Soils, Soil Water and Soil Fertility

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This is a test……

are you smarter than the average 5th grader?

- You can't teach and old dog new……
  - Math
- An idle mind is the ……
  - Best way to relax
- A penny saved is……
  - Not much
- It's always darkest before……
  - Daylight savings time

What I hope to teach

- A basic understanding of soil physical & chemical properties, soil water, plus the basics of soil fertility and fertility sources (fertilizers, green manure, manure)

Agriculture and Culture - 1

- Agriculture is about culture
  - The 'local's have survived there a long time
  - There is always local 'knowledge'
  - Locals understand their environment
  - But, stuck there, little outside input
  - Observation can be valuable, but explanation of 'why' is lacking (even US farmers!)
  - What are local traditions and eating habits/preferences?

A Balanced Diet
Cereals + Food Legumes

Food Legumes:

- **High in protein and lysine but low in S-containing Amino Acids**

Protein percentage:	
Faba bean	**20 – 36 %**
Lentil	**22 – 35 %**
Grass pea	**25 – 31 %**
Kabuli Chickpea	**16 – 24 %**

Cereals/Wheat

- **Low in Protein & Lysine but high in S-containing Amino Acids**

- Combining food legumes & cereals provides a fully balanced diet: reducing malnutrition in poor communities

Cereal Improvement

Food Legumes

Agriculture and Culture - 2

- Look at the 'culture' of agriculture
  - Who are the leaders?
  - Who makes the decisions?
  - Who has the 'knowledge'?
  - Who does the work (field prep, plant, weed, harvest, thresh, store, keep seed, make flour)?
  - Who controls financial resources for inputs?

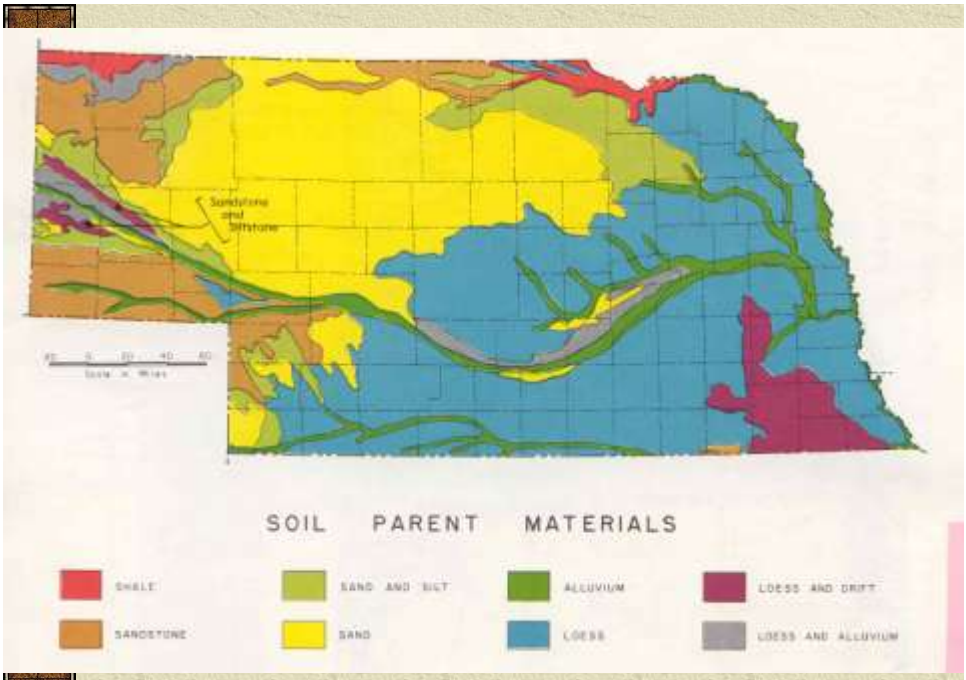
Change: Barriers and Solutions

- Barriers
  - Old Habits/Traditions
  - Lack research/knowledge
  - Perception by landlord, lenders, neighbors, family
  - Fear of Failure-$$$$
  - Long vs short term
  - Learning Curve
  - Age of producer
- Solutions
  - Planning: strategic, tactical, operational
  - Education
  - Demonstration
  - Mentoring
  - Start small: walk before you run

Units of Measure

- 1 ha = 2.47 ac = 10,000 m^2 = 107,600 ft^2
- 1 quart = 0.946 liters
- 1 lb/acre = 1.12 kg/ha
- 3 T/ha = 45 bushels/ac wheat

- How much does a hand-full weigh?
- How long is your walking pace?



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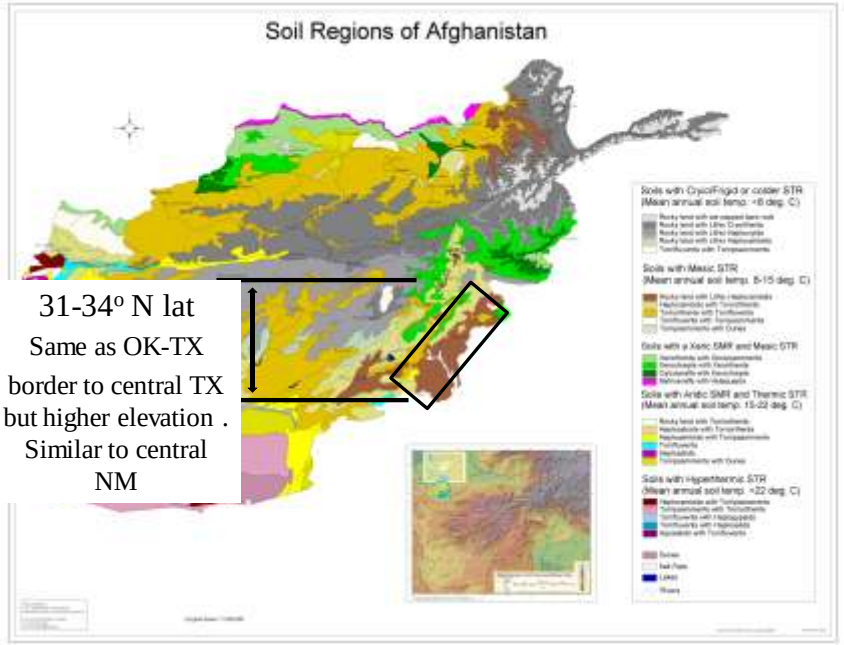
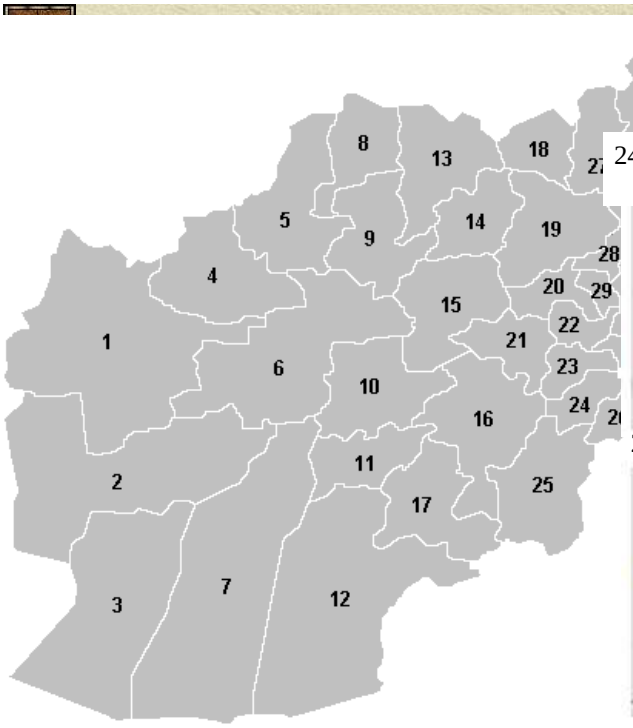
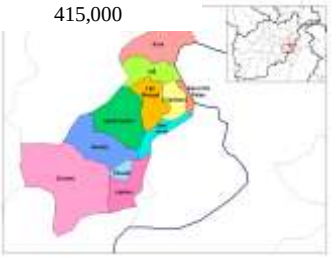




24 - Paktia districts

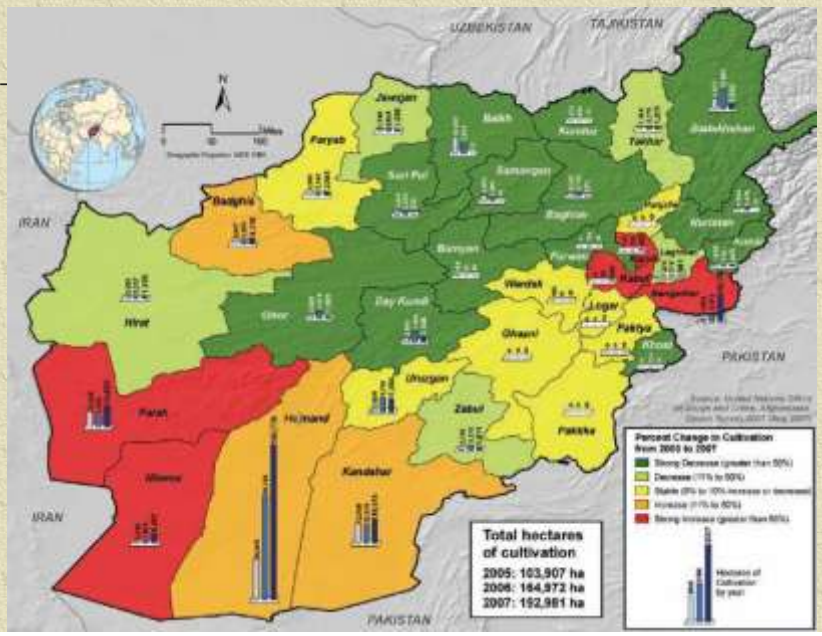
415,000



25 - Paktika districts

809,772

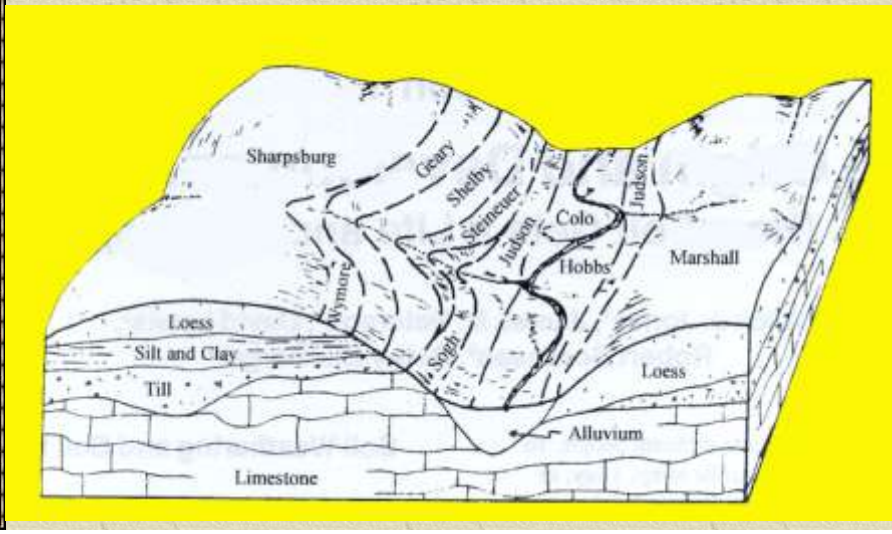
Poppy production area 2005-2007



The Five Soil Forming Factors

- Parent Material
- Climate
- Vegetation/soil
- Topography
- Time

Same parent material but different landscape position = different soil



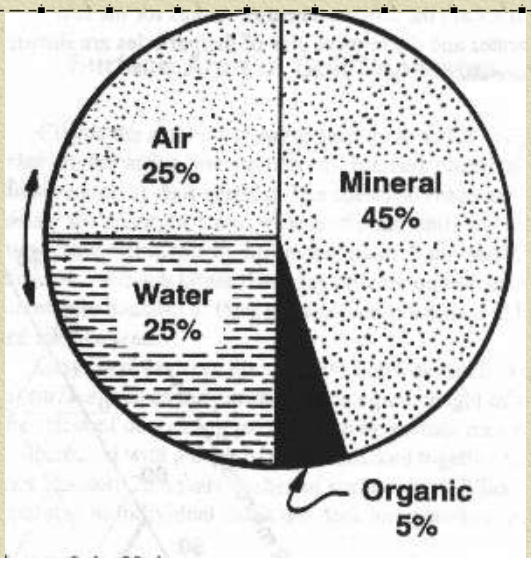
Typical western Nebraska soil

Four Major Components of Soil

- Mineral – 45-49% of soil volume
- Organic Material – 1-5% of soil Volume
  - Dead: organic material, humus, soil carbon
  - Living: microbial
- Air – Soil is half air!!!
- Water – Found in the pore space of soil

Major Components of Soils

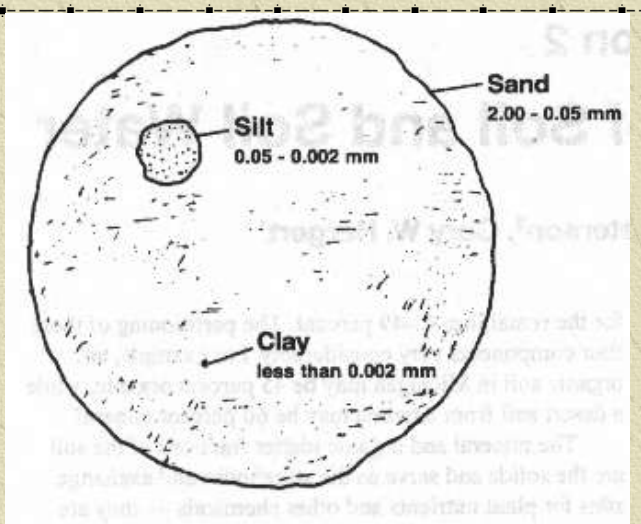
The organic portion of soil is called organic matter or humus or the soil carbon fraction

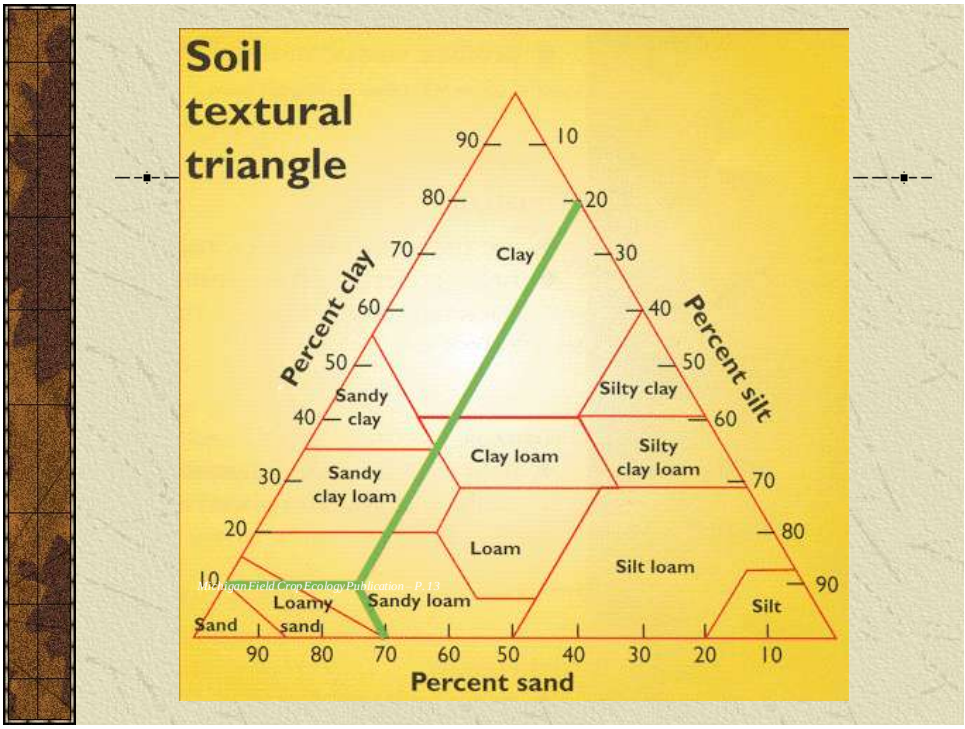


Soil Texture

- Soil Texture – Relative proportion of sand, silt and clay sized particles in soil
- Soil separates
  - Sand – Clearly visible by the eye
  - Silt – Microscope needed to see particle
  - Clay – Electron Microscope needed to see

Relative Sizes of Soil Separates



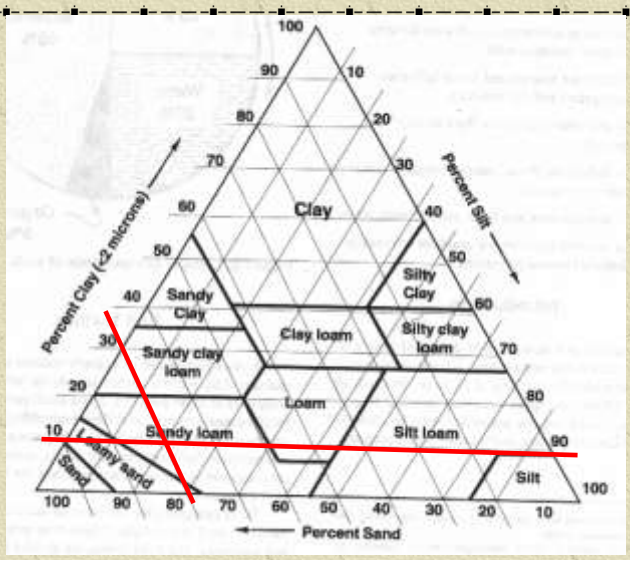

Soil textural triangle
Percent clay
Percent silt
Percent sand
Clay
Sandy clay
Silty clay
Clay loam
Silty clay loam
Sandy clay loam
Loam
Silt loam
Silt
Sandy loam
Loamy sand
Sand
90
80
70
60
50
40
30
20
10

Hydrometer Method for Texture

Soil Texture Calculations

- Mechanical analysis:
  - 10% Clay
  - 10% Silt
  - 80% Sand
- What is the texture of the soil?

Textural Triangle



Soil Nomenclature

- Texture is part of a soil's name

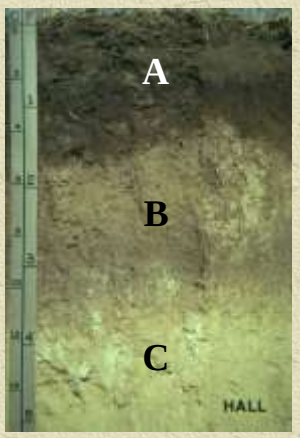
Colby silt loam

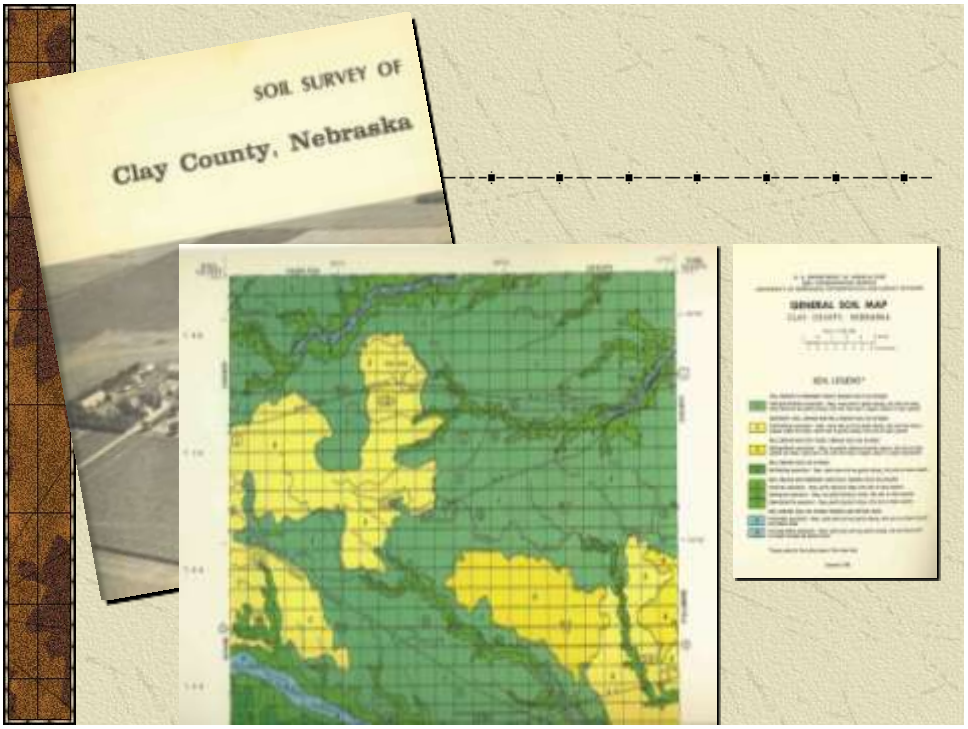
Valentine sand

Hall silt loam

Soil Horizons (layers)

- A horizon: OM accumulation, leaching of cations, dissolution of primary minerals, reformation of new
- B horizon: accumulation of clay, weathering and reforming
- C horizon: parent material





Web-based Soil Survey

http://websoilsurvey.nrcs.usda.gov/app/

Google Earth

Soil Biology

"A healthy soil, full of active microorganisms in active balance, is essential to productive agriculture."

But, it's a jungle down there!!!

Soil Biology

5 major soil microbial populations

- Bacteria
- Actinomycetes
- Fungi
- Algae
- Protozoa
- plus Viruses

Rhizobia:
A symbiotic relationship with the plant that provides N to the plant and sugars to the bacteria

Soil Structure

- Arrangement of soil separates into units called soil aggregates
- Separated by planes of weakness
- Dominated by clay particles

Natural Processes that Aid in Forming Aggregates.

- Wetting and drying
- Freezing and thawing
- Microbial activity/OM decay
- Activity of roots and soil animals
- Adsorbed cations
- Think of soil as a 'sponge'
- Aggregates create 'sponginess'
  - But they can be crushed!!

Destruction of Soil Structure- Physical

- Tillage
  - Cutting edge of tillage tools: plow = plow pan
  - Disk: Cutting action and shearing action
  - Field Cultivator/Strip-till; destroys fewer aggregates
- Beating action of raindrops
  - Forms a crust when the soil dries
  - Water infiltration slowed

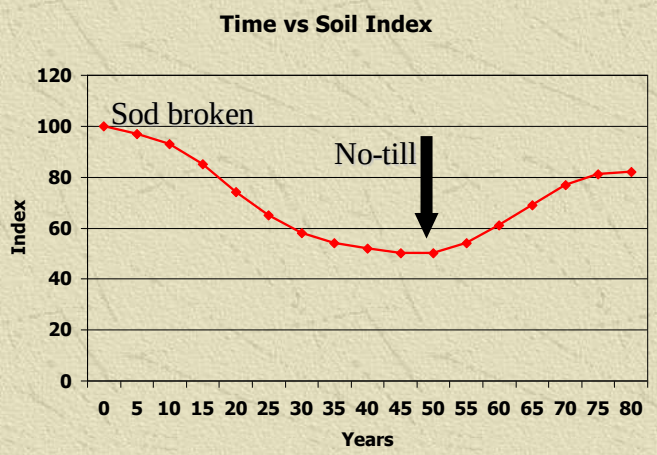
Aggregate Stability:
the ability of soil aggregates to resist disruption.

Good Aggregate Stability reduces erosivity, facilitates infiltration,
permeability and
root growth

Wind and water erosion in the same field!

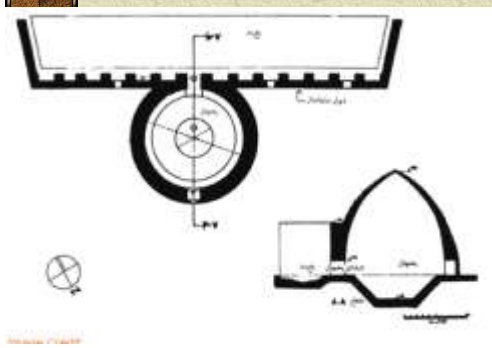
more natural precipitation!!

Soil Carbon, Nitrogen and tillage



Compaction Destroys Soil Structure

- Breaks down if the applied force is greater than the force holding an aggregate together
  - Wheel traffic
  - Animal traffic
  - Human traffic
- How do you make mud bricks?
  - Soil with some clay + straw + water + breaking down structure + sun to dry



By 400 BC, Persian engineers had mastered the technique of storing ice in the middle of summer in the desert. The ice was brought in during the winter from nearby mountains in bulk amounts, and stored in a Yakhchal, or ice-pit. These ancient refrigerators were used primarily to store ice for use in the summer, as well as for food storage, in the Iranian desert.

Made with mud brick.

Destruction of Soil Structure- Chemical

- Deflocculating ions
  - Predominately monovalent ions
  - Sodium (Na)
  - Ammonium (NH_4)
- Salts

Salinity increases soil water osmotic potential making it more difficult for plants to take up water.

Excess sodium (>15%) weakens aggregates and soil structure.

Promotion of Aggregation

- Adding organic matter
  - Crop residue
  - Animal manure
  - Sludge, compost
  - Green manure
- Develops granular and crumb structure.
- Replace/reduce monovalent ions with divalent (replace Na with Ca , Mg)

Bulk Density

- weight of soil per unit volume
  - solids and the pore space
- Ideal Soil
  - ½ solids
  - ½ pore space
- 2.66 g/cm^3 (particle density)
  - ½ solids = 1.33 grams/cm^3 bulk density

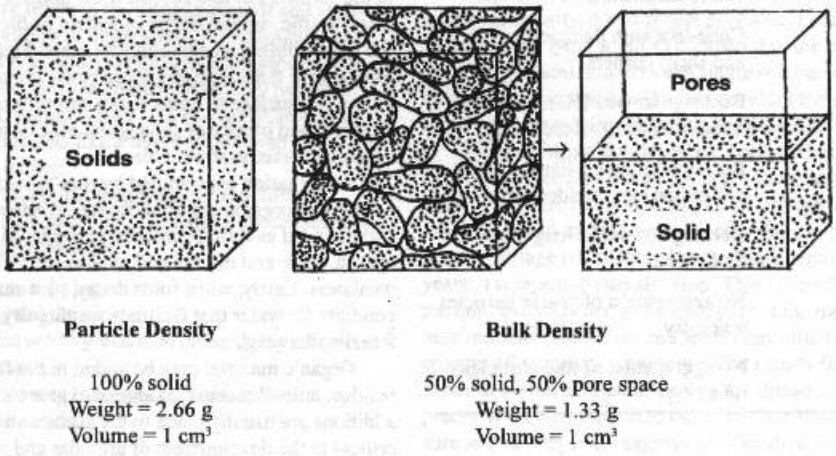
Quick Quiz on Bulk Density

- How much does a cubic foot of soil weigh?
- What is its bulk density?
- 1.33
  - It's 1.33 times as heavy as water
- What does a cubic foot of water weigh?
  - 62.4 lbs
- So, 1 ft^3 of soil weighs 62.4 x 1.3 = 83 lbs

Effect of Bulk Density on Root Growth

- Bulk density >1.45 to 1.60 g/cm^3
  - plant root growth restricted
- Bulk density 1.8gm/cm^3 = no root growth

Bulk and Particle Density



Porosity

- Loose, porous soils
  - low bulk density and high porosity
- organic soils>clay soils>sandy soils

Infiltration and aggregate stability

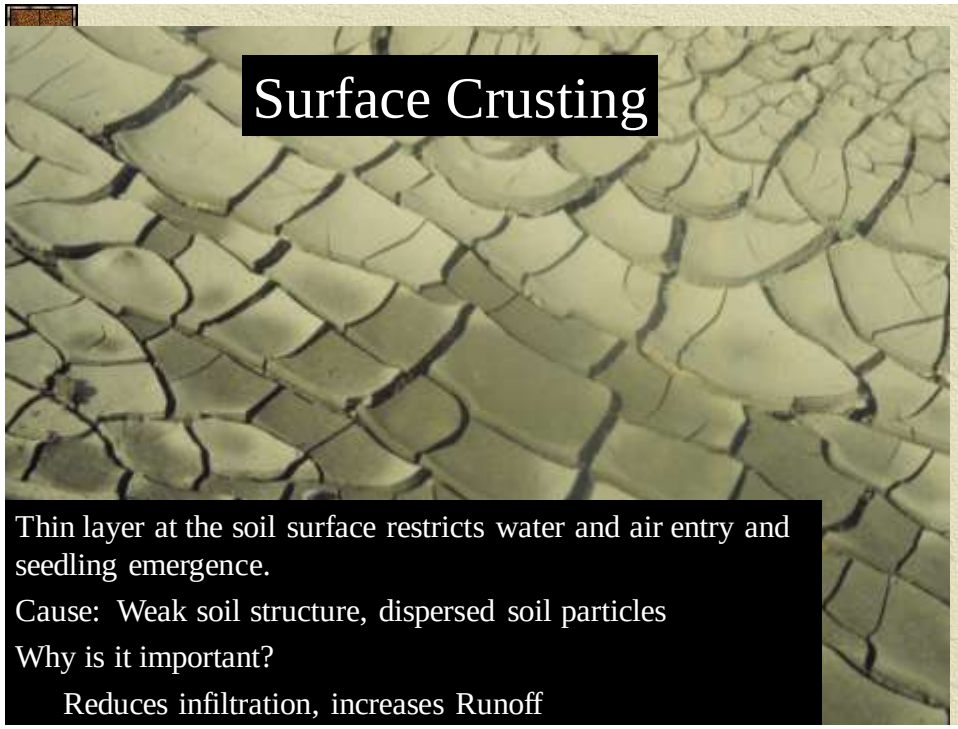
0.1 in/min

35%
Water Stable Aggregates

0.5 in/min

88%
Water Stable Aggregates

Surface Crusting



Thin layer at the soil surface restricts water and air entry and seedling emergence.

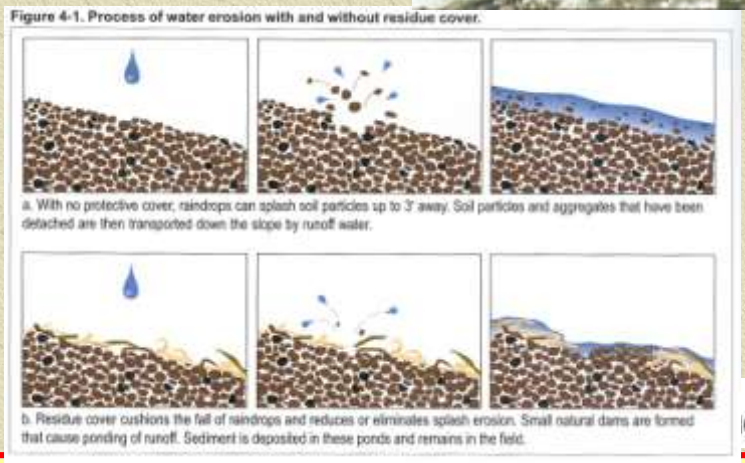
Cause: Weak soil structure, dispersed soil particles

Why is it important?

Reduces infiltration, increases Runoff

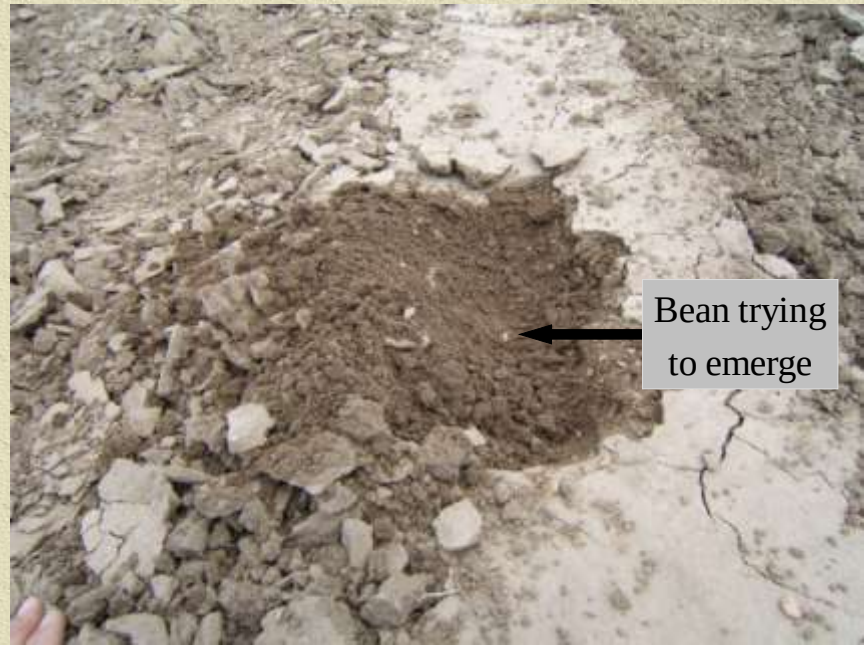
Soil Erosion Processes

Raindrop splash



ION

Scottsbluff soil after a hard rain



Old School: Soil Tilth
New School: Soil Quality

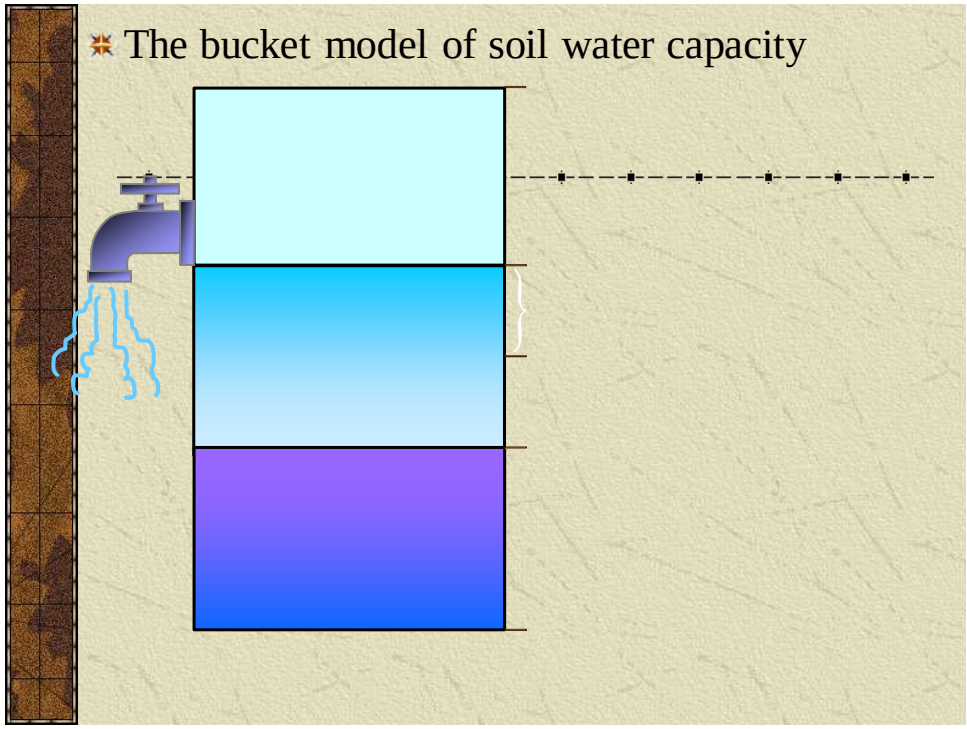
Understanding Soil Quality

- High soil quality = healthy soil
- High soil quality = productive soil
- Easy to work
- Good nutrient supply
- Favorable soil water conditions
- Nice concept, BUT… difficult to ‘quantify’

Soil Water Holding – 2 Steps

- Infiltration – Water moves into the soil.
- Percolation, permeability or hydraulic conductivity
  - Downward movement of water in the soil.
  - Pore space is the conduit for infiltration and percolation.

The bucket model of soil water capacity



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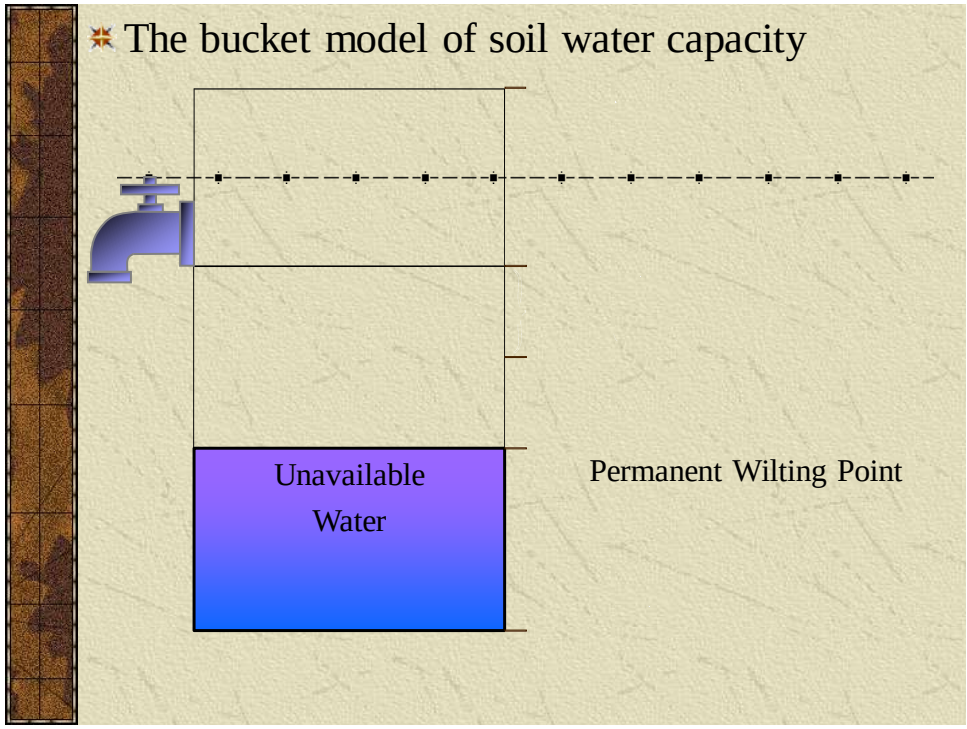

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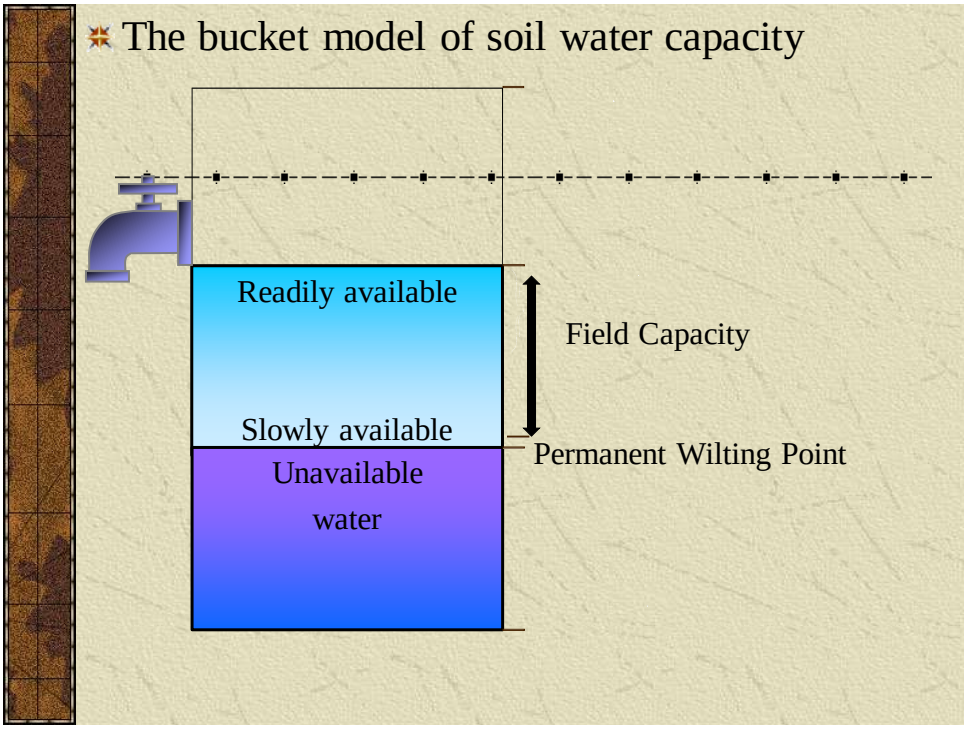

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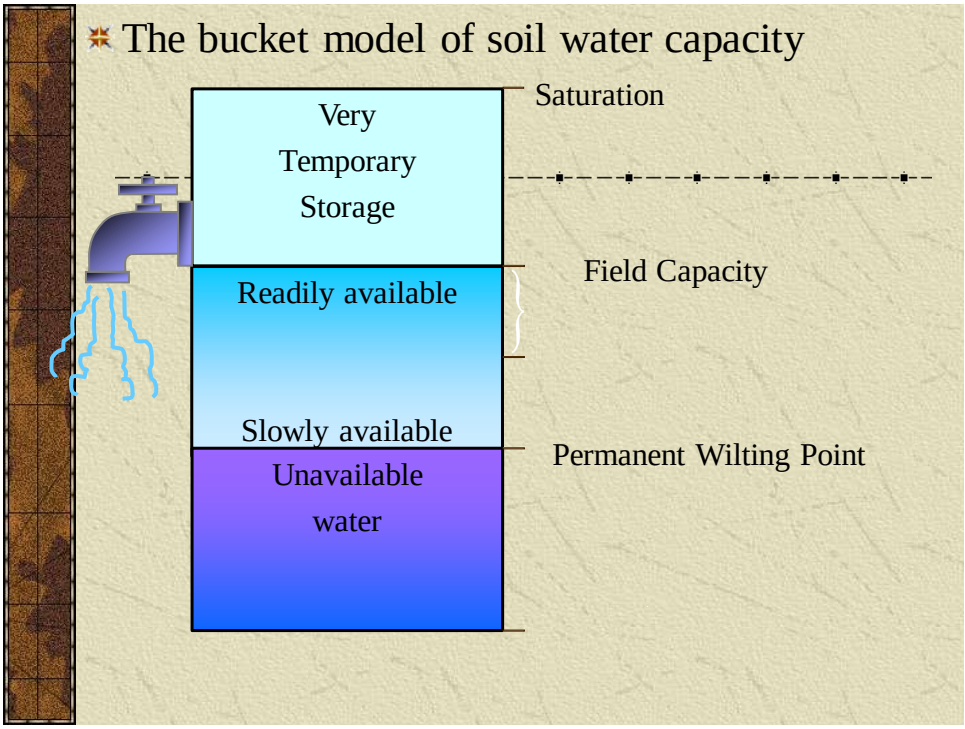
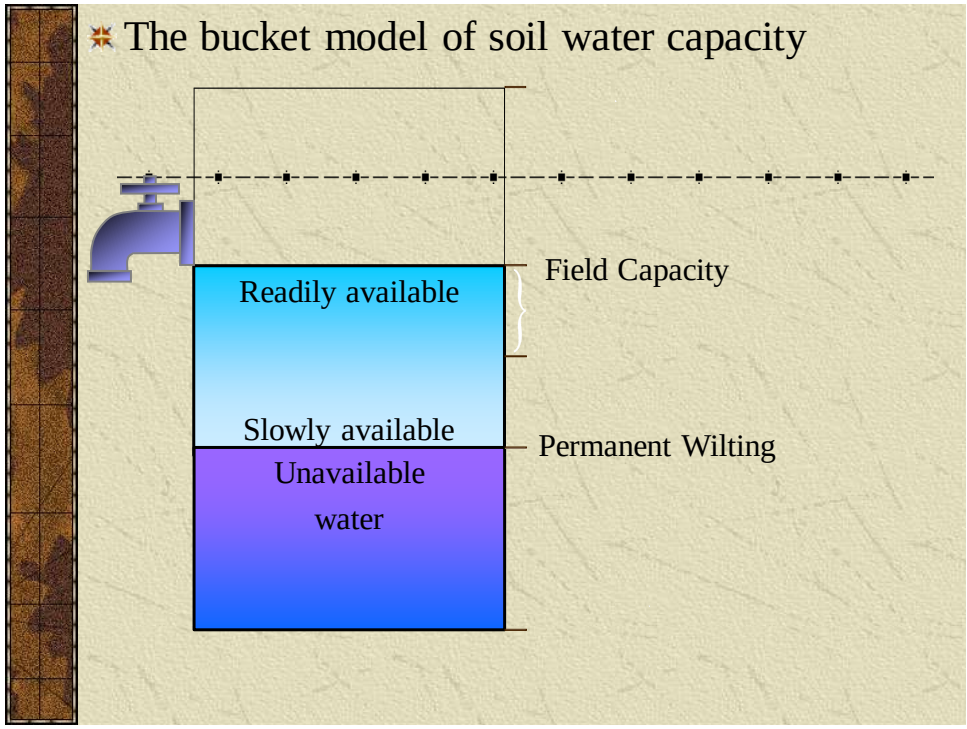
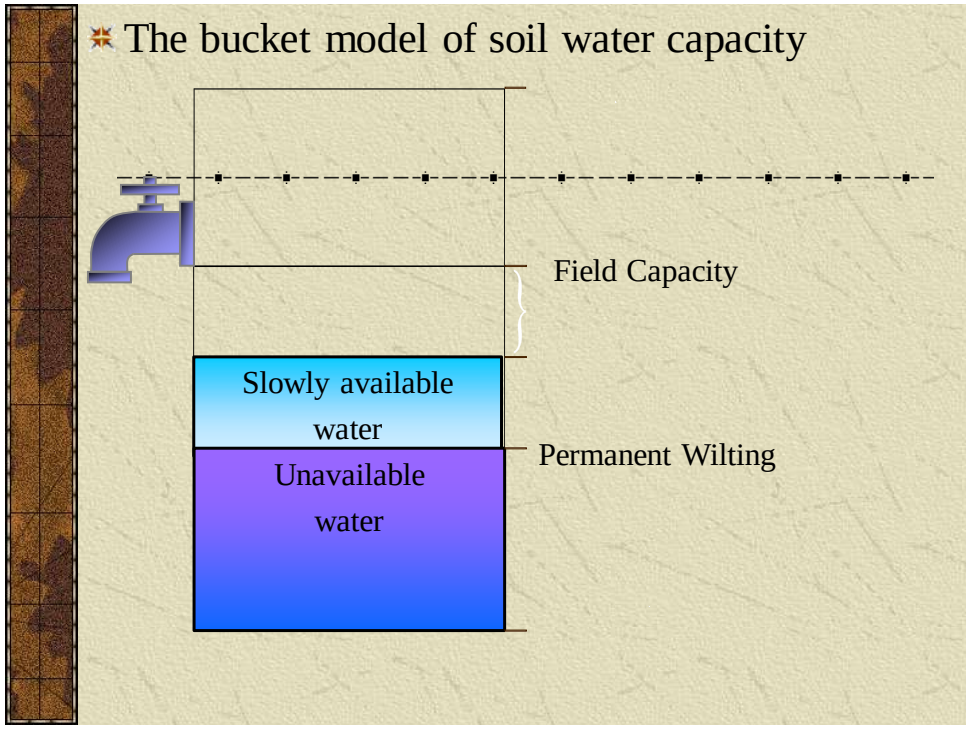



The bucket model of soil water capacity
Field Capacity
Readily available
Slowly available
Permanent Wilting
Unavailable
water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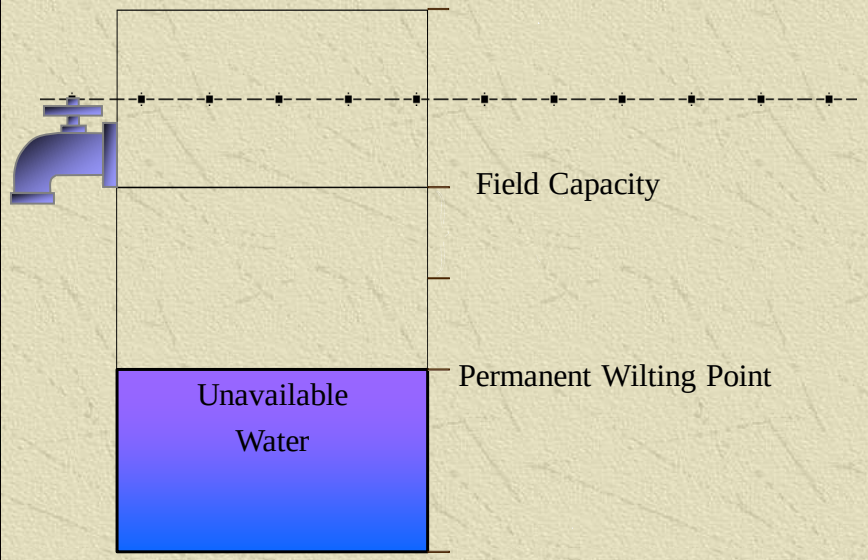
- The bucket model of soil water capacity



Water Content of the Soil

- Saturation – All pores are filled with water
- Field capacity – Soil has been allowed to dry/drain for 36 to 48 hours
- Permanent wilting point – plants have extracted all the water they can.
  - Plant will wilt and not recover

Water Content of the Soil

- Gravitational water – Water held between saturation and field capacity.
- Water holding capacity (WHC) – Water held between field capacity and wilting point.
- Plant available water (PAW) - Part of water holding capacity that can be absorbed by a plant.
  - General Rule: PAW = 0.5 x (WHC)

Gravimetric Water Calculation

- % Water = 100% * $\frac{\text{Wet soil - Dry soil}}{\text{Dry soil}}$

- 100% * $\frac{100 - 80}{80}$ = 25% gravimetric water

Volumetric Water Calculation

- % Gravimetric Water * Bulk Density = %Volumetric Water
- 25% gravimetric * 1.3 g/cc = 32.5% vol
- Volumetric % * depth(in) = inches of water
- 12" * 32.5% = 3.9" total
- But…~ half {2"} is "plant available"

Water Holding Capacity of the Soil

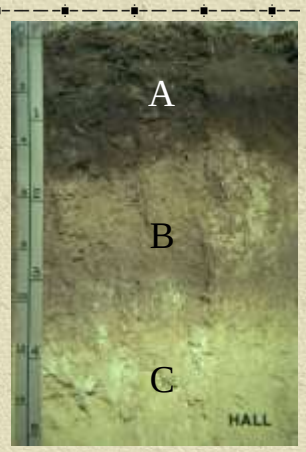
- Amount and Ability of soil water
- Useful for:
  - Irrigation scheduling
  - Groundwater recharge
  - Estimating runoff
  - Determining plant stress
- Water holding capacity varies by soil texture

Range of Water Holding Capacities

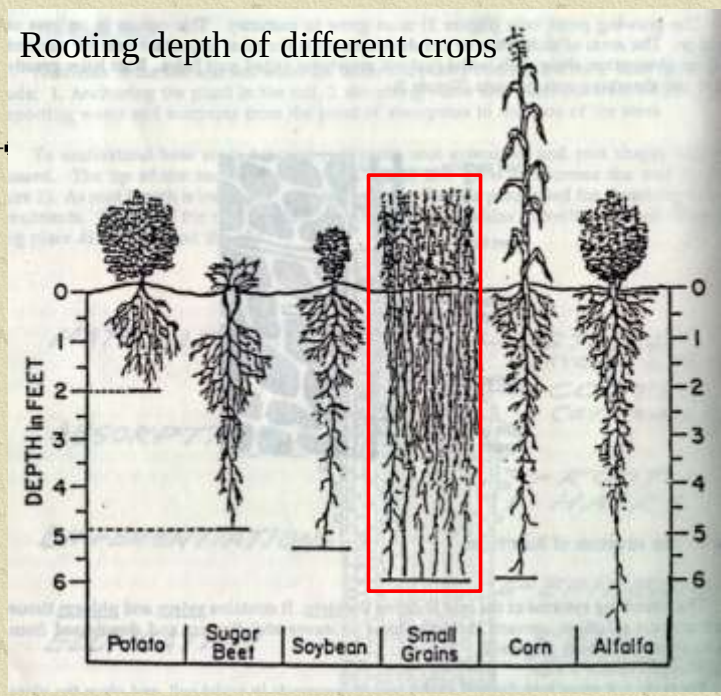
Soil Texture	Water Holding Capacity Inches/foot of soil
Coarse Sand	0.45 - 0.75
Sandy loam	1.25 - 1.50
Silt loam	2.00 - 2.50
Clay loam	1.50 - 2.00

Water Content of Soil Varies by Depth

- Soil texture varies by depth, so does water holding capacity
- Water holding capacities for the soil profile
  - Depth of each horizon is multiplied by the available water for that soil texture & depth
  - Add values for the different horizons



Rooting depth of different crops



Plant Available Water

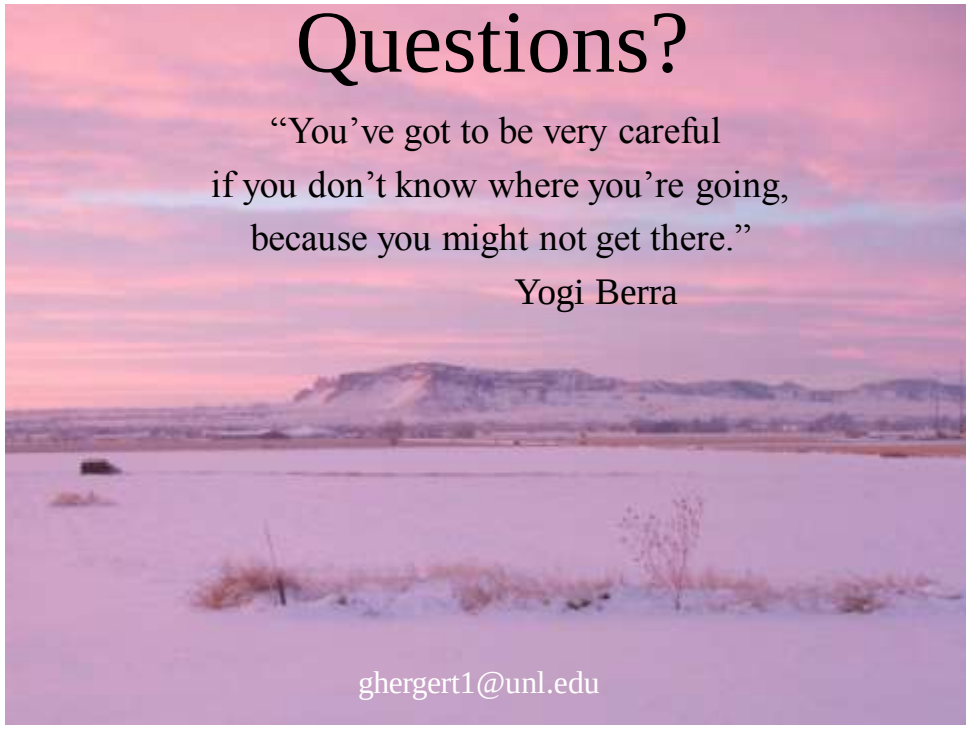
- Texture & structure affect water holding capacity
- Depends on plant species
- Depends on stage of growth
- Depends on rooting depth and plant's ability to extract soil water

Putting it all together

- Soil texture affects soil structure which is affected by climate/topog/parent material/tillage
- Texture & structure (aggregate stability) affect infiltration and water holding capacity
- Anything that destroys soil structure affects infiltration and WHC
- Rooting depth and plant's ability to extract soil water and nutrients are affected by all above

Questions?

"You've got to be very careful
if you don't know where you're going,
because you might not get there."
Yogi Berra



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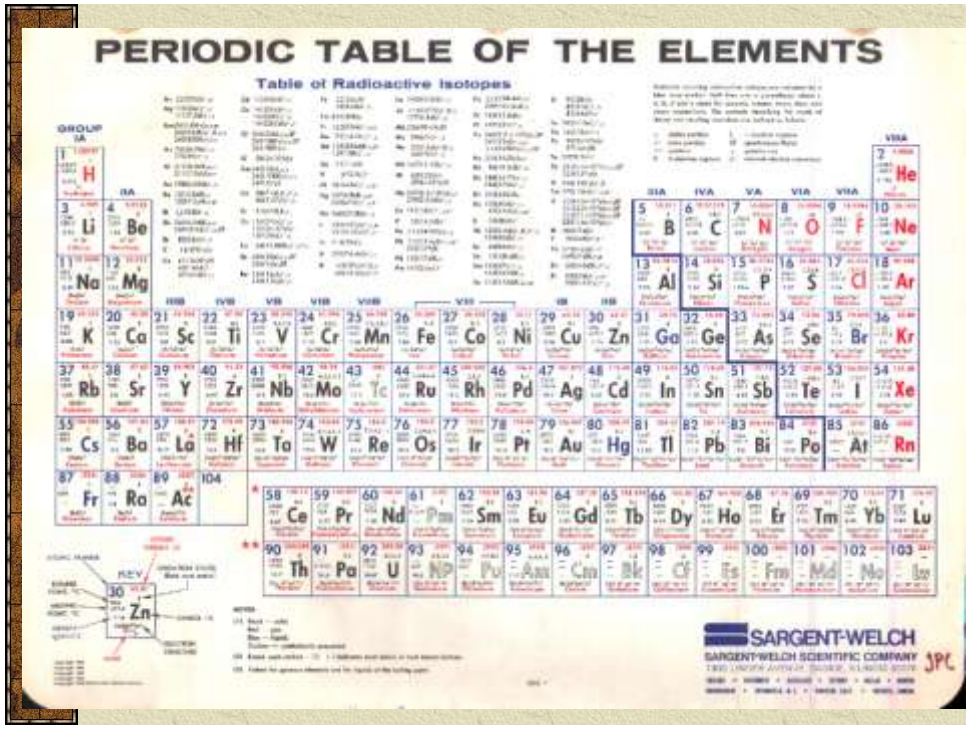
Soil Chemistry

- The chemical properties of the soil include:
  - Mineral solubility
  - Nutrient availability
  - Soil reaction (pH)
  - Cation exchange capacity
  - Buffering action



Cations and Anions

- Nutrients exist in the soil as ions
  - Electrically charged atoms or groups of atoms
  - Ions are either positive charged (cations)
  - Or negatively charged (Anions)
- Plants take up ions, not organic molecules
  - Anything organic must be broken down to inorganic before plants can take it up as they take up water

Most Important Cations Found in Soil

Ca^{++} (Calcium)	NH_4^{+} (Ammonium)
Mg^{++} (Magnesium)	Zn^{++} (Zinc)
K^{+} (Potassium)	Fe^{++} (Iron)
Na^{+} (Sodium)	Mn^{++} (Manganese)
Cu^{++} (Copper)	Al^{+++} (Aluminum)
H^{+} (Hydrogen)	

Important Nutrient Anions in the Soil

- NO3- (Nitrate)
- SO4= (Sulfate)
- H_2PO4- (Phosphate)
- HPO4= (Phosphate)
- Cl- (Chloride)
- HCO3- (Bicarbonate)
- CO3= (Carbonate)

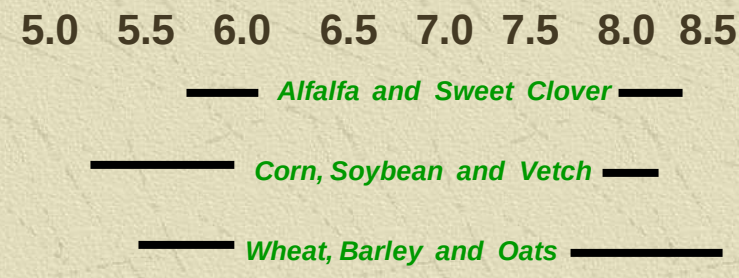
Cation Exchange

- The replacement of one adsorbed cation by another cation is called “cation exchange”
- Knowing something about CEC is important if you are liming a soil or trying to reclaim sodic/salt affected soils

Relationship Between Soil Texture and CEC

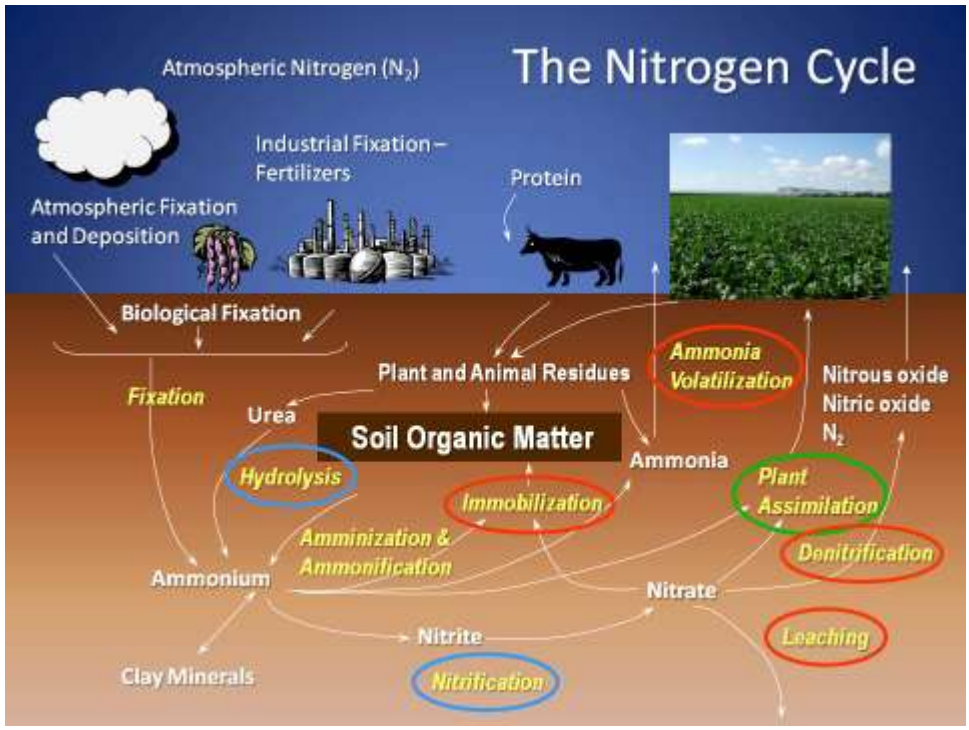
Soil Texture	*Cation Exchange Capacity*
Sands	1-5
Fine sandy loams	5-10
Loams and silt loams	5-15
Clay loams	15-30
Clays	>30

Soil pH



Eating and living is all about nutrient cycling whether we are hunter-gatherers or farmers



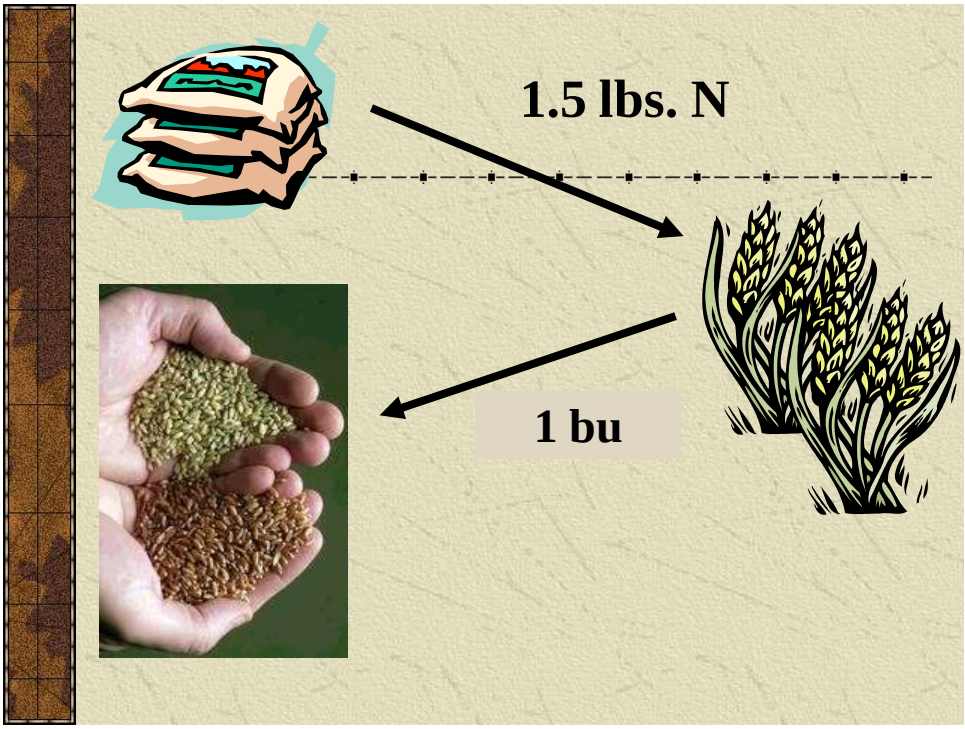



The 16 Essential Plant Nutrients

- Macronutrients
  - C, H, O (carbon, hydrogen and oxygen)
  - N, P, K (nitrogen, phosphorus, potassium)
- Secondary Nutrients
  - Ca, Mg, S (calcium, magnesium, sulfur)
- Micronutrients
  - B, Cl, Cu, Fe, Mn, Mo, Zn (boron, chlorine, copper, iron, manganese, molybdenum, zinc)

Nutrients for Wheat in Afghanistan

- Macronutrients
  - **N, P**, (nitrogen, phosphorus)
- Secondary Nutrients
  - Maybe **S** (sulfur)
- Micronutrients
  - **Zn** (zinc)
  - Maybe **Fe** (iron)



Plant Nutrient Sources

- The Soil
  - Breakdown of soil OM to release nutrients
  - Weathering of soil minerals
- Irrigation water: some nutrients, but snow-melt water is very pure (low salts)
- Nutrient Additions
  - Manures (animal, green), compost, commercial fertilizers

Soil Nutrients

- What's in the soil?
  - SoilSampling/Testing
  - Portable soil testing kits
    - pH, OM, P, salinity: essential
    - Nitrate, sulfate, K, buffer pH, micronutrients: secondary
- How much of which nutrient do you need to add?
- Are commercial fertilizers available and affordable?

Google Portable soil testing kits

- http://www.hach.com/
- http://www.lamotte.com/pages/soil/index.html
- http://www.omega.nl/shop/subsectionSC.asp?subsection=GG08&book=Green
- http://www.indoeximindia.com/prod_387_19_8.htm
- http://*www.labsafety.com/Soil-Fertility-Kit*

Fertilizer Sources, Placement & Timing

- Nutrients need to be mixed through soil to allow uptake
  - Mass-flow concept: N, K, S, mobile nutrients
- Nutrients need to be close to plant roots and mixed with minimal soil to avoid reversion to insoluble forms: P, Fe, immobile nutrients

Soil Nutrient Sources-1

- Manure
  - Good source for P, K, micronutrients, low in N and nutrient release can be slow
  - In poor countries, not enough livestock concentration to have enough
  - Often used as fuel source for heat or cooking
- Human waste
  - Cultural limitations in some areas
  - Pathogen, disease problems if not handled properly

Soil Nutrient Sources-2

- Green Manures
  - Legumes a good source of N, but need to plow under
  - Doesn't add any other nutrients, only recycles what has been taken up in dry matter
  - Other cover crops supply little N and only recycle what's been taken up

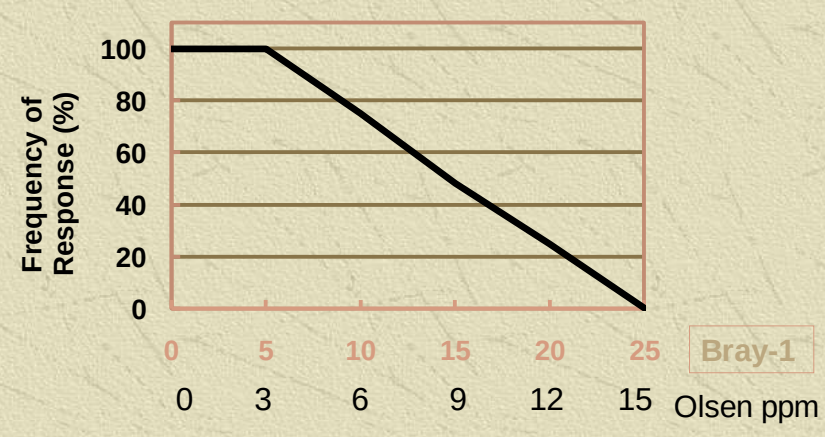
Soil Nutrient Sources-3

- Commercial Fertilizers
  - Readily available, can add what's needed
  - Relatively expensive unless subsidized by government or co-op
  - Easy to spread by hand or small machine
  - Can broadcast or band even by hand

N rates for dryland winter wheat in Western NE

NO_3-N ppm	NO_3-N lbs/A-4 ft	lbs N/A
<1	<12	70
1.1 - 2.8	12 to 40	60
2.9 - 5.6	41 to 80	40
5.7 - 8.3	81 to 120	20
>8.3	>120	0

Winter Wheat Yield Response as Related to Soil Test P



Simple Phosphorus Recommendations

Soil Test P	Row-applied P	Broadcast P
ppm	lbs/acre-2 ft	lbs./acre
0 to 3	40	80
3.1 to 9	30	60
9.1 to 15	20	40
> 15	0	0

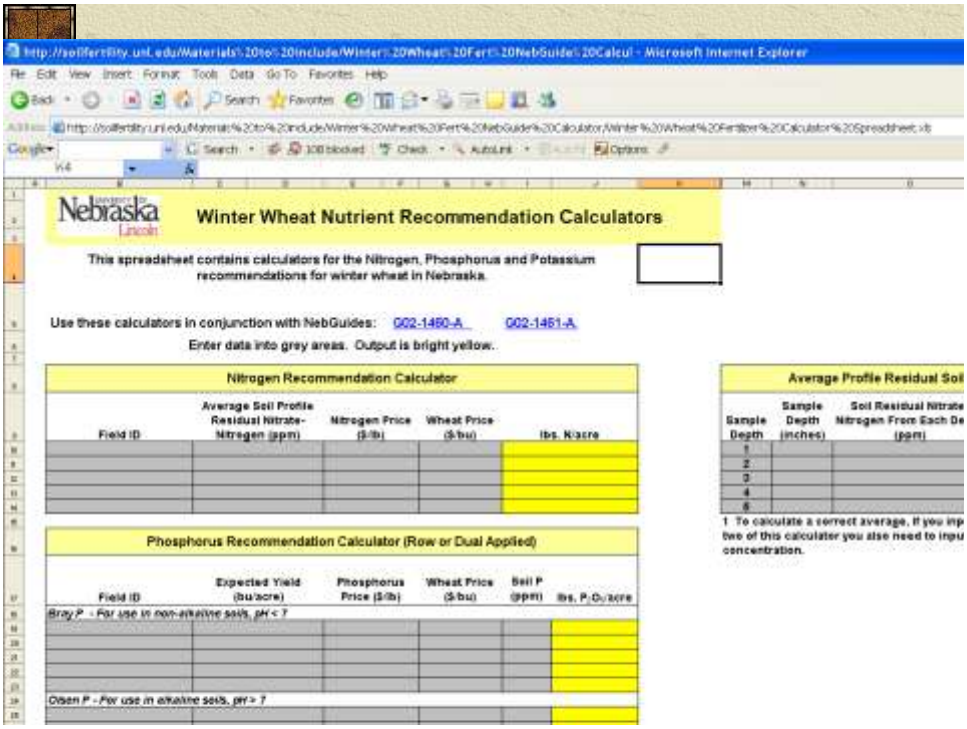
Calculating P Fertilizer Rate (Row or Dual Placement)

Bray-1 P Test:

P_2O_5 Rate (lbs/acre) = (-9.98 – 2.38 * LN BrayP + 4.39*LN Yield) / (P Price / Wheat Price)

Olsen P Test:

P_2O_5 Rate (lbs/acre) = (-9.98 – 2.38 * LN (OlsenP* 1.5) + 4.39*LN Yield) / (P Price / Wheat Price)



CropWatch:/Wheat

http://plantandsoil.unl.edu/croptechnology2005/soil_sci/

Construction Work On The Interstate (Pathfinder) Canal

(Photos Courtesy of Pathfinder Irrigation District)

The future: pioneering efforts still needed

Scottsbluff National Monument

Questions???