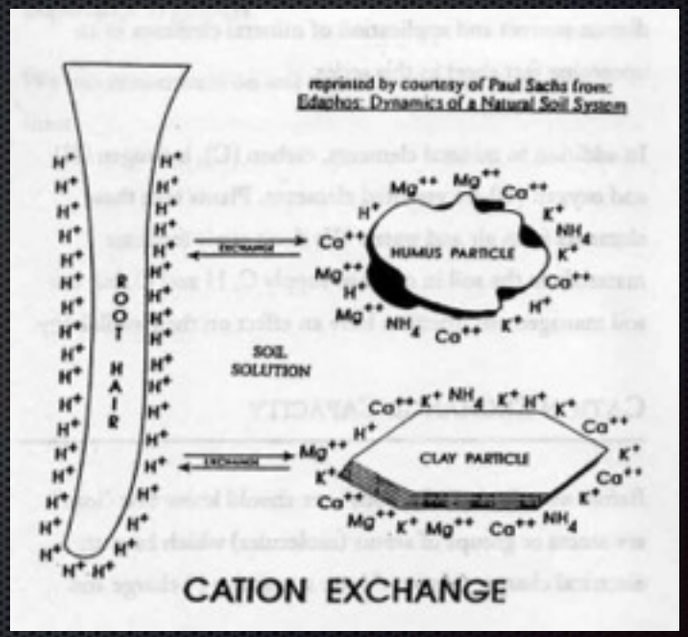
- much faster in tropics
- much slower in arctic (permafrost)
- effects of climate change = increased decomposition!



assessing healthy soils

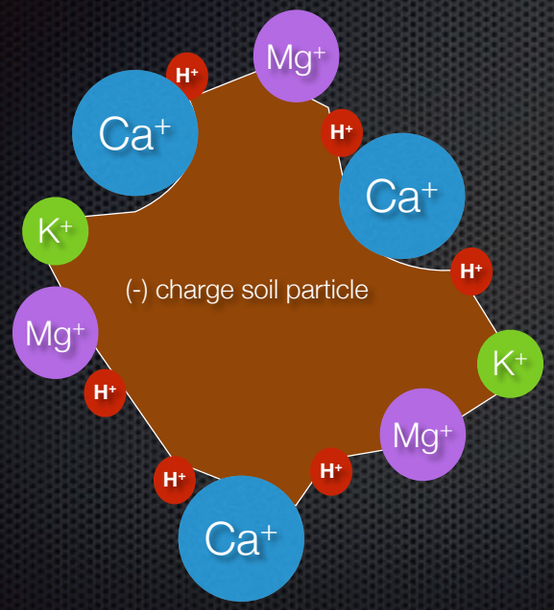
- fertility
- erosion
- contamination

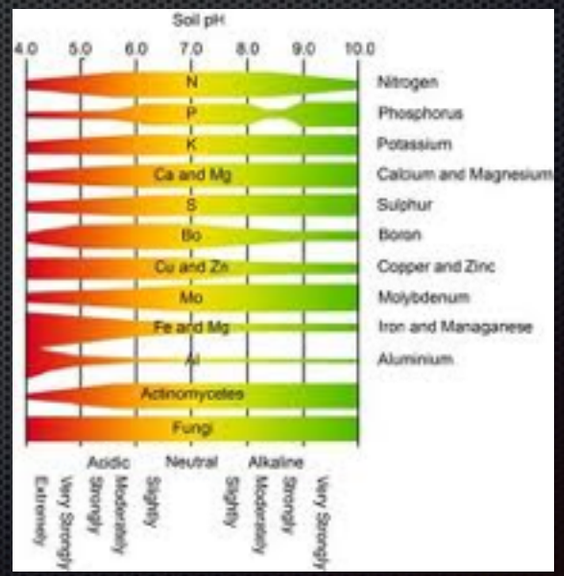
adsorption

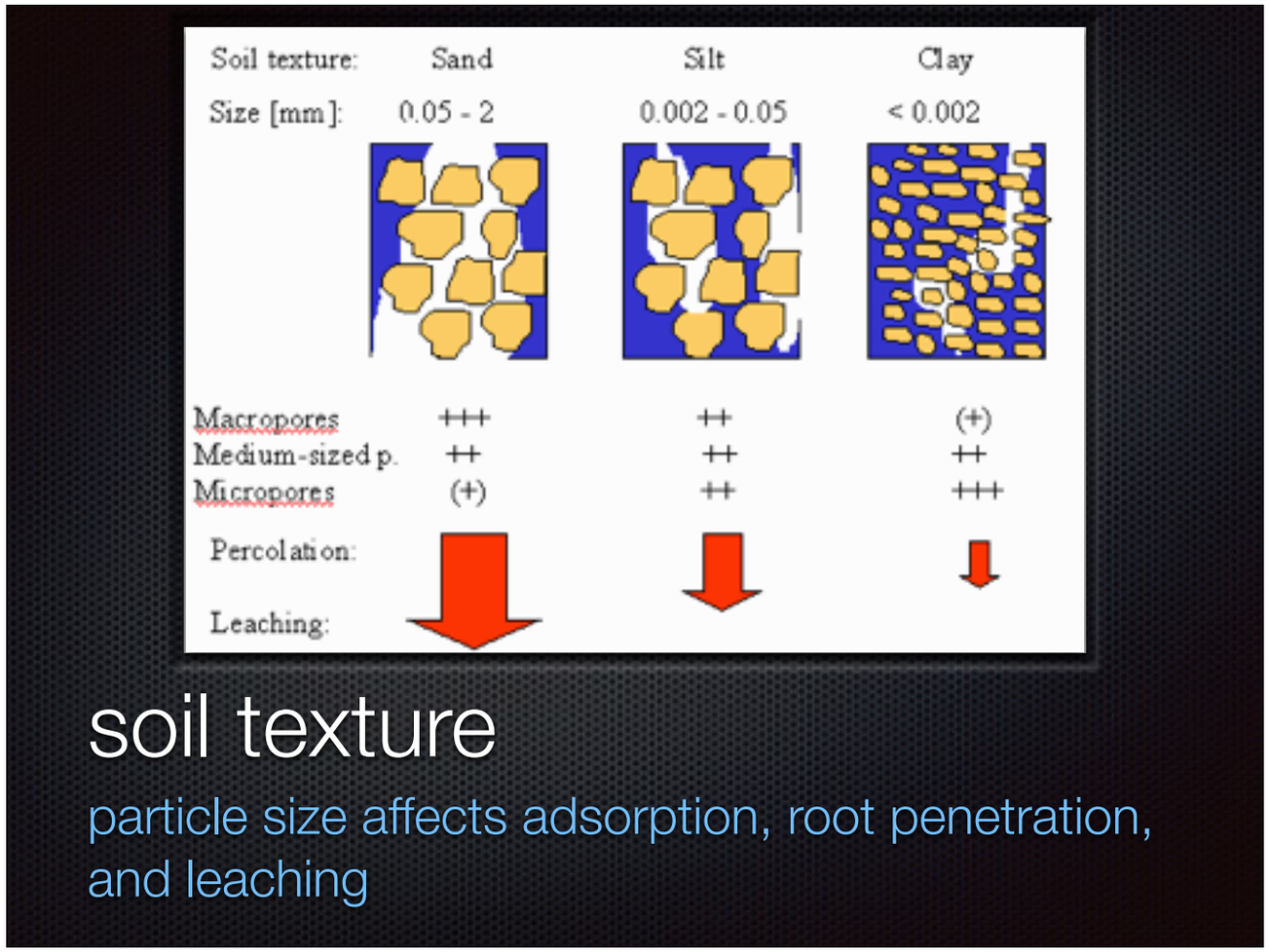


plants can remove ions from soil by releasing H+ which “competes” for negatively charged sites on the particle surface and can “bump” plant nutrients into solution.

adsorbtion and pH







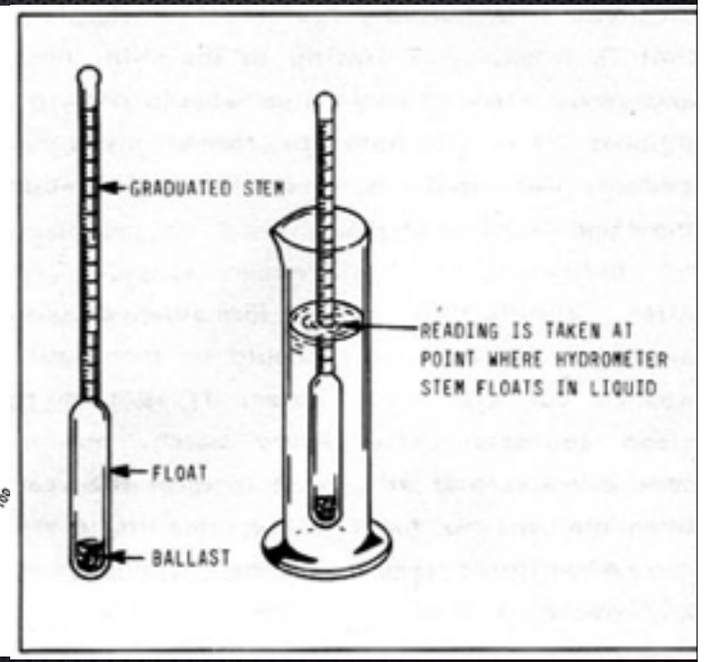
soil texture

particle size affects adsorption, root penetration, and leaching

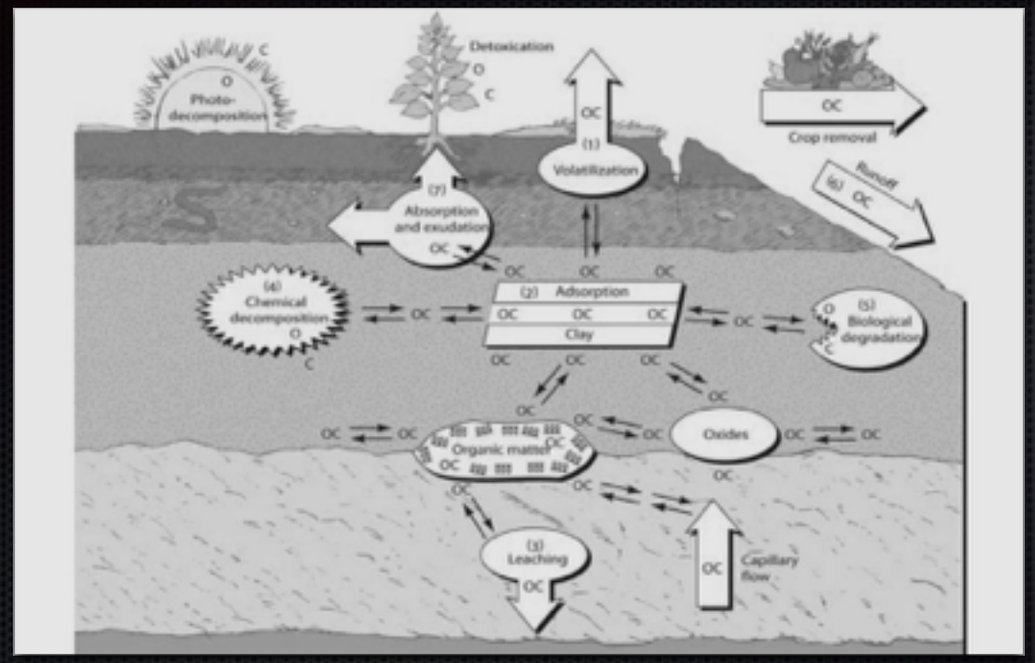
smaller particles have higher surface area, more sorbtion, but more difficult for roots to penetrate. Larger particles have higher leaching, can’t hold onto nutrients well.

quantifying soil texture

A soil texture triangle assists with classifying soil type.



soil hydrometer



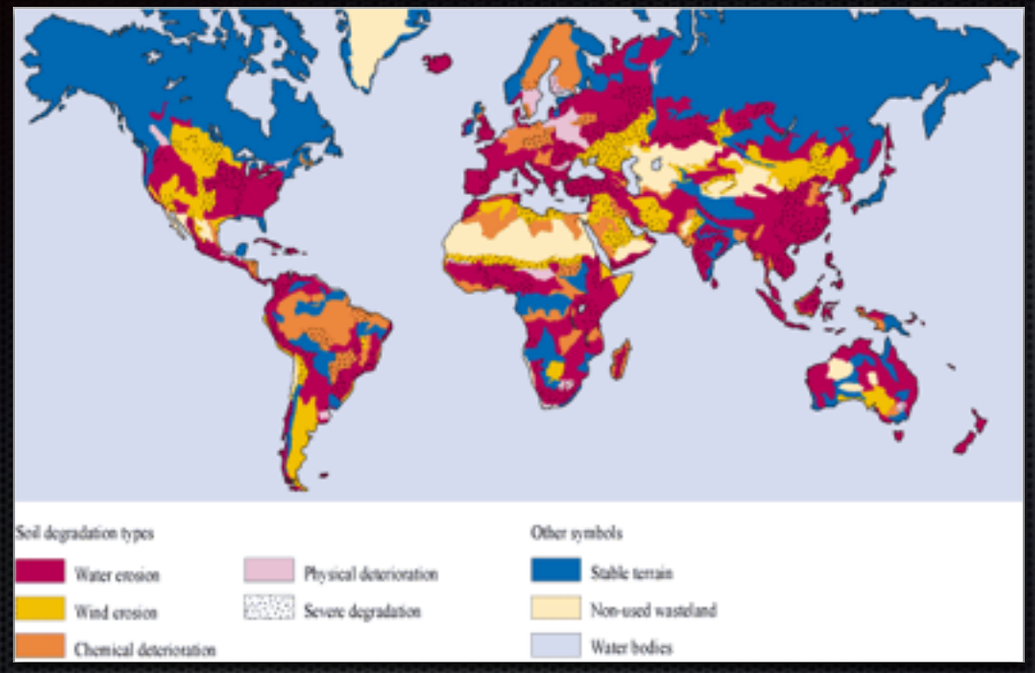
pollution

soils play a role in the flow of contaminants

The immense and sustained growth of the People's Republic of China since the 1970s has exacted a price from the land in increased soil pollution. The State Environmental Protection Administration believes it to be a threat to the environment, to food safety and to sustainable agriculture. According to a scientific sampling, 100,000 square kilometers of China's cultivated land have been polluted, with contaminated water being used to irrigate a further 31.5 million mi (21,670 km2.) and another 2 million mi (1,300 square kilometers) covered or destroyed by solid waste. In total, **the area accounts for one-tenth** of China's cultivatable land, and is mostly in economically developed areas. An estimated 12 million tons of grain are contaminated by heavy metals every year, causing direct losses of 20 billion yuan (US$2.57 billion).[8]

how does soil become contaminated?

- urban & agricultural runoff
- mining
- industrial effluents
- atmospheric deposition
- contaminated groundwater



erosion

loss of soil to water bodies

this week

- learn sampling and soil prep skills
- revisit nutrient chemistry (PO_4^{2-}; pH)
- quantify soil texture
- analyze samples for organic content analysis

<u>Field Sampling</u> for soils is varied and depends on the soil composition and the purpose for sampling. Pit cores can be sampled simply by careful digging with a shovel or a motorized post-hole digger. More precise sampling (for analyzing soil layers) can be taken using a variety of soil augers and probes. Depending on the application, care must be taken when removing the core and preparing the sample for transport and storage.

1) measure soil temperature as a function of depth using the **digital temperature probe**
2) practice taking a small soil core using the **soil probe**.
3) observe how a large soil core can be taken using the **auger**.
4) homogenize a subsample of soil from each of the samples provided (see page 1) using a **mortar & pestle**
5) sieve soil samples using the **sieve shaker** in the laboratory.

mortar & pestle (left), soil push probe (left middle), a “russian” auger (right middle), and a soil sieve shaker (right).

Soil Extraction **is a fundamental procedure for the study of soil chemistry. Briefly, soil particles are generally charged and attract positive and negative ions (cations and anions). Clays tend to be negatively charged and thus strongly bind cations (like Ca, Mg, K) while organic matter tends to have mixed charges and thus bind all ions depending on it's composition. Plants can secrete ions (like H^+) to "push" other ions off of soil particles. If the pH is slightly acidic, this process is easier for plants. We can analyze ions by forcing ions off using strong ionic solutions. Today we will DEMO the KCl extraction a common technique primarily used to assess dissolved inorganic nitrogen. However, we will see if we can analyze phosphate instead (note that phosphate extractions are usually conducted using a bicarbonate extraction, which is not practical for our lab).**

Soil Moisture (this has been done for you)

1) Dry one 10g subsample (field moist) in oven for 48 hours @ 105°C
2) return to re-weigh the oven-dry sample.
3) calculate % moisture using:

% moisture = (field moist mass - dry mass)/field moist mass

Extracting Soil

4) Weigh out a 20g subsample of **field moist soil** in a specimen cup. With a graduated cylinder measure 40 ml 2M KCl and add to soil. Cap specimen cups.
5) Make several "blank" cups of KCl.
6) Shake for 1 hour at 200 rpm.
7) Allow samples to settle for 1 hour after shaking.
8) Set up vacuum filter with 9cm filter. Pretreat filters by leaching them 2x with 2M KCl.
9) Vacuum filter the supernatant through filter paper and collect extract into pre-labeled vials or sample bottles.
10) Freeze extracts to store.

A filtration system for preparing multiple extracts simultaneously.

STATION #2: SOIL PHOSPHATE DETERMINATION (SPECTROPHOTOMETRY)

Phosphate (PO_4^{2-}) limits terrestrial plant productivity and is vital for essential plant functions including ATP cycling (energy), photosynthesis (reductants like NADP), sugar cycling, and DNA synthesis. Lack of P reduces leaf and root growth and extension. Again, we will measure soluble reactive phosphate (SRP or orthophosphate = dissolved inorganic phosphate), which is directly taken up by plant cells.

1) create a combined reagent <u>in the following order</u> with mixing after each addition:
- **i.** 5mL H_2SO_4 (5N)
- **ii.** 0.5mL potassium antimonyl tartrate
- **iii.** 1.5mL ammonium molybdate
- **iv.** 3mL ascorbic acid

2) all solutions should be at room temperature before proceeding.
3) pipette 5mL of each standard and soil extract** into a 15mL "Falcon" tube (see table to the right)
4) add 0.8mL combined reagent to each tube. Screw on cap and vortex.
5) wait 10 minutes but no more than 30 minutes to measure
6) pour 5 mL of each standard and soil extract into the cuvette and record the absorbance at **880 nm**. Make sure the mark on the cuvette is lined up with the mark on the spectrophotometer. Rinse cuvette with DI water between each sample.

** Recall that the soil extract was made by diluting 100g soil in 200mL KCl solution**

9) calculate the equation of the line of best fit from the standard curve using the laptop. (Absorbance = slope * concentration + intercept.
10) using the absorbance values from your extracts, calculate their concentration based on the best fit line.

Concentration (ug L^{-1})	Absorbance (880)	Extract	Absorbance (880)	Concentration (ug L^{-1})
0		Shek O		
100		A		
200		B		
400				

QUESTION: HOW DO YOU CALCULATE THE FINAL SOIL EXTRACT CONCENTRATION?

STATION #3: Soil pH

Soil pH is critical for plant growth as the relative acidity/alkalinity of the soil affects the abundance of dissolved free ions in water surrounding soil particles. relatively acidic soils contain more free ions and thus more nutrients available for plant growth. Use of the pH probe is as before (instructions below). This time you will stir the probe in a **beaker** with the soil solution to improve the precision of our analysis. The probe is calibrated to pH 4 and 7.

1) add 10g of each soil sample to 10mL DI water in a small beaker. stir.
2) allow the solution to equilibrate for 15min. stir.
3) carefully remove the pH probe from the storage solution by first unscrewing the cap, removing the bottle, and then sliding the cap off the probe. GENTLY! **DO NOT YANK THE STORAGE BOTTLE OFF THE PROBE OR YOU MAY BREAK IT!**
4) open the blue vent on the side of the probe.
5) rinse the probe with DI water
6) Use the pH probe to measure the pH of two standards pH 4.0 and pH 7.0 **while stirring**. **rinse the probe between each measurement** with DI water.
7) if the standards do not match the pH reading, please inform your demonstrators.
8) if the readings match, Record pH for each soil solution, while stirring and **rinse the probe between each measurement** with DI water.
9) rinse and store the pH probe in the provided storage solution bottle. First, slide on the cap and o-ring with the threads facing down. Then insert the probe into the bottle's solution. Bring the cap down and screw on gently.
10)replace the vent cap

Figure 1. Soil pH and Plant Growth

Soil Reaction	pH	Plant Growth
	>8.3	Too alkaline for most plants
	7.5	Iron availability becomes a problem on alkaline soils.
Alkaline soil	**7.2**	6.8 to 7.2 – "near neutral"
Neutral soil	**7.0**	6.0 to 7.5 – acceptable for most plants
Acid soil	**6.8**	
	6.0	
	5.5	Reduced soil microbial activity
	<4.6	Too acid for most plants

STATION #4: ORGANIC CONTENT

% Organic is calculated by mass difference. A mass of soil is weighed and then combusted in a **muffle furnace.** Unlike a drying oven which we've used for drying filters and incubating microbes, a muffle furnace is capable of much higher temperatures (>500 ºC). As such, the muffle furnace is a suitable tool for removing organic matter via burning. For example, the GF/F filters we used in the water quality laboratory were pre-combusted in the muffle furnace to remove organic matter contamination.

1) pre-weigh a ceramic crucible. to this add 1g oven-dried soil of any type
2) label the crucible on the bottom with pencil (marker will burn off in the furnace).
3) carefully place in the muffle furnace.
4) combust at 500ºC for at least 6 hrs (this will be done for you).
5) move samples from the furnace to a low humidity dessicator to avoid water re-absorption.
6) in 24 hrs, re-weigh the crucible and subtract the initial mass from the final mass to determine the mass of material remaining. the "ashed" sample now contains only the inorganic fraction of the soil sample.
7) calculate % organic matter using the equation below.

A common muffle furnace. Note the thick insulating layer on the inside to prevent overheating of the exterior

% organic matter = (oven dry weight - ash free dry weight) / oven dry weight