Midwest Soil Improvement Symposium:

Research and Practical Insights into Using Gypsum

Gypsum Effects on Soils

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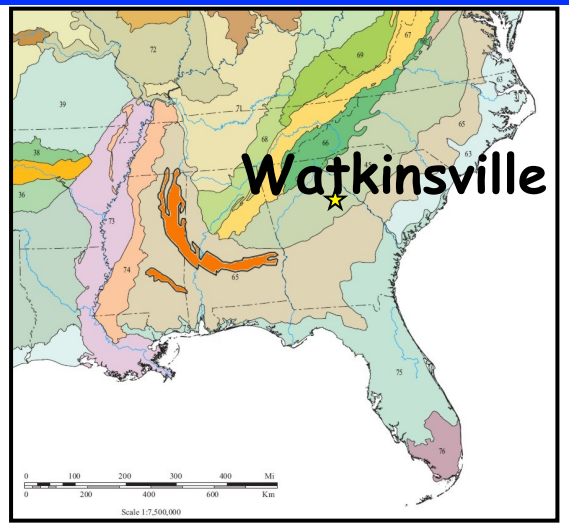


Brief Outline

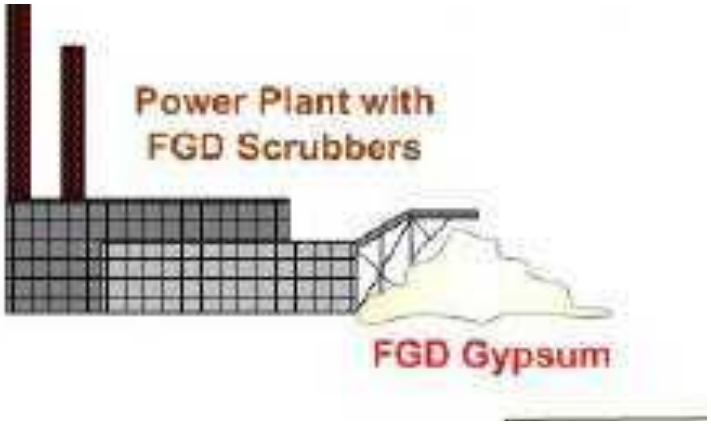
- Sources
- Properties
- Soils background
- Role of gypsum in soils
  - Plant nutrients
  - Subsoil acidity
  - Soil aggregation
  - Sodic soils

Sources of Gypsum

- Geologic deposits
- By-product of electricity generation
- By-product of phosphorus mining
- Recycled casting gypsum
- Recycled drywall gypsum

Flue Gas Desulfurization Gypsum

- By-product from scrubbing of SO_2 gases from coal-fired power plants
- Wide-range of potential agricultural applications

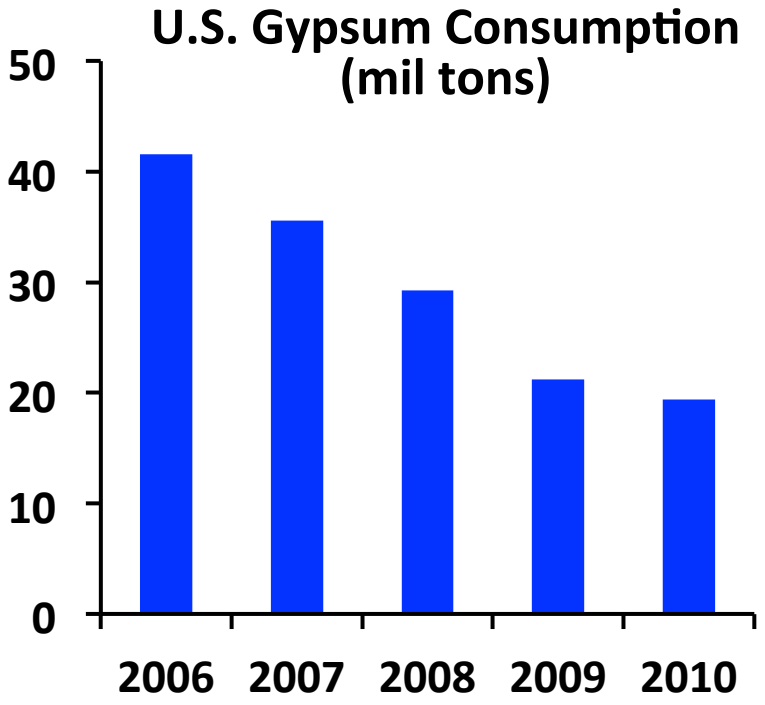


Estimated Production and Demand

U.S. Gypsum Production (mil tons)

	2004	2010	2020
Mined	17.2	9.0	
Synthetic	12.0	25.0	40.0
Import	10.1	3.3	

Manufacturing markets cannot absorb all FGD gypsum at peak production



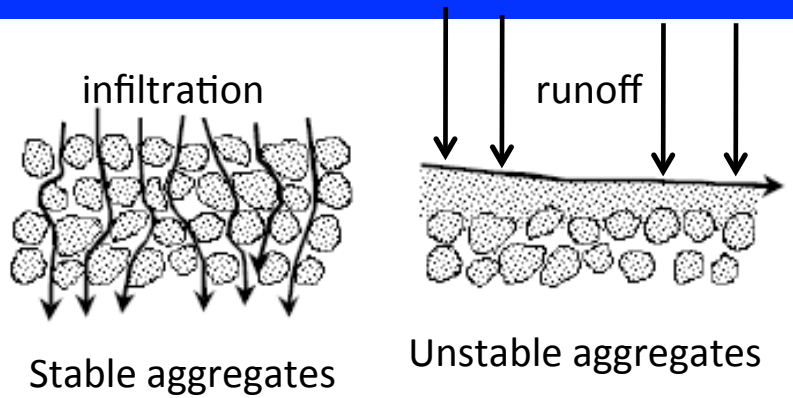
Source – USGS 2011

Gypsum Benefits in Agriculture

- Source of Ca and S for plant nutrition
- Ameliorate subsoil acidity and Al^{3+} toxicity
- Reduce P loss in runoff
- Flocculate clays to improve soil structure
- Reclaim sodic soils
- Decrease pH of sodic soils

Soil Physical Properties

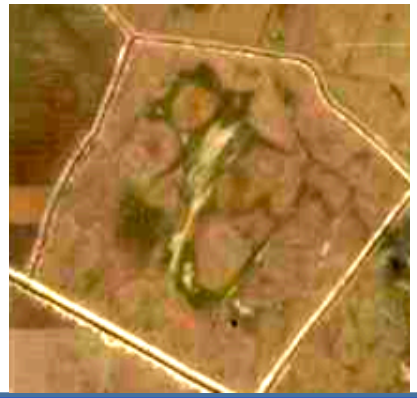
- Improves aggregation
  - crust and seal formation
  - compaction
  - organic matter stability
  - soil and water erosion
  - water infiltration and water use efficiency
  - loss of nutrients, sediment and agricultural chemicals



Soil Chemical Properties

- Alleviate subsoil acidity
  - Improves water and nutrient use
  - Improves crop yield and quality
- Remediate saline and sodic soils
  - Improves crop productivity
  - Important in some areas of South

Sodic affected field near Teoc , MS



Properties of Gypsum

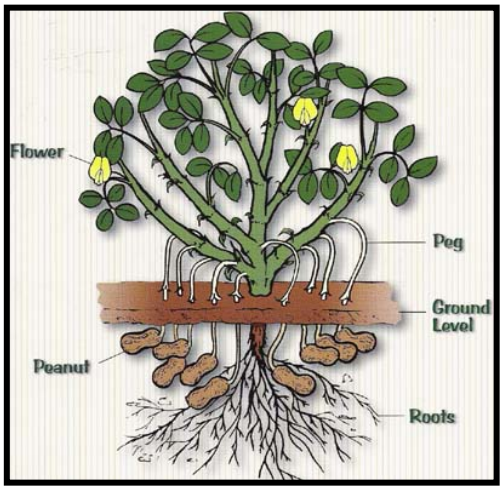
- Solubility
  - *Gypsum 2.5 g/L*
  - *Ag Lime 1.73 g/L*
  - *NaCL 14.9 g/L*

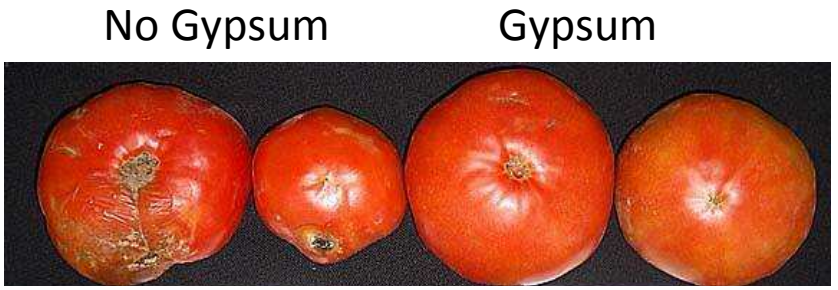
Ca^{++} clay flocculation

SO_4^{--} complex ion formation

Plant Nutrition Ca and S

- Plants require relatively large amounts of Ca and S
  - Ca – 0.5% shoot dry weight
  - S – 0.1% to 0.5% dry weight for optimal growth



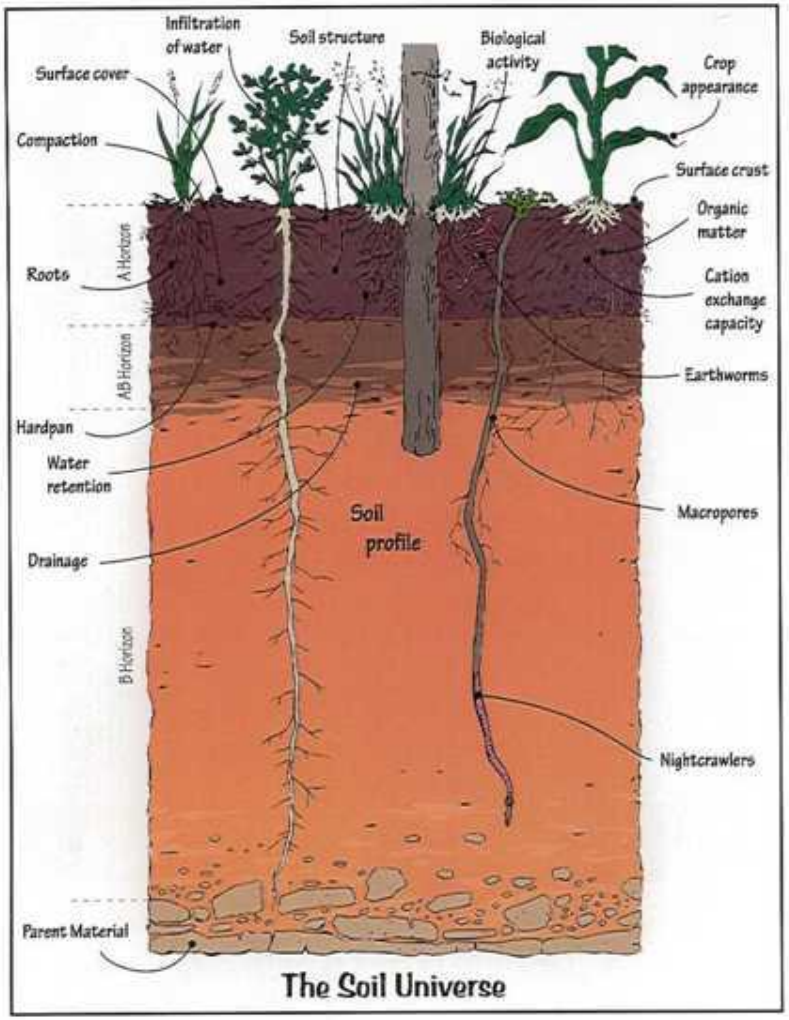


SOIL –

The Fundamental Concepts

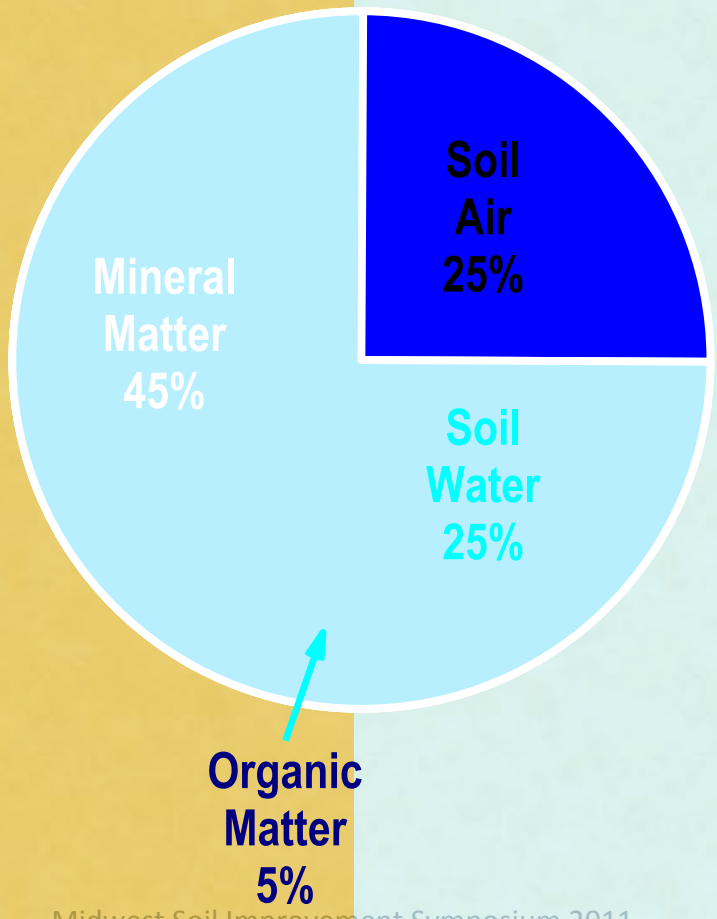
Soil Components

- Mineral
- Organic matter
- Water
- Air
- Organisms



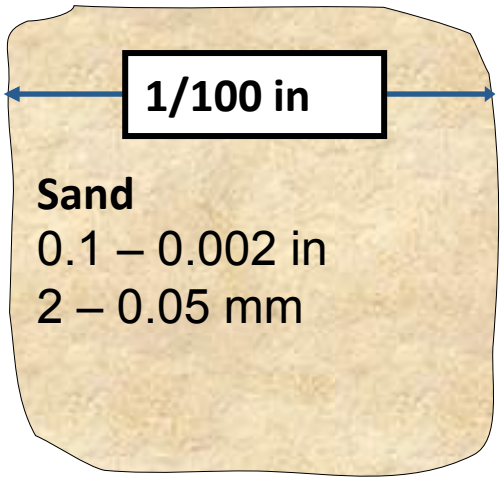
Soil Components
4 parts of soil

About ½ of the soil volume is solid particles

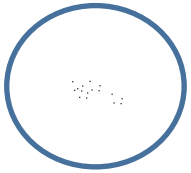


About ½ of the soil volume is pore space

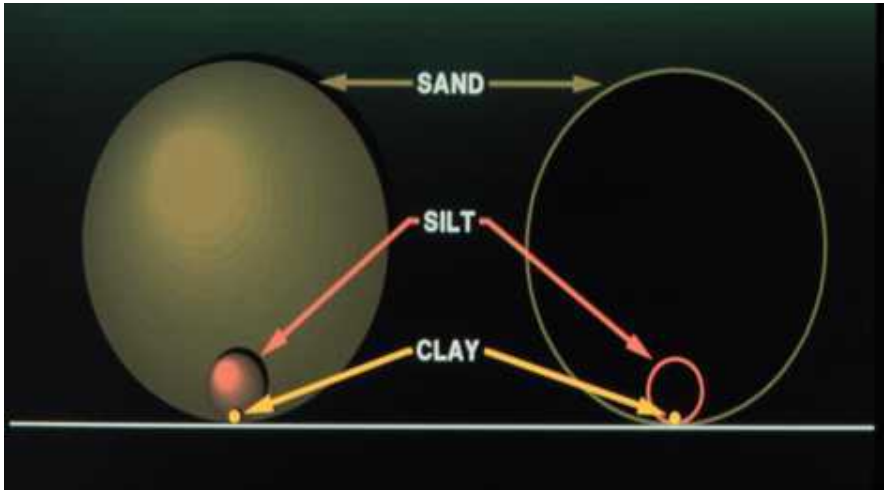
Mineral Components



Silt
0.002 – 0.0001 in
0.05 - 0.002 mm



Clay
Less than 0.0001 in
Less than 0.002 mm

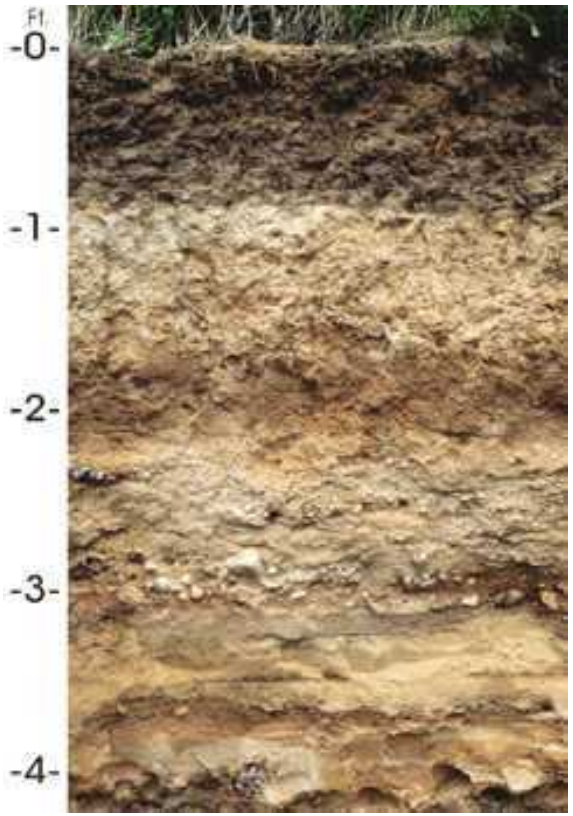


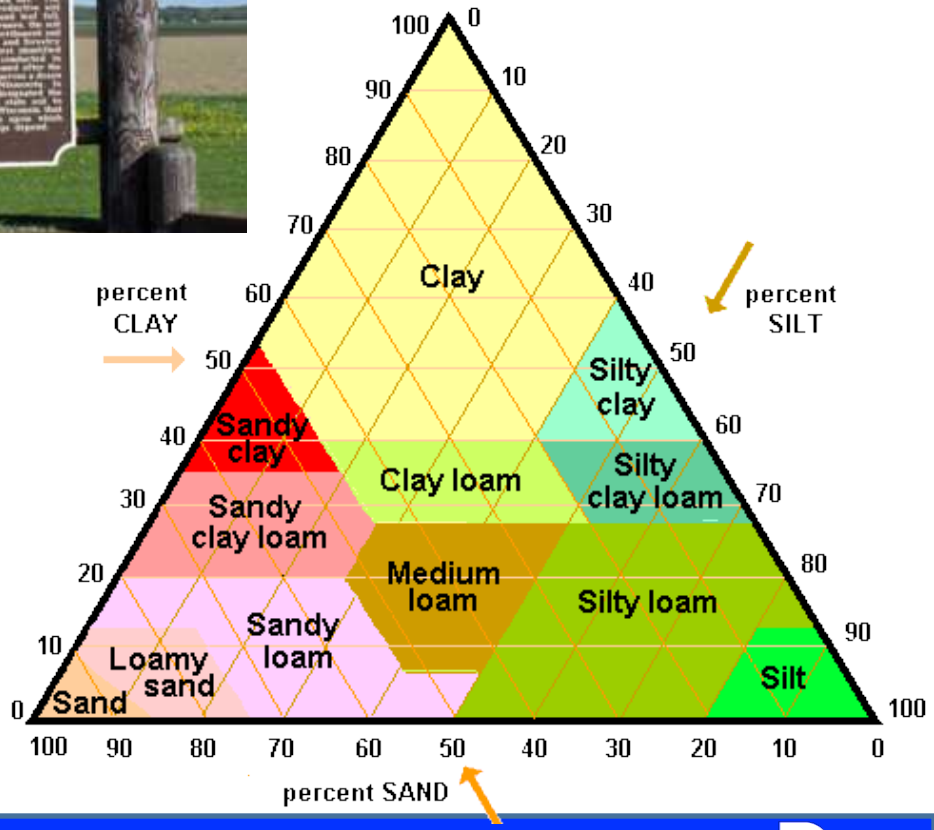
Determine textural property of the soil

- Coarse textured, loose (more sand, less clay)
- Fine textured, heavy (more clay, less sand)
- Loamy (more even mix of sand, silt and clay

Soil Texture

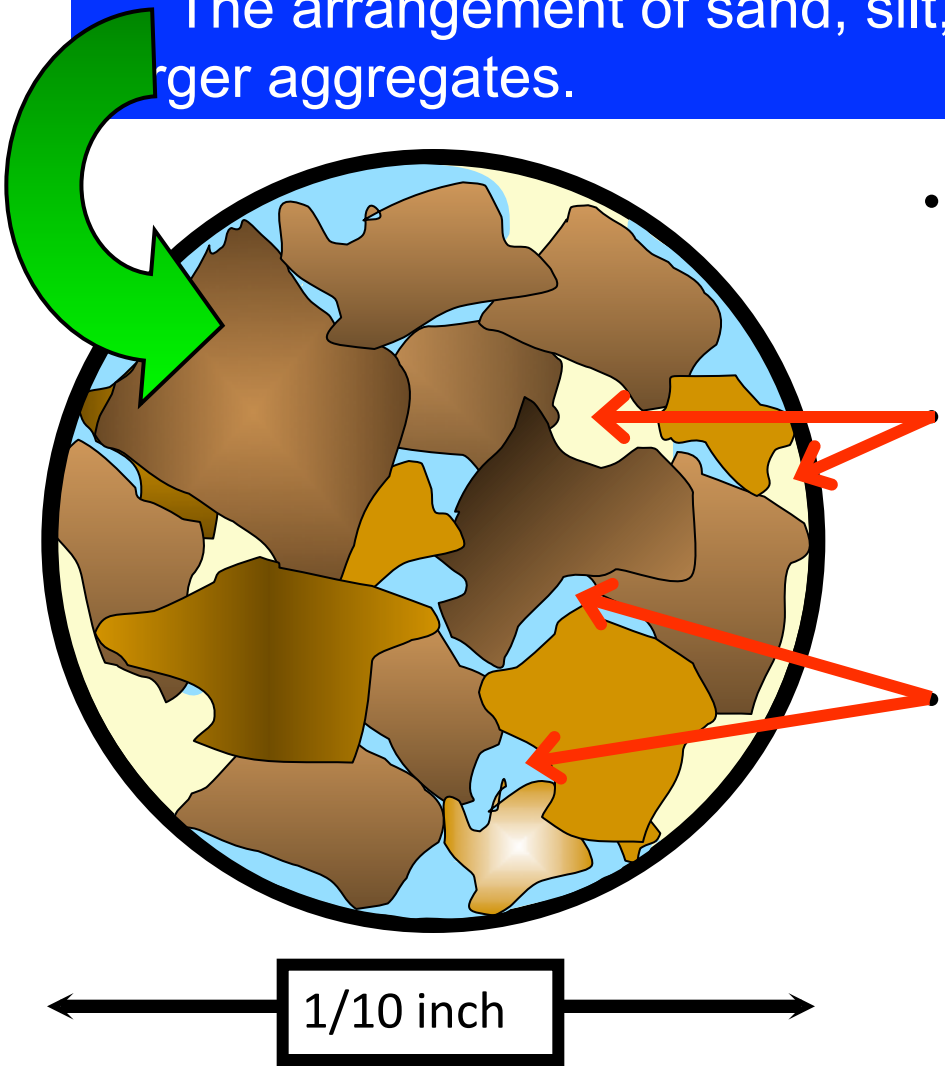
Antigo Silt Loam





Soil Structure

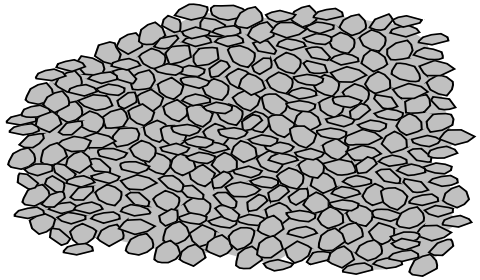
The arrangement of sand, silt, and clay particles to form rger aggregates.



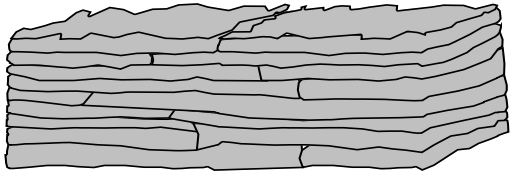
- Organic matter is the glue that holds the aggregates together
- Large pores (spaces) between aggregates are filled with air in a moist soil.
- Small pores are filled with water in a moist soil. Even smaller pores inside the aggregates (not shown) are also filled with water.

Soil Structure

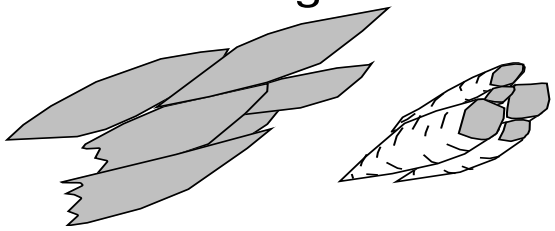
Granular



Platy



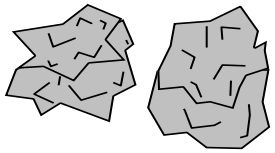
Wedge



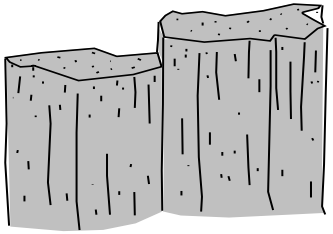
Blocky

(Subangular)

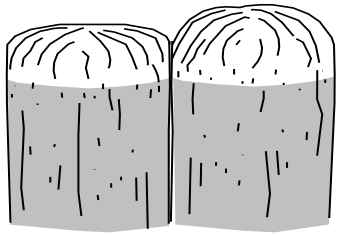
(Angular)



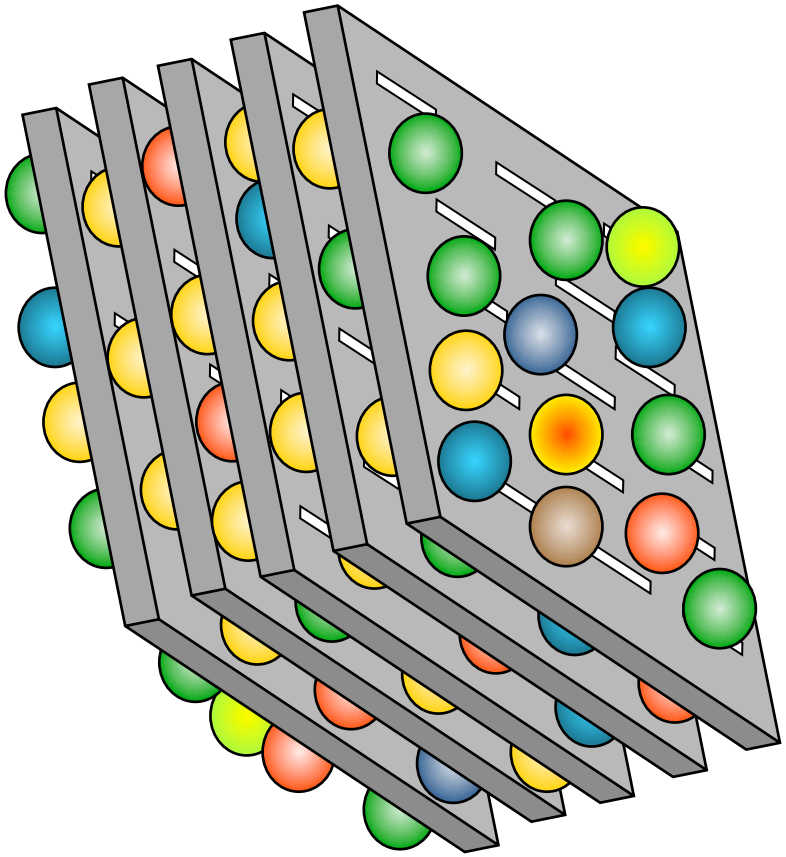
Prismatic



Columnar



Cation Retention on Soil Clays



Calcium, +2

Magnesium, +2

Potassium, +1

Ammonium, +1

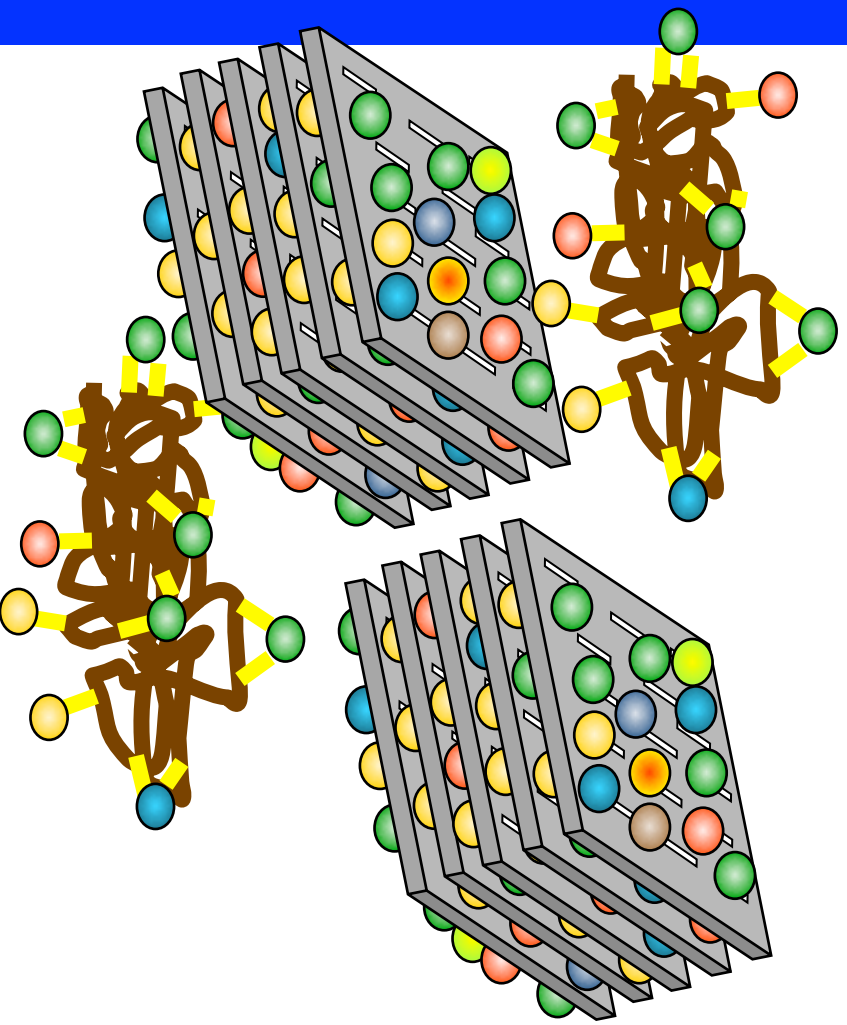
Sodium, +1

Copper, +2

Aluminum, +3

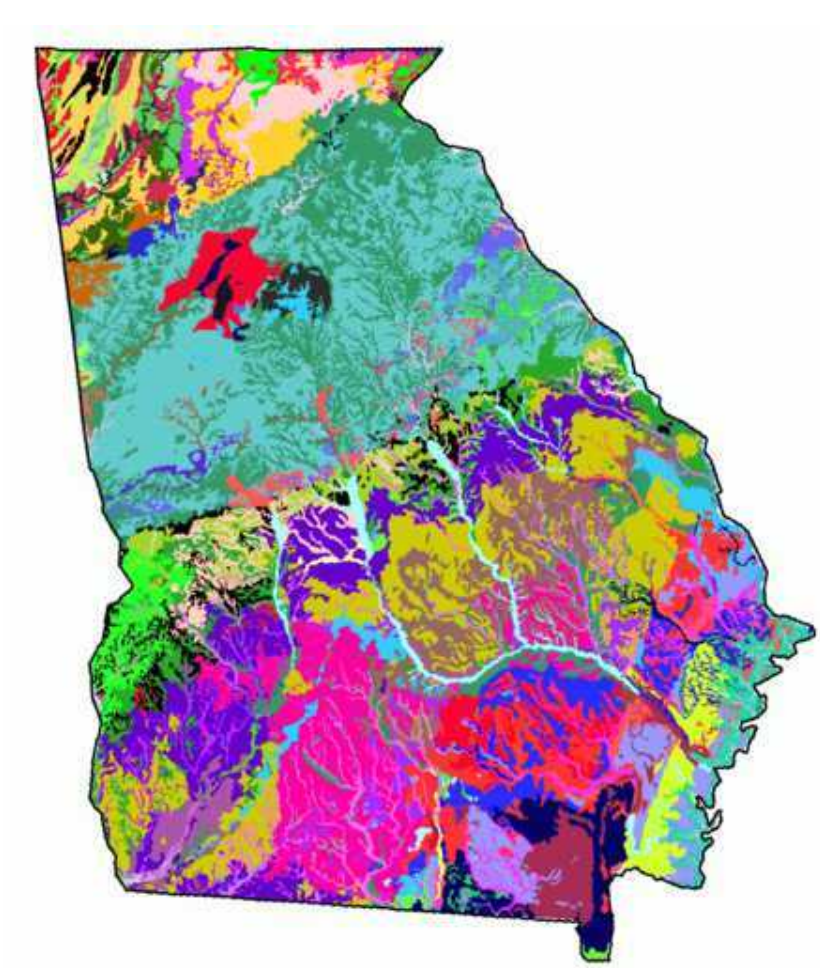
Hydrogen, +1

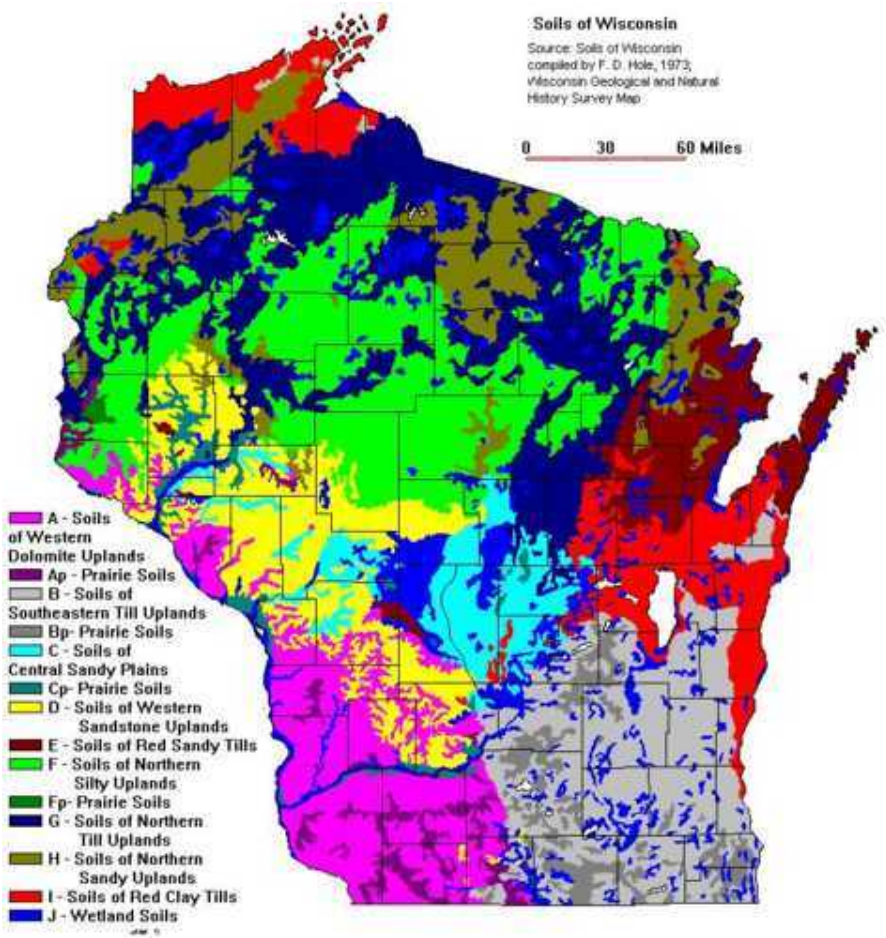
Cation Exchange Capacity



- (CEC) is the total amount of cations a soil can retain
- Higher CEC greater ability to store plant nutrients
- Soil CEC increases
  - With clay content
  - With organic matter content
  - With soil pH (to a point)

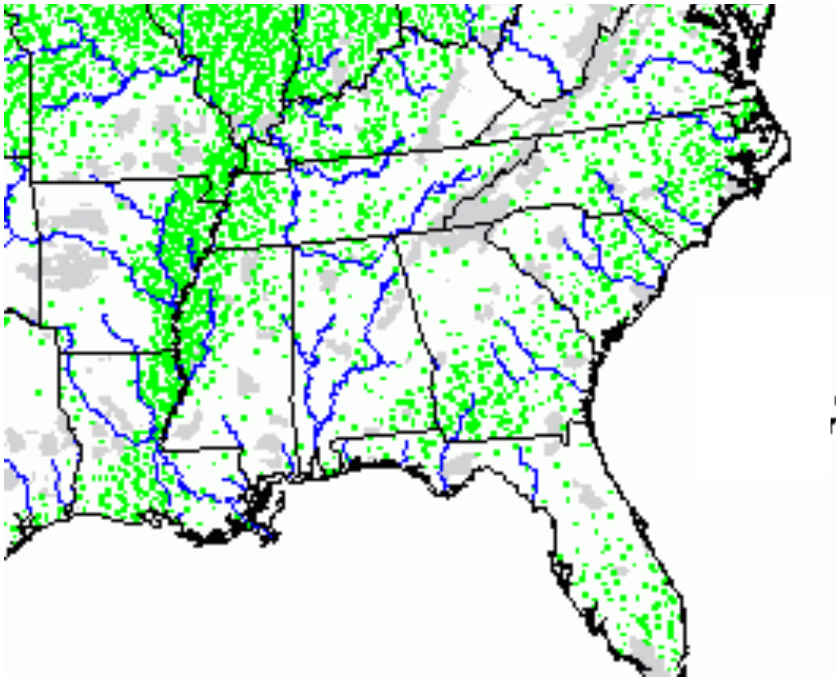
Soil Classification





Agriculture in the Southern USA

- 25 million acres crop and pasture land
- Soils highly weathered
- Low nutrient and water holding capacity
- Impaired water bodies by contaminants (sediment, nutrients, agricultural chemicals)



Green dots represent 25,000 acres of cropland.
Source NRCS

Southern USA Soils

- Sands to clay loams
- Low concentration of basic cations (Ca, Mg, K)
- Very acid subsoils with toxic levels of Al^{3+}

Cecil Soil
NRCS Photo

Tifton Soil
NRCS Photo

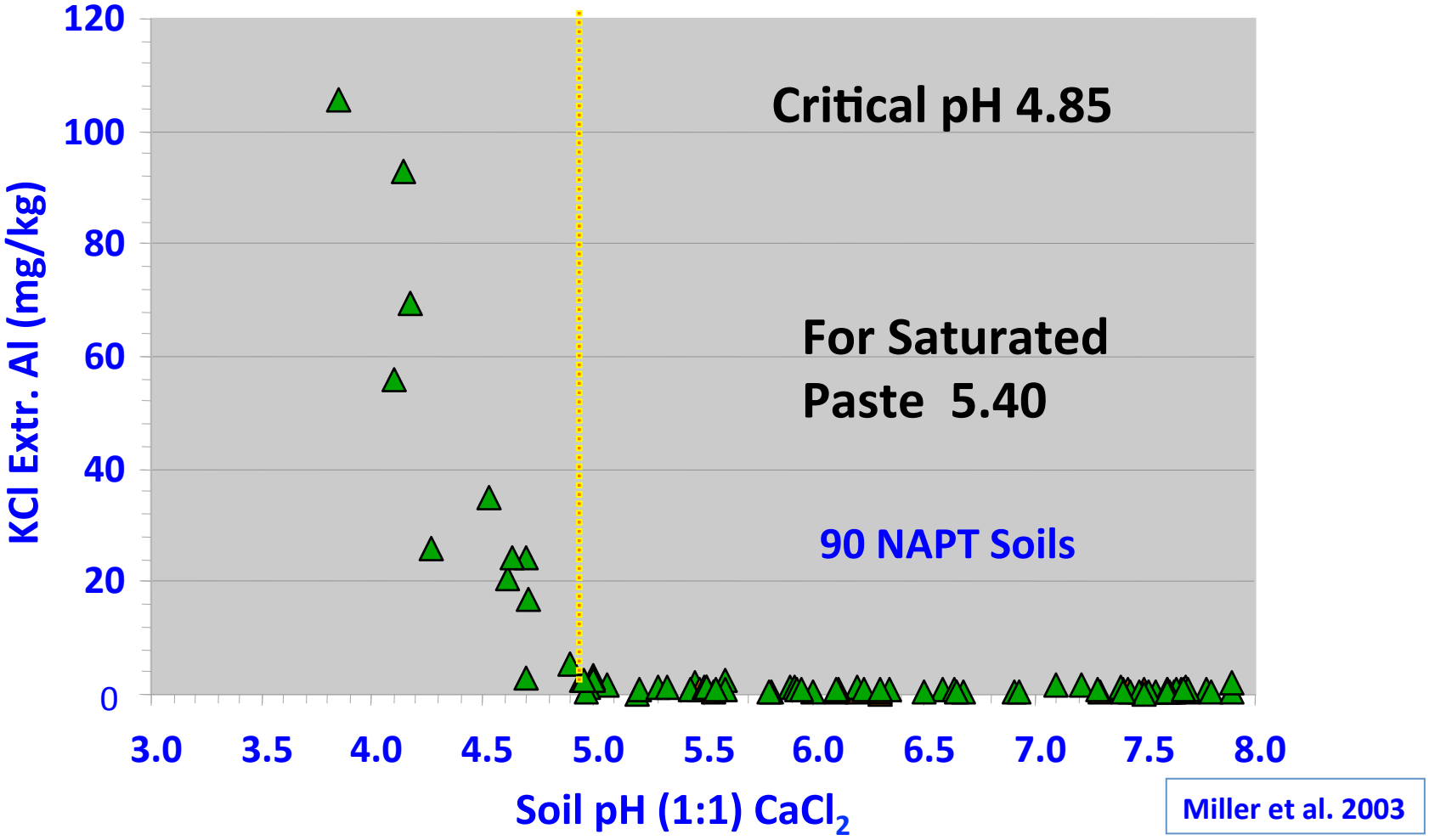
Characteristics of Southern Soils

- Weak structure
- Crust prone
- Low infiltration & high runoff rates
- Low nutrient & water retention
- Highly Erodible

Soil Acidity

- Top- and subsoil acidity
  - Excess Al and Mn
  - Deficient Ca
- Root extension and proliferation
  - Require adequate Ca
  - Limited by toxic levels of Al
- Poor root system
  - Limited water and nutrient uptake
  - Low yields

$pHCaCl_2$ vs. KCl Extractable Al



Soil pH_w vs depth
Crisp County

Depth inches	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
0-6	5.8	5.8	6.2	5.7	5.3	6.1
6-12	5.6	6.0	6.0	5.2	5.2	5.9
12-24	4.9	6.1	5.5	4.8	5.0	5.3
24-36	5.0	5.7	5.0	5.0	4.8	5.2
36-48	4.9	5.3	5.0	5.0	4.5	4.9

Kissel, 2006

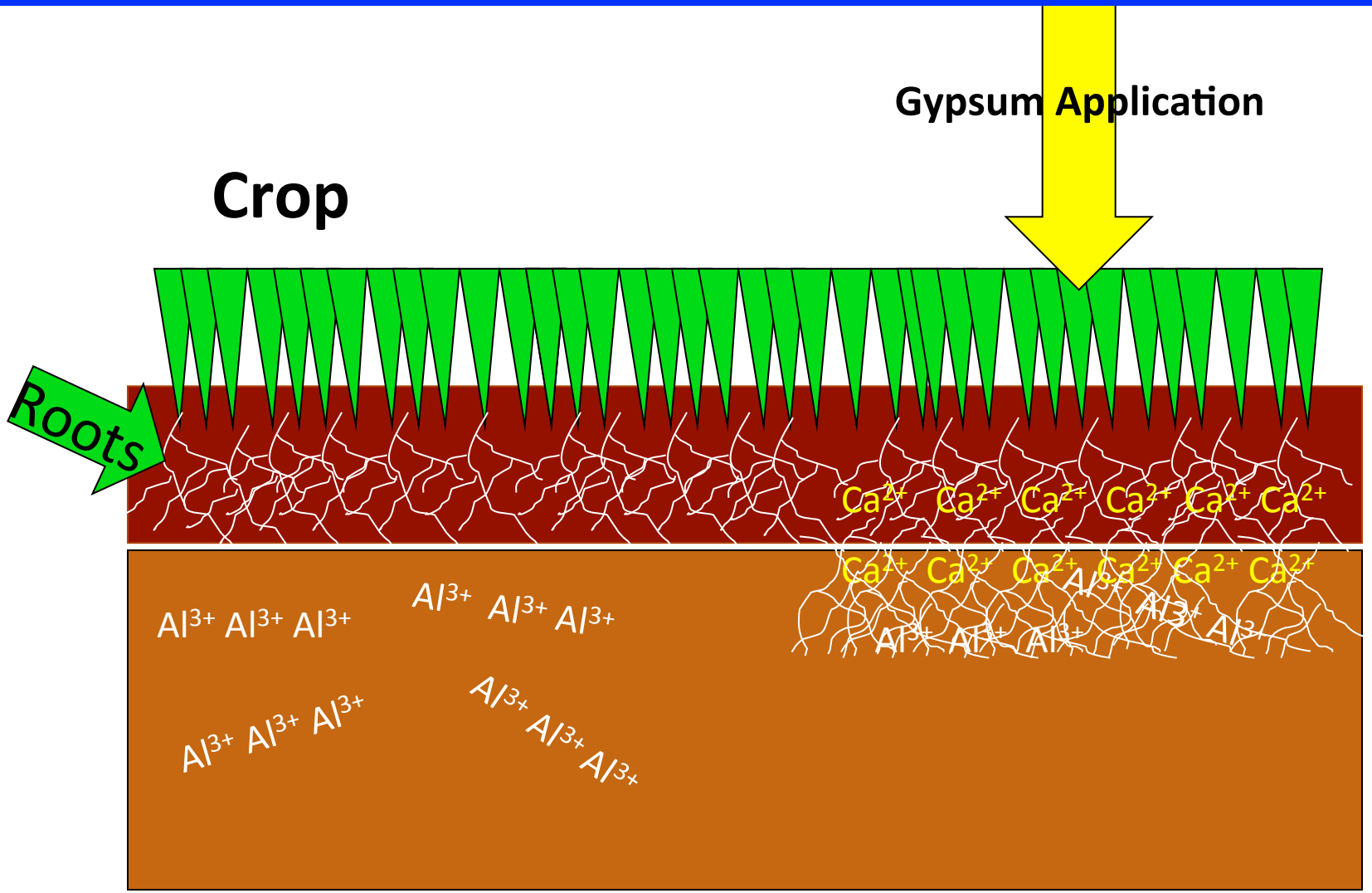
Ca and Root Growth in Acid Subsoils

- Phloem immobile
  - Is not translocated to lower root even if topsoil is adequately limed
- Ca from gypsum leaches to subsoil
  - reduces toxic Al^{3+}
  - Allows better root profileration
  - Allows better exploitation of subsoil water
  - Translates into increased yields

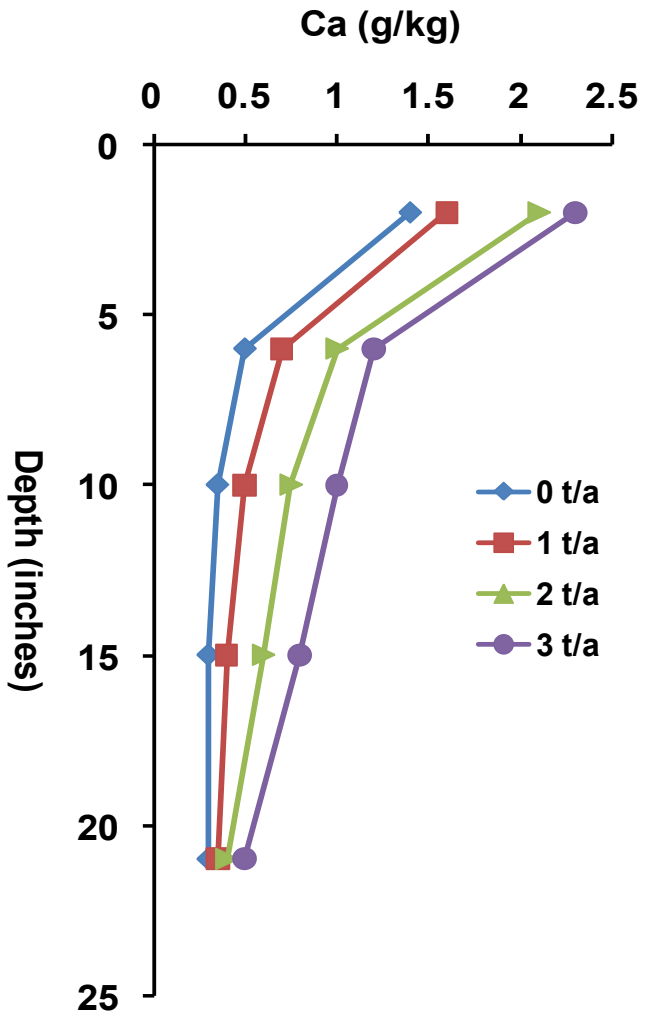
Amelioration of Subsoil Acidity and Al^{3+} Toxicity

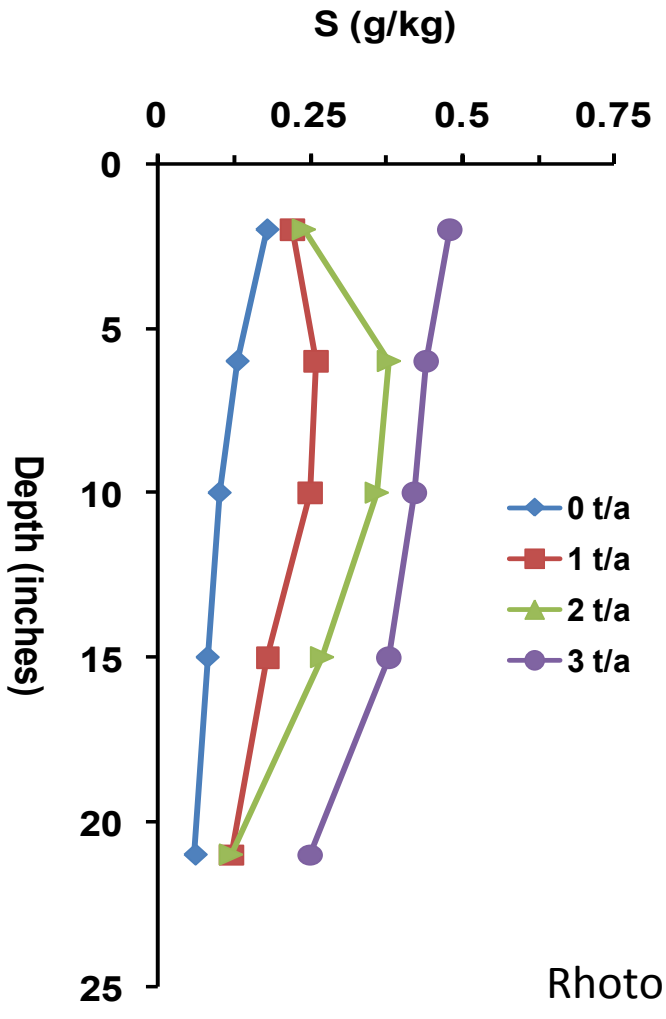
- Surface-applied gypsum leaches down to subsoil
- Ca^{2+} exchanges with Al^{3+}
- SO_4^{2-} forms complex ion $AlSO_4^+$ with Al^{3+}
- $AlSO_4^+$ is not toxic to plant roots

Reduction of Subsoil Acidity



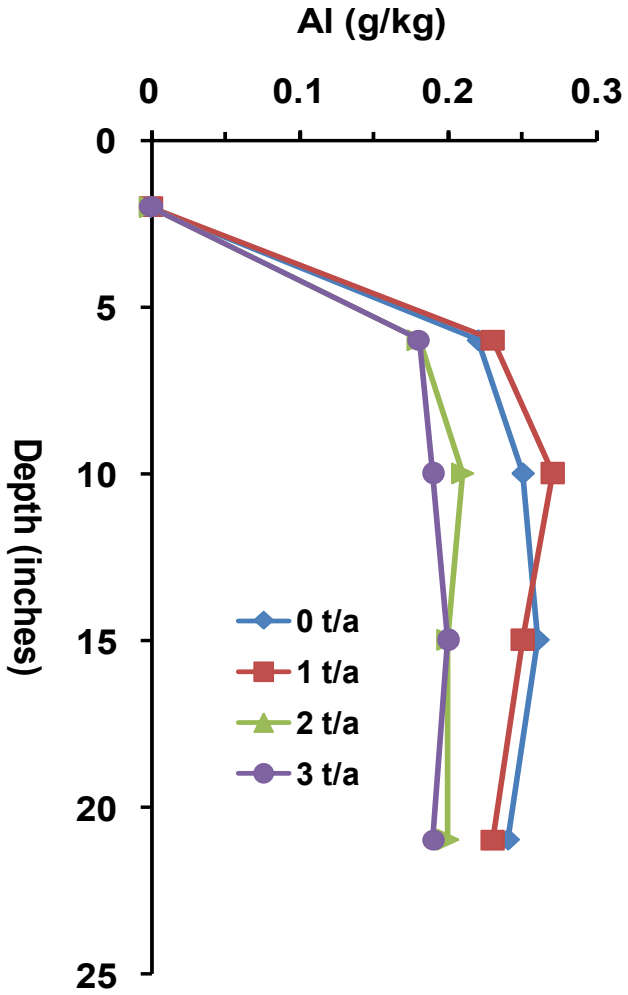
Soil Profile Ca and S After 3 Years

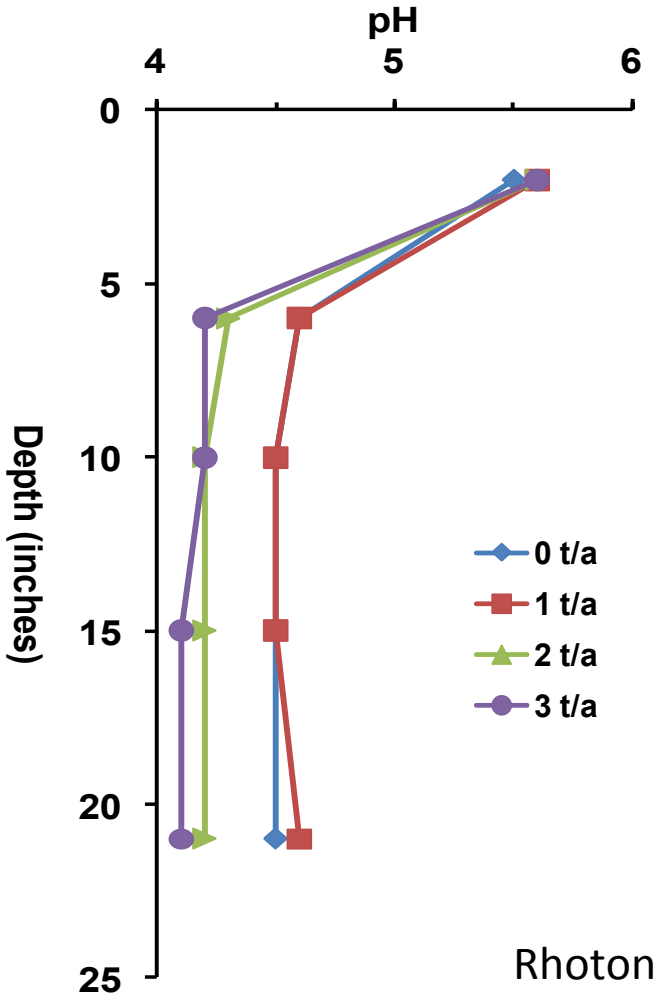




Rhoton 2008

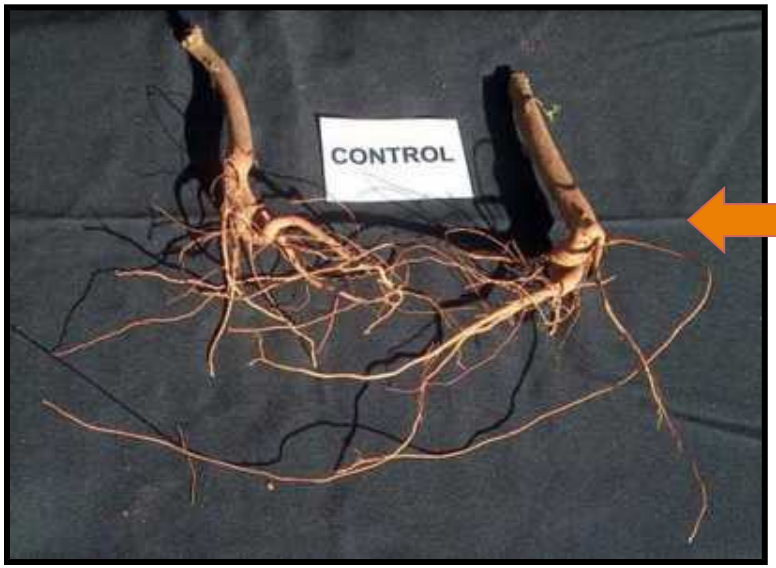
Soil Profile Al and pH After 3 Years





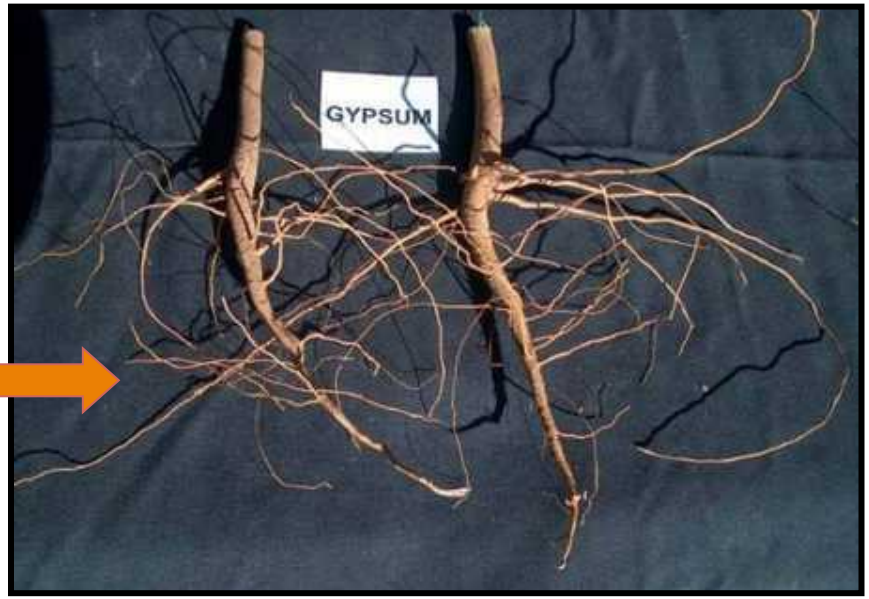
Rhoton 2008

Cotton Root Development - Mississippi



Contorted tap roots due to Al toxicity

Straight tap roots in absence of Al

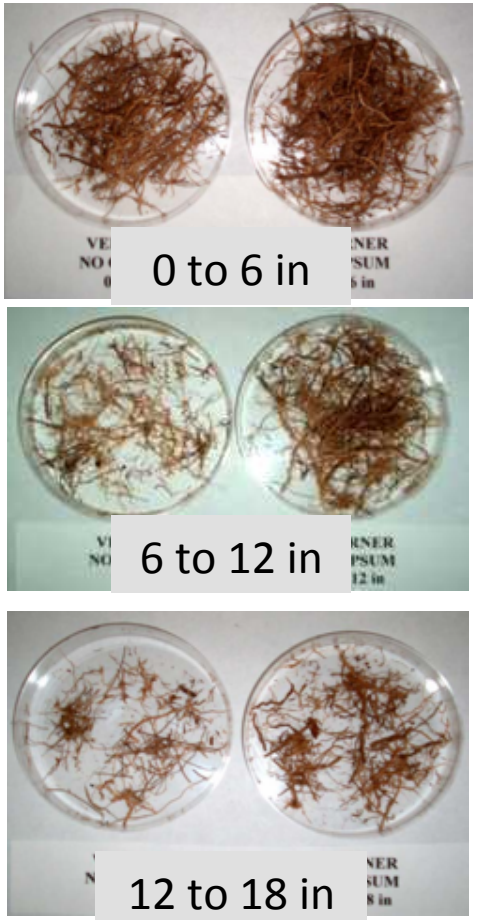


Effect of Gypsum on Cotton Yield & Value

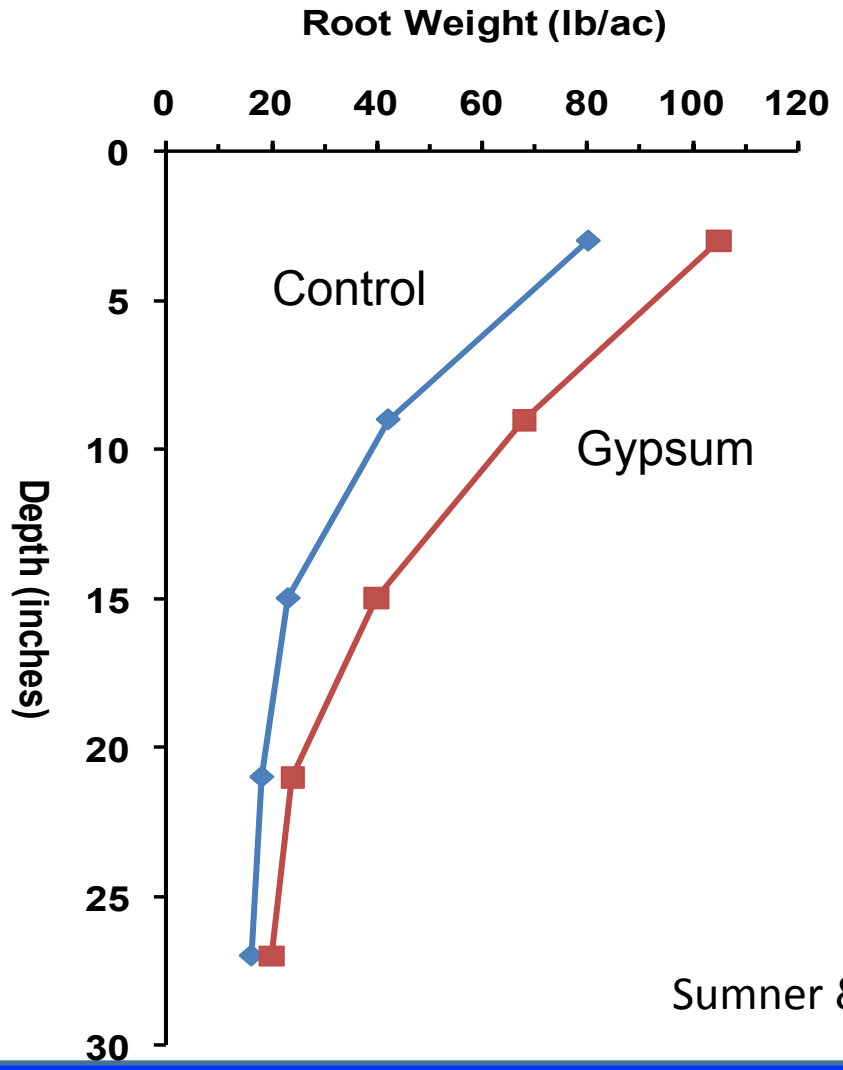
Treatment	Lint Cotton Yield (lb/acre) 2000	2001	2002	2003	2004
Control	309	767	889	338	745
Gypsum	308	985	1,113	383	867
Difference	0	218	224	50	122
Value	0	$218	$224	$50.00	$133.00
Cumulative Profit	-$125.00	$93.50	$317.60	$367	$598.60

Sumner

Bermudagrass Root Growth



Bermudagrass



Sumner & Larrimore

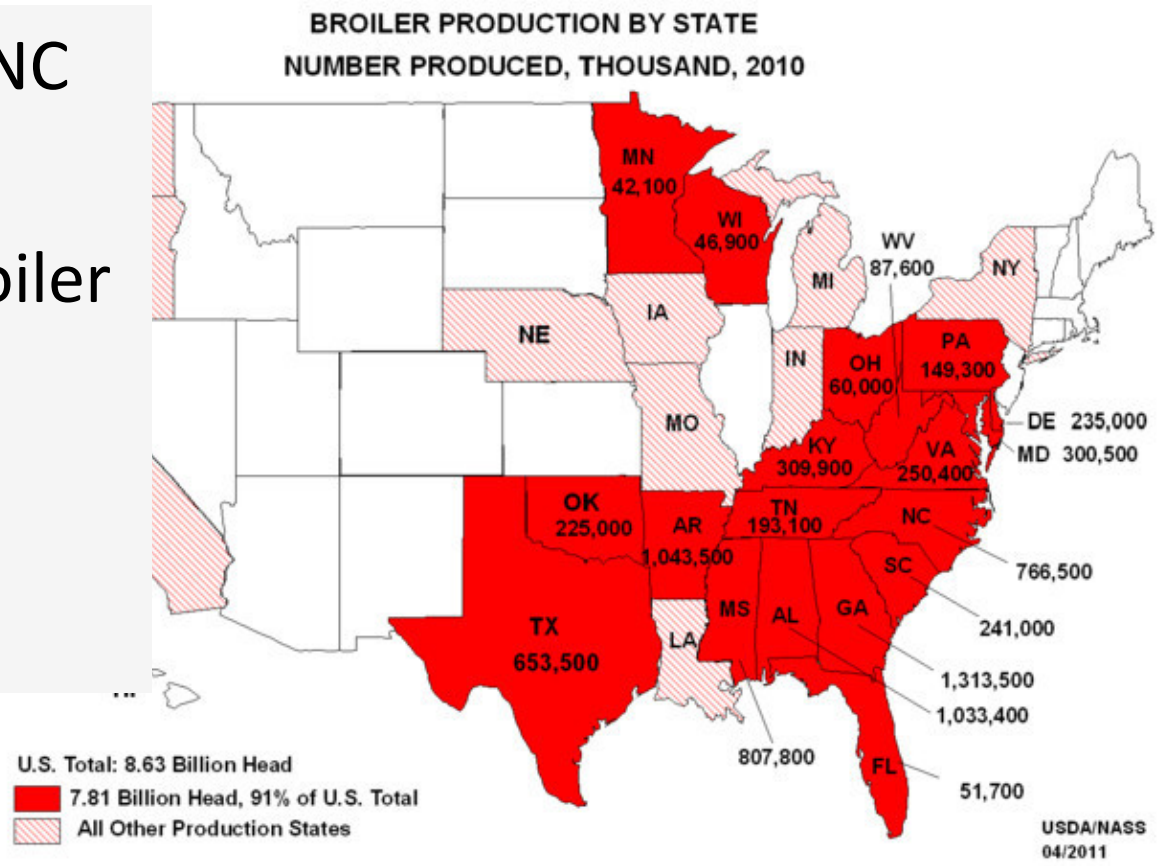
Poultry Production in the US

7.8 Billion Broilers

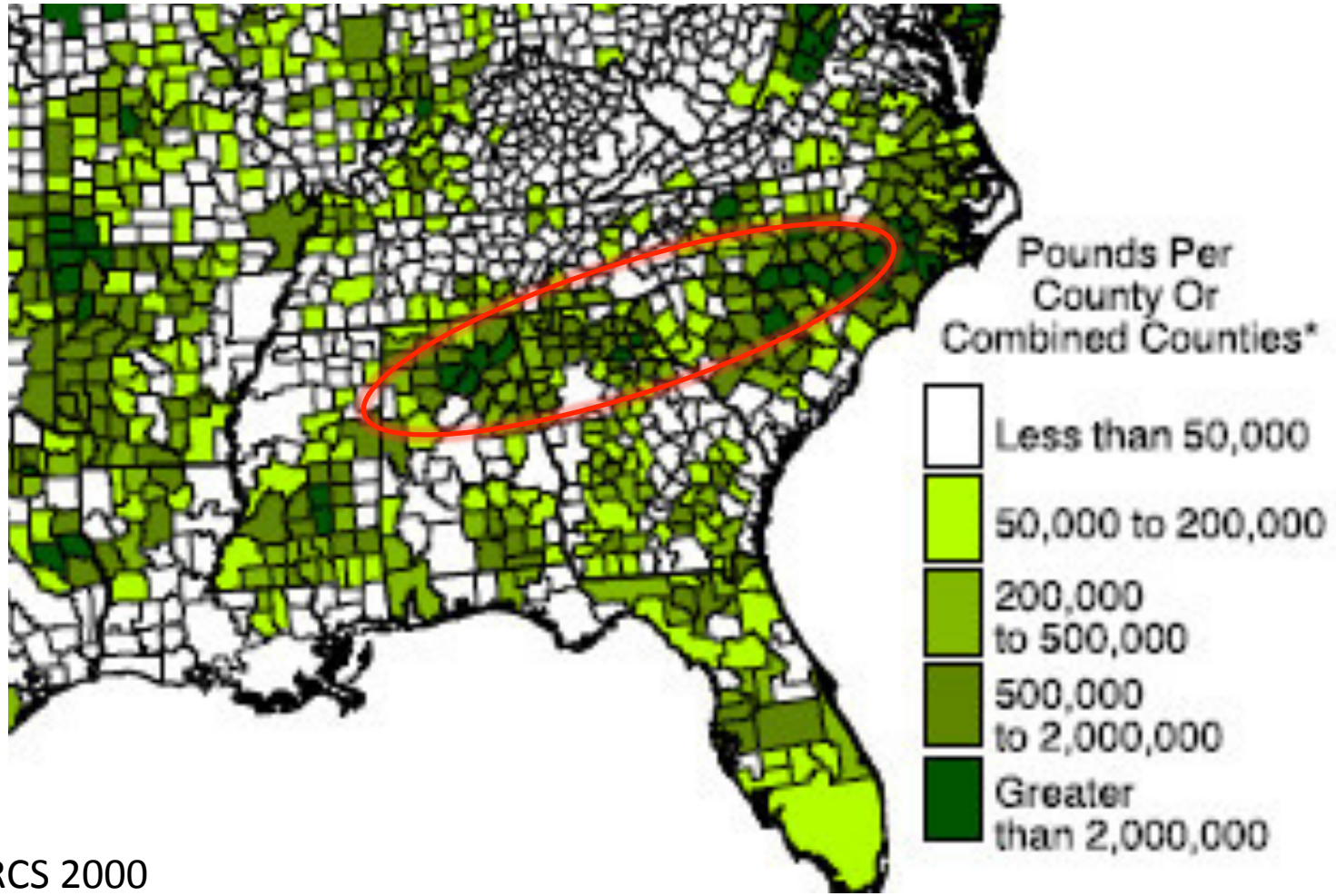
33 Million Tons Poultry Litter

Poultry Production In the South

- GA, AR, AL, MS & NC
- 4.9 billion broilers
- 21 million tons broiler litter
- 289,000 tons N
- 277,000 tons P

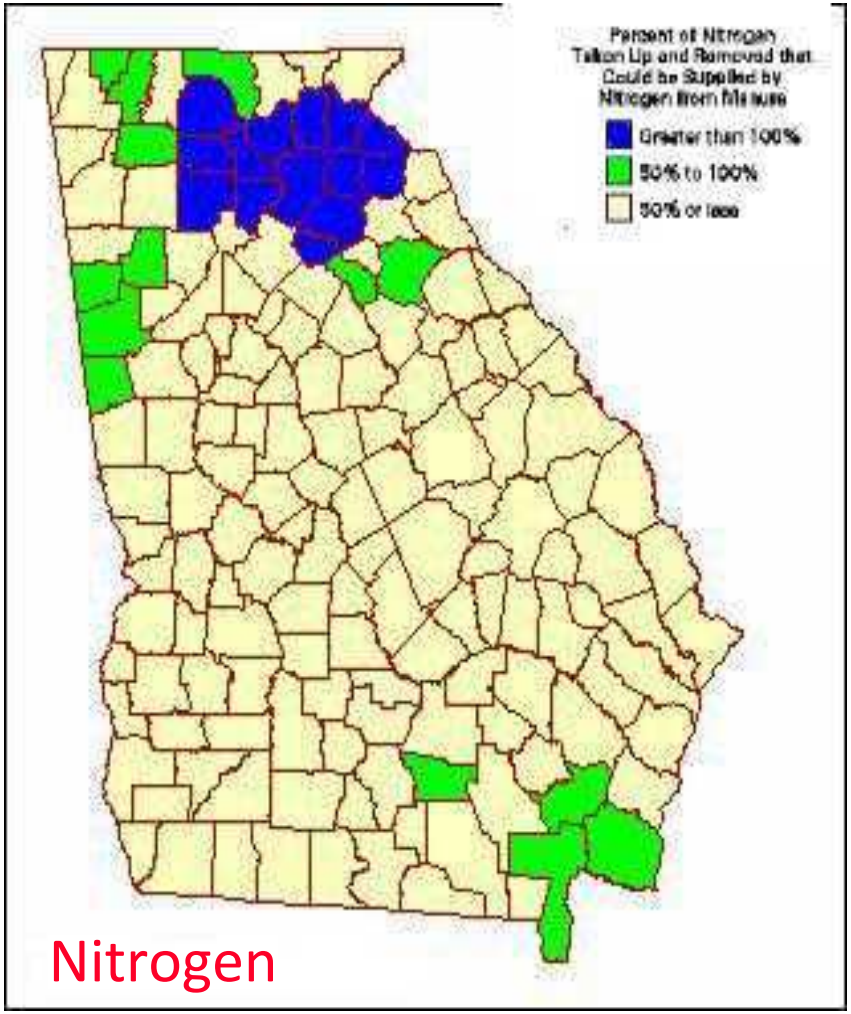


Excess Manure P

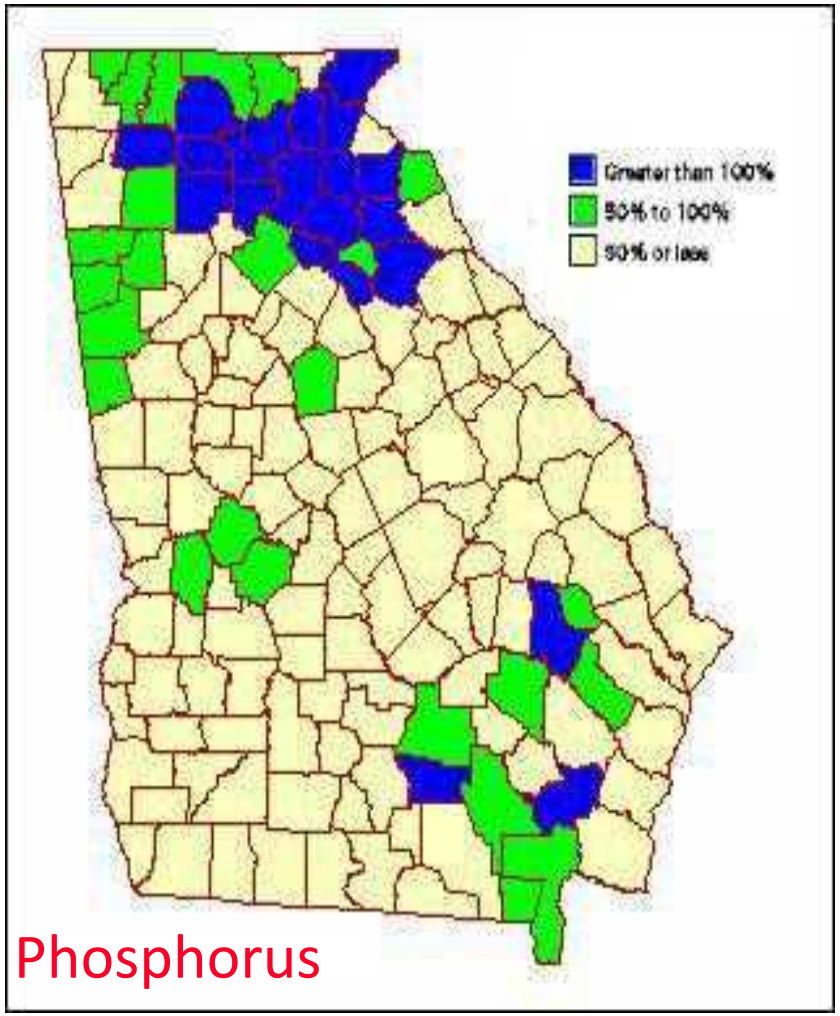


NRCS 2000

FGD Gypsum to Remediate High Soil P

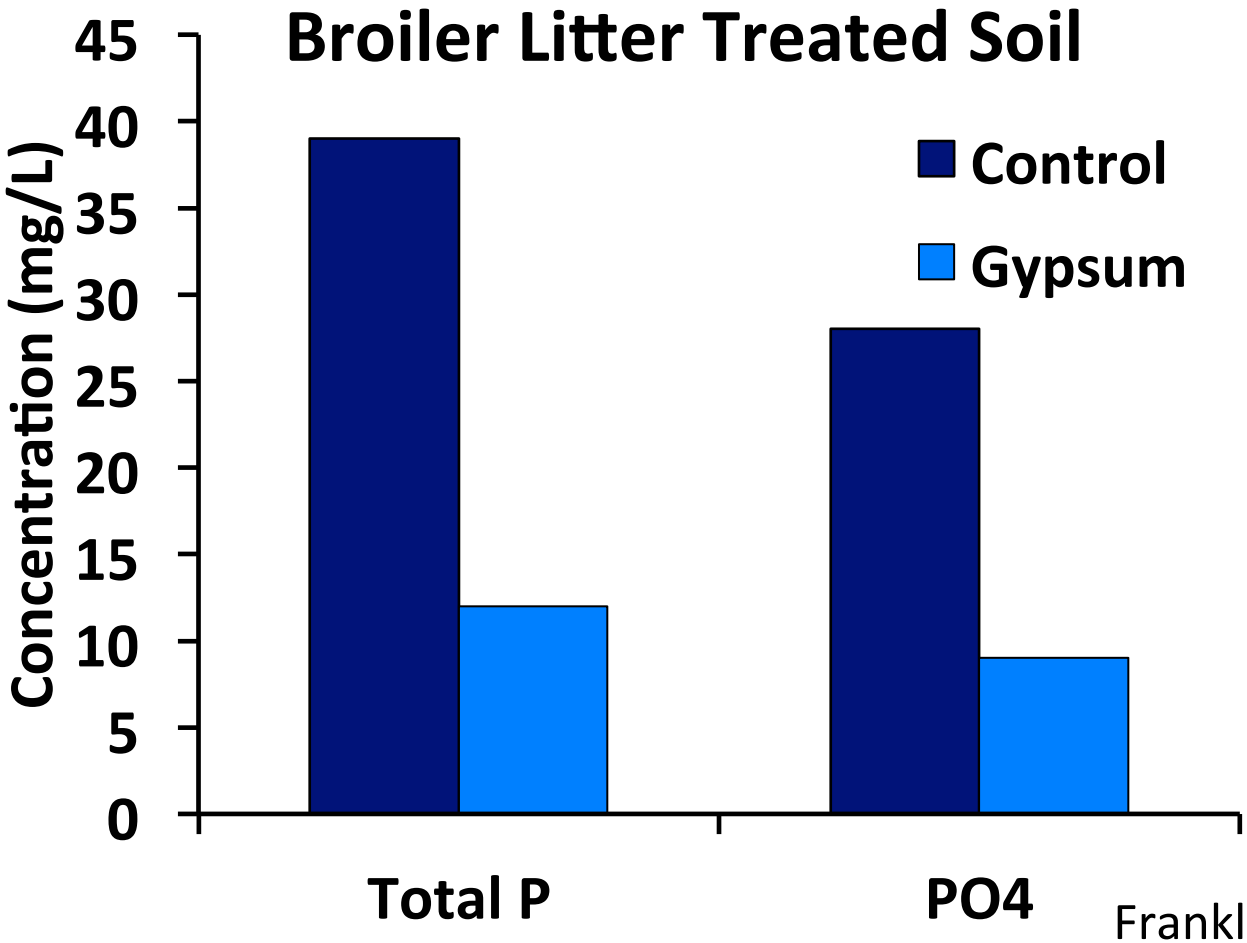


Nitrogen



Phosphorus

FDG Gypsum and Phosphorus



Franklin et al., 2007

Potential Impact of FGD-Gypsum

- Mississippi River –

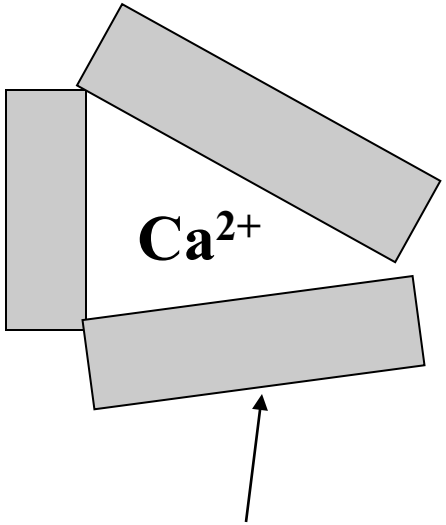
  100 - 700 tons P day^{-1}
- Reduce P loss from PL by 4,000 tons yr^{-1} in Southern States

Gypsum and Clay Flocculation

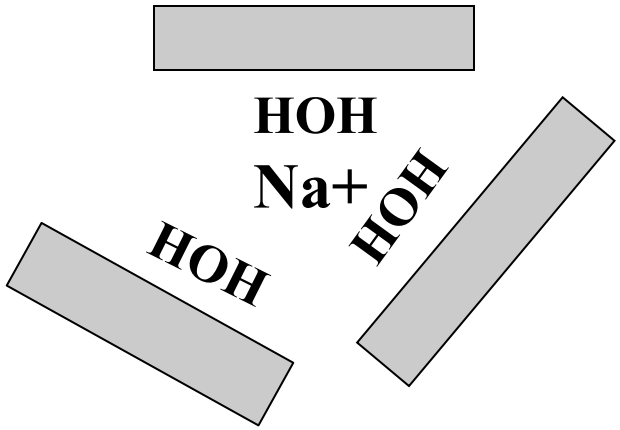
- Reduces soil crusting
- Improves water infiltration
- Improves water transmission (conductivity)

Flocculation and Dispersion

Flocculated clay

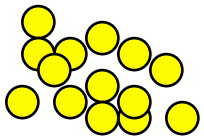


Dispersed clay

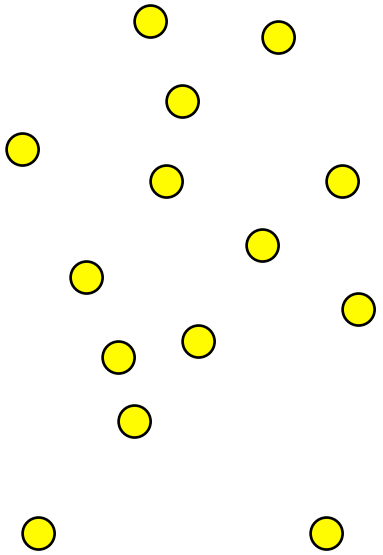


Soil aggregates -- cemented clusters of sand, silt, and clay

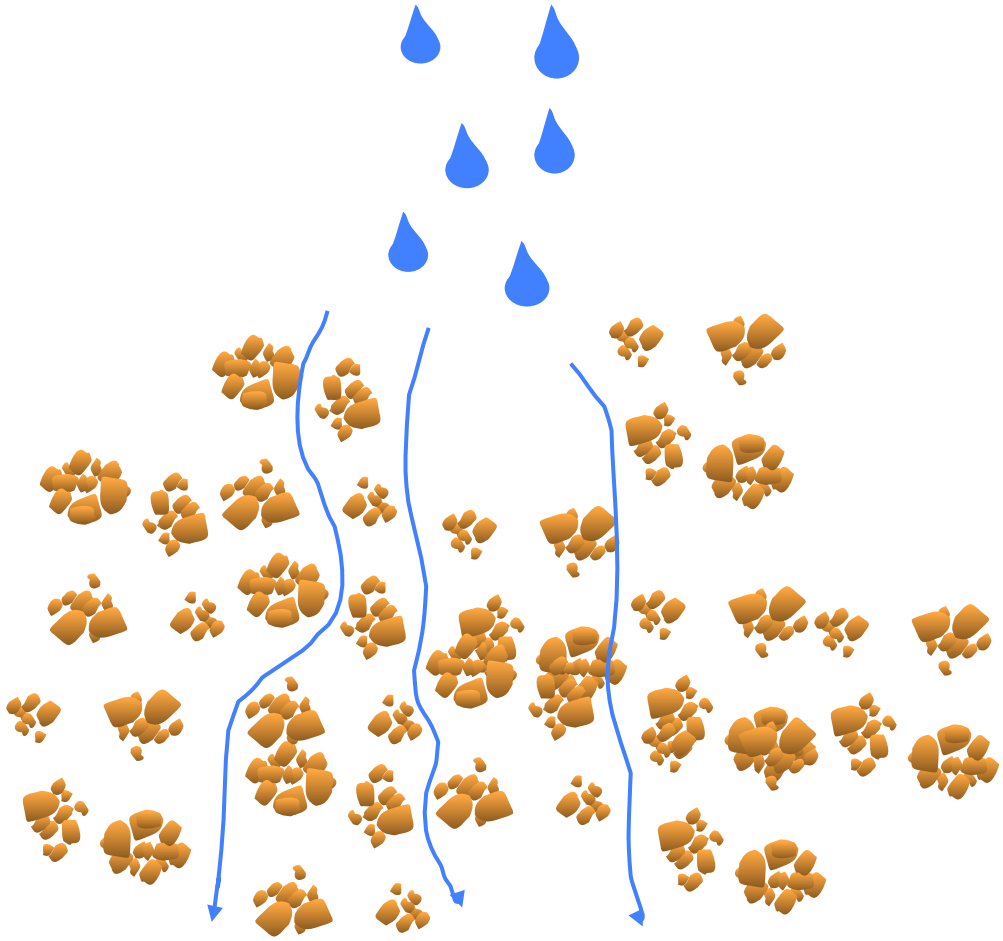
Flocculated Particles



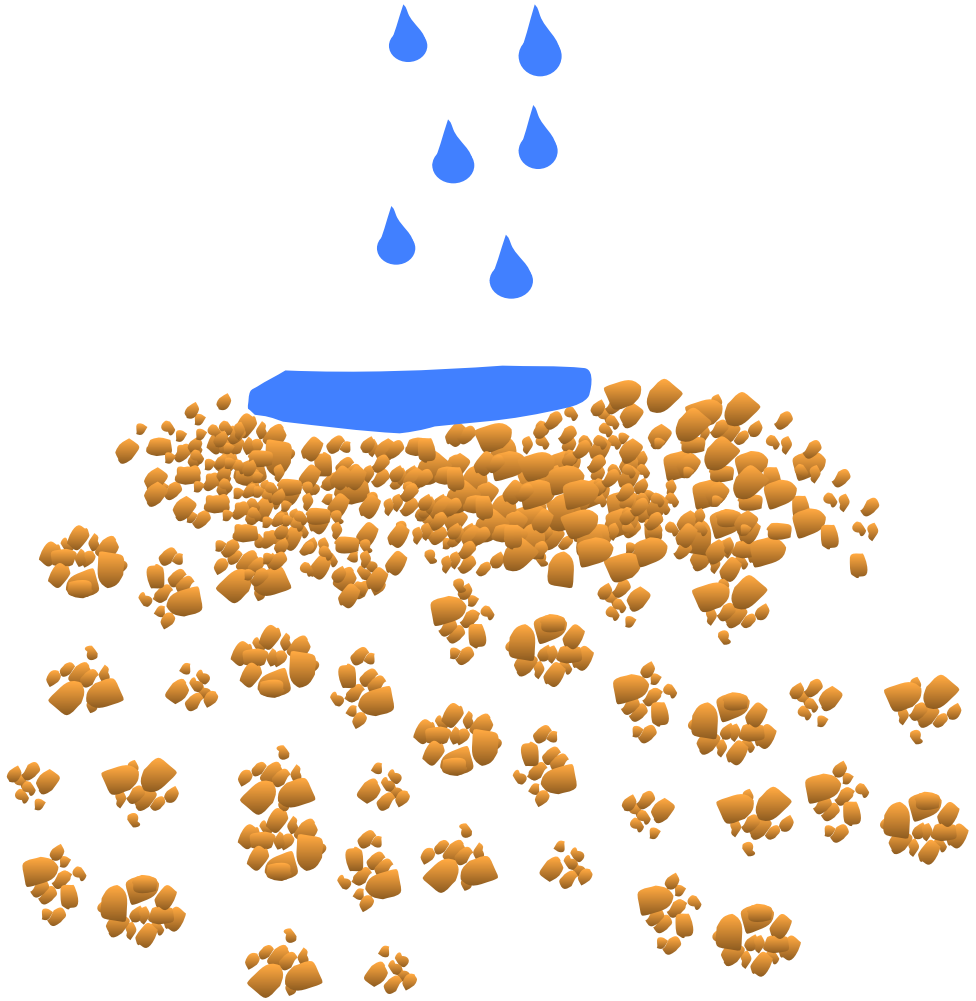
Dispersed Particles



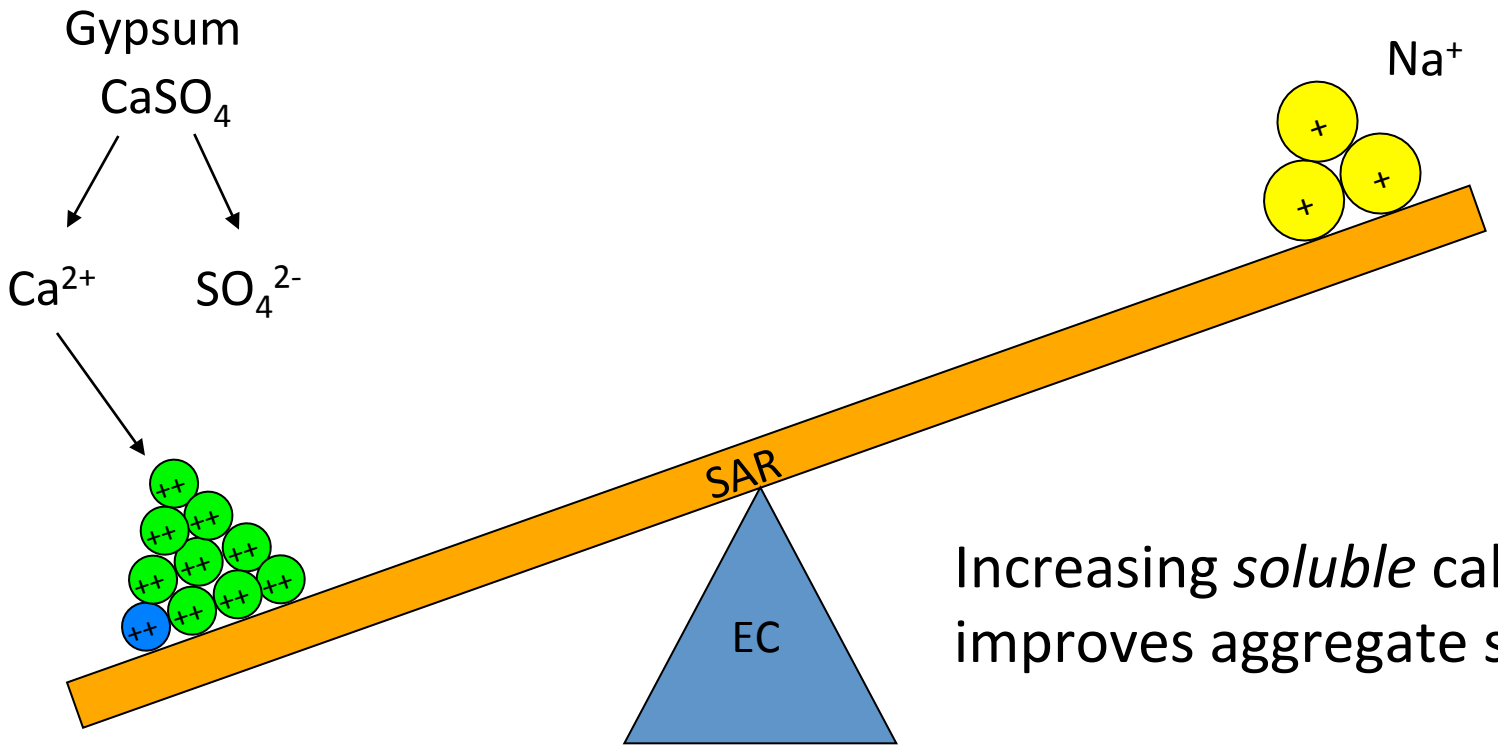
Flocculation allows water and plant roots to penetrate the soil



Dispersed clays plug soil pores and impede water infiltration and soil drainage.



Poorly Structured Soil

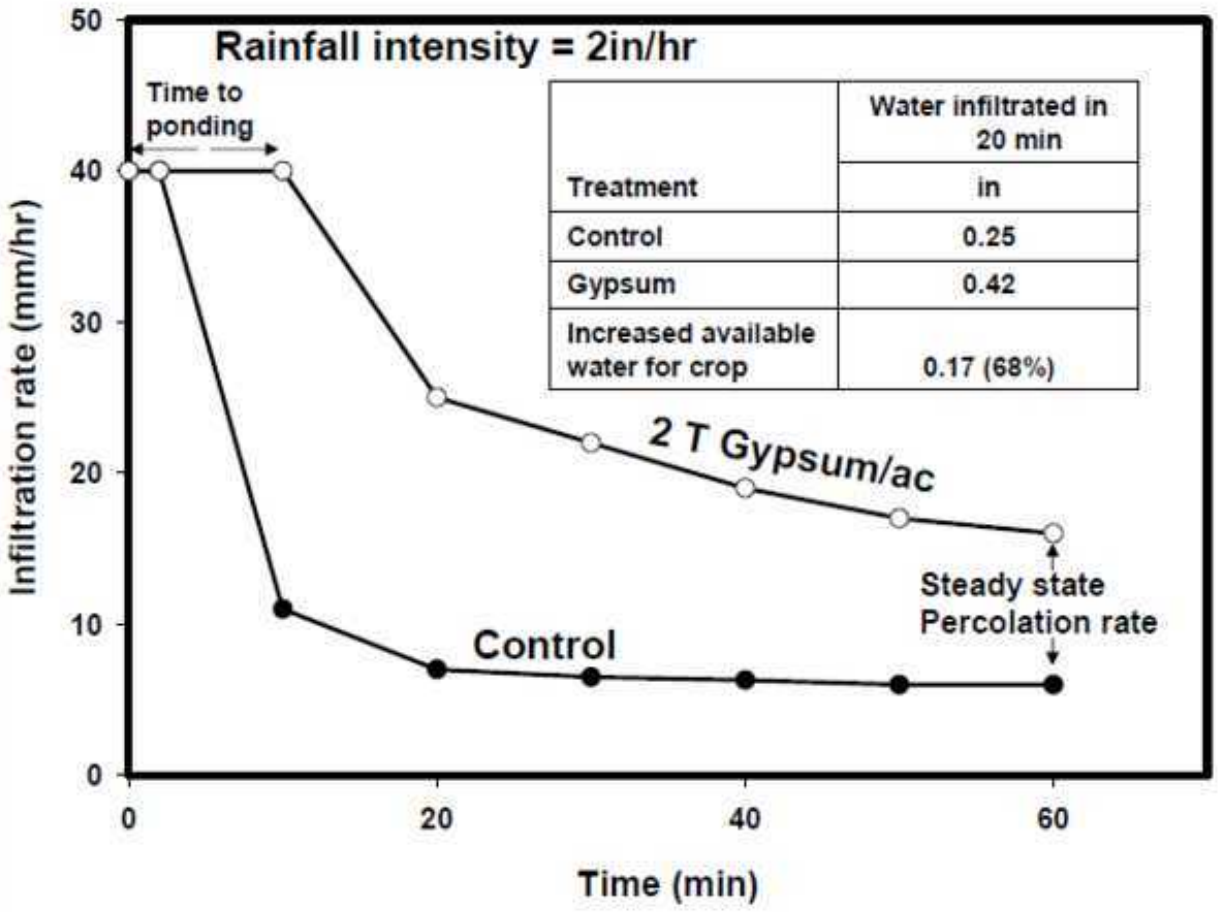


Increasing *soluble* calcium improves aggregate stability

Flocculated soil

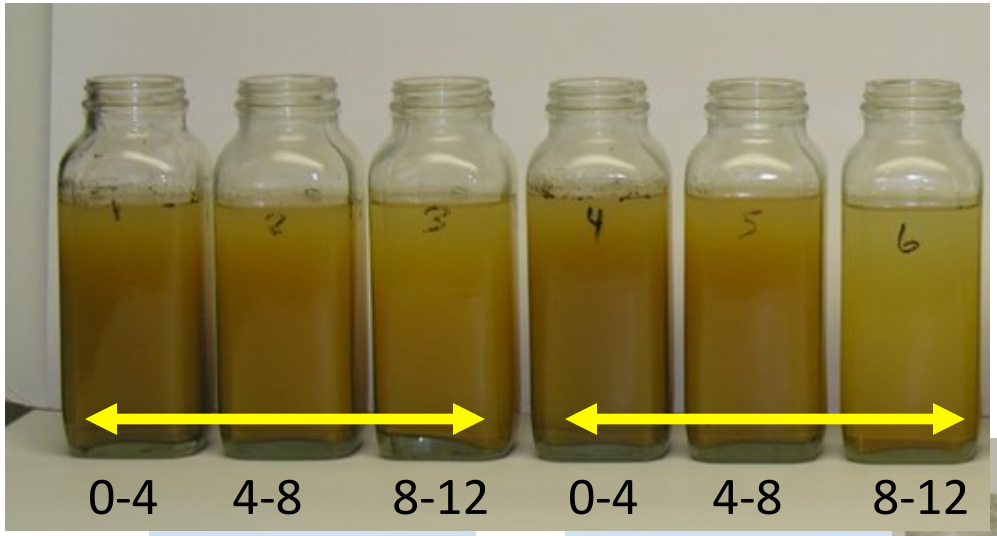
Dispersed soil

Gypsum & Rainfall Infiltration



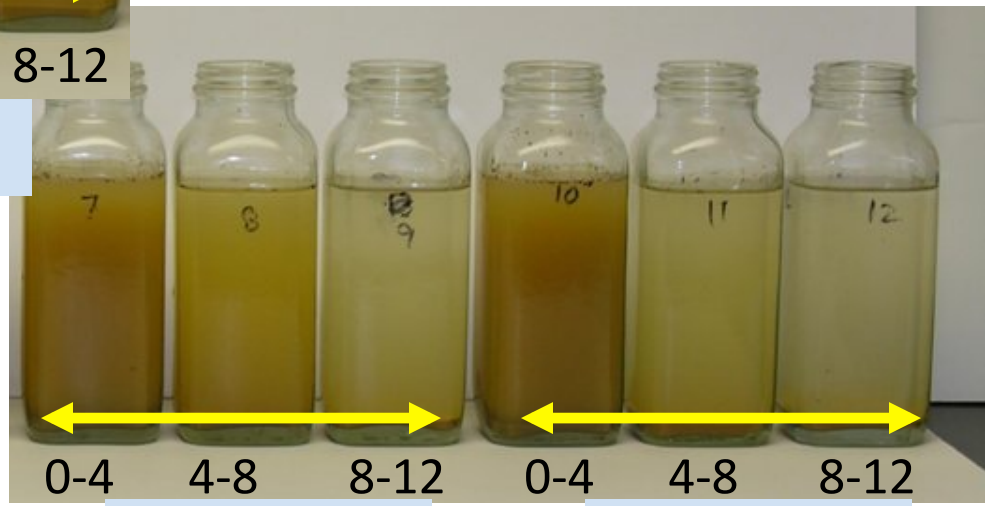
Miller & Scirefs 1988

FGD Gypsum Influence on Soil Aggregation



0 ton/acre

1 ton/acre



3 ton/acre

4 ton/acre

Flocculation of the Bonn soil at the end of first cropping season

Rhoton, 2007

Gypsum Functions in Reclamation of Sodic Soils

Sodic soil properties are dominated by excessive exchangeable Na

- Ca to replace exchangeable Na
- Salt to maintain electrolyte concentration at soil surface
  - Prevents (reduces) clay dispersion and swelling
  - Maintains good surface infiltration rate

Flocculating Cations

Ion		Relative Flocculating Power
Sodium	Na^+	1.0
Potassium	K^+	1.7
Magnesium	Mg^{2+}	27.0
Calcium	Ca^{2+}	43.0

We can divide cations into two categories

- Poor flocculators
  - Sodium
- Good flocculators
  - Calcium
  - Magnesium

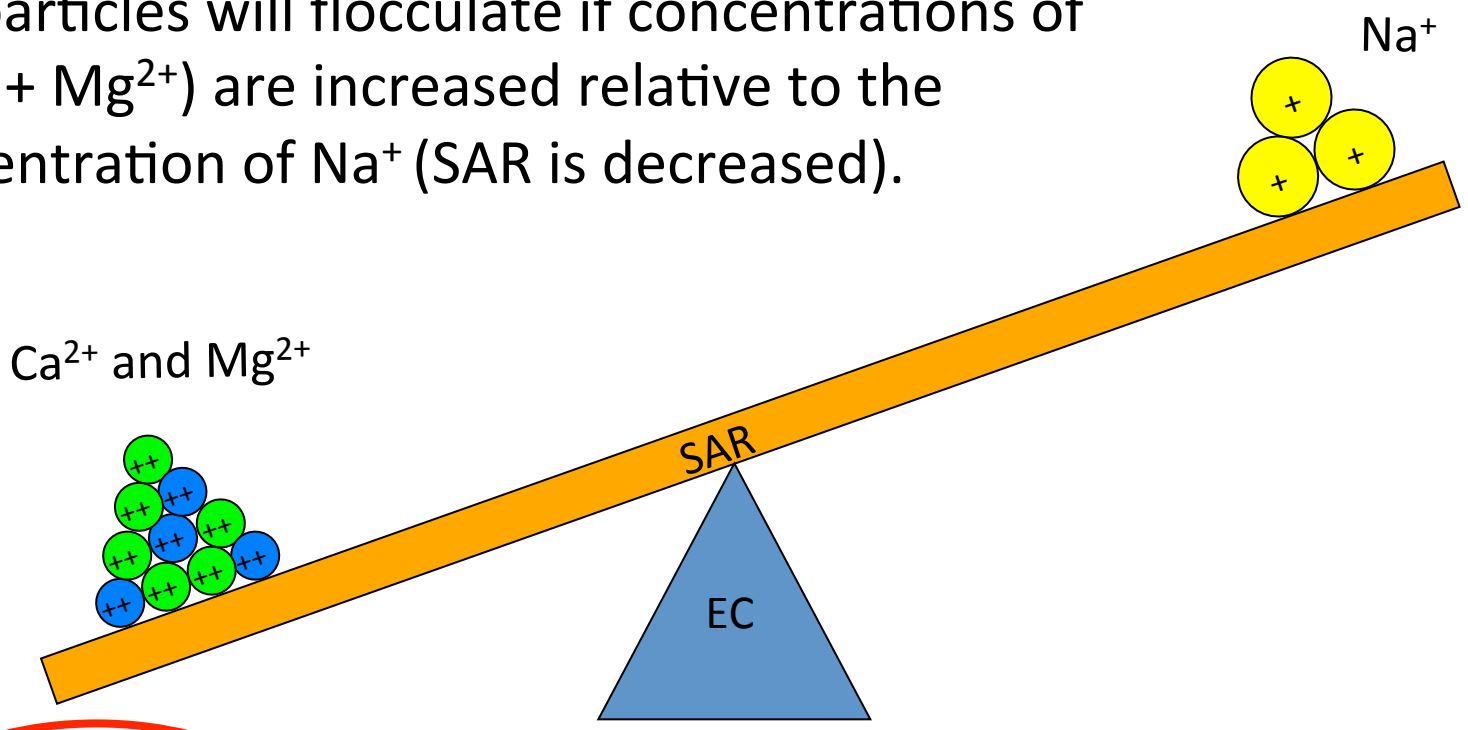
Sumner and Naidu, 1998

Flocculation Classification

Soil Classification	EC	SAR	Condition
Normal	<4	<13	Flocculated
Saline	>4	<13	Flocculated
Sodic	<4	>13	Dispersed
Saline-Sodic	>4	>13	Flocculated

Flocculated Soil

Soil particles will flocculate if concentrations of (Ca^{2+} + Mg^{2+}) are increased relative to the concentration of Na^{+} (SAR is decreased).

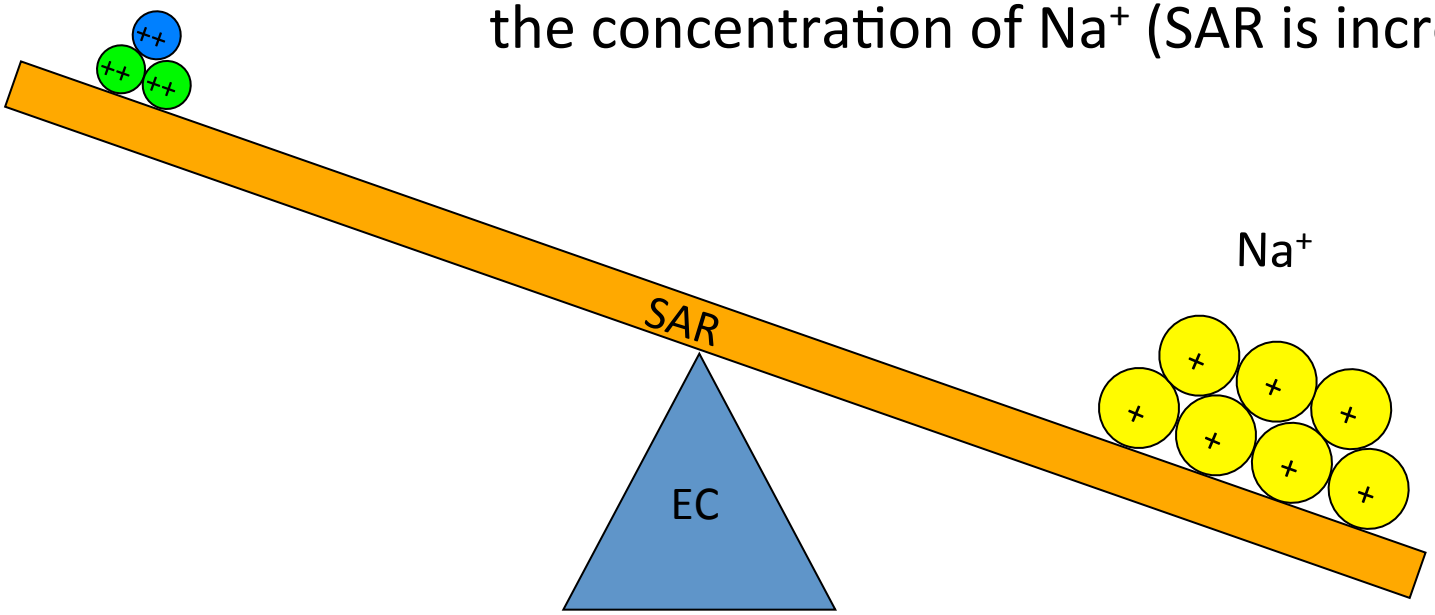


Flocculated soil

Dispersed soil

Dispersed Soil

Soil particles will disperse if concentrations of (Ca^{2+} + Mg^{2+}) are decreased relative to the concentration of Na^{+} (SAR is increased).



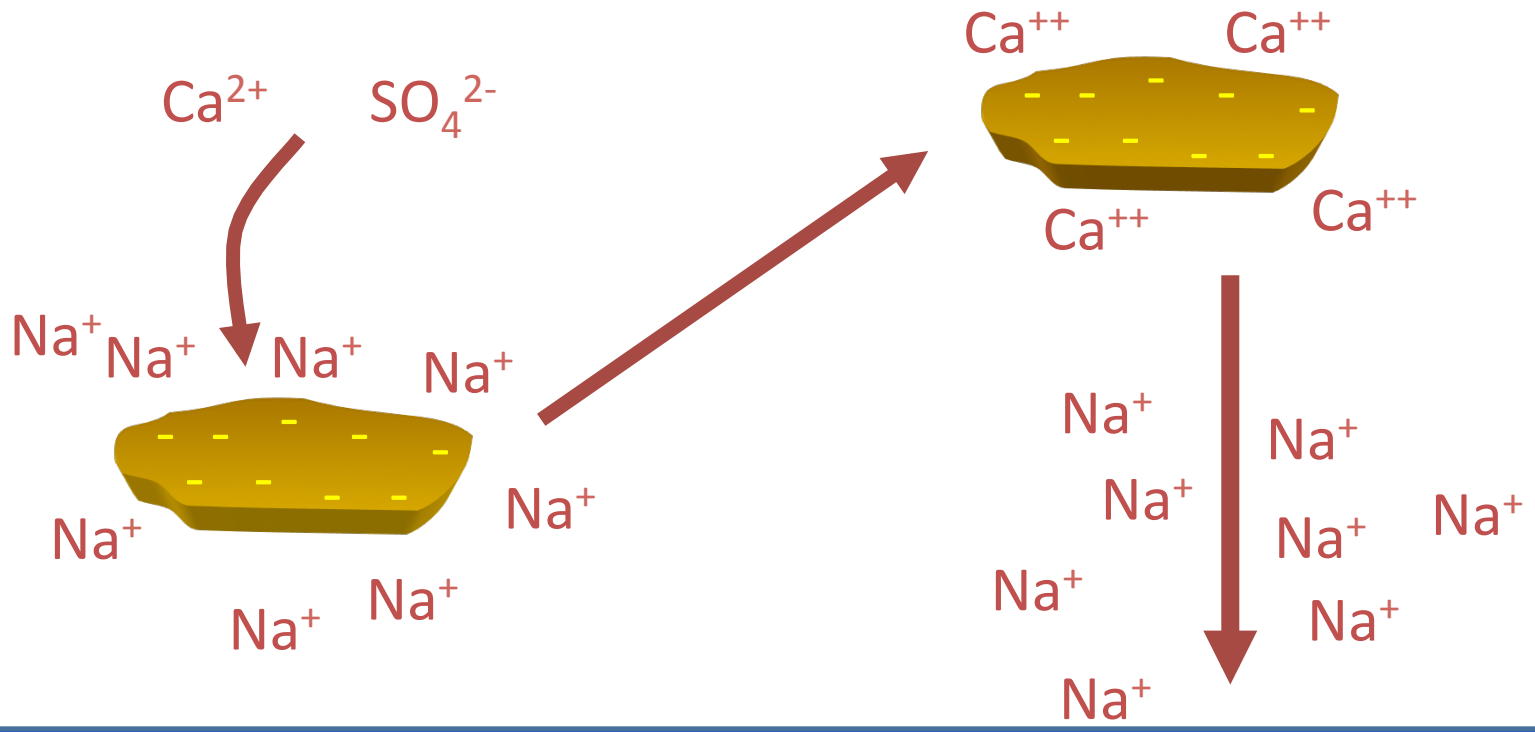
Flocculated soil

Dispersed soil

Gypsum on Sodium Affected Soils

Apply ***before*** leaching salts out of soils susceptible to dispersion

- ❖ Amount needed can be determined by a soil test
- ❖ Replacing sodium before leaching stabilizes soil structure.



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Questions?