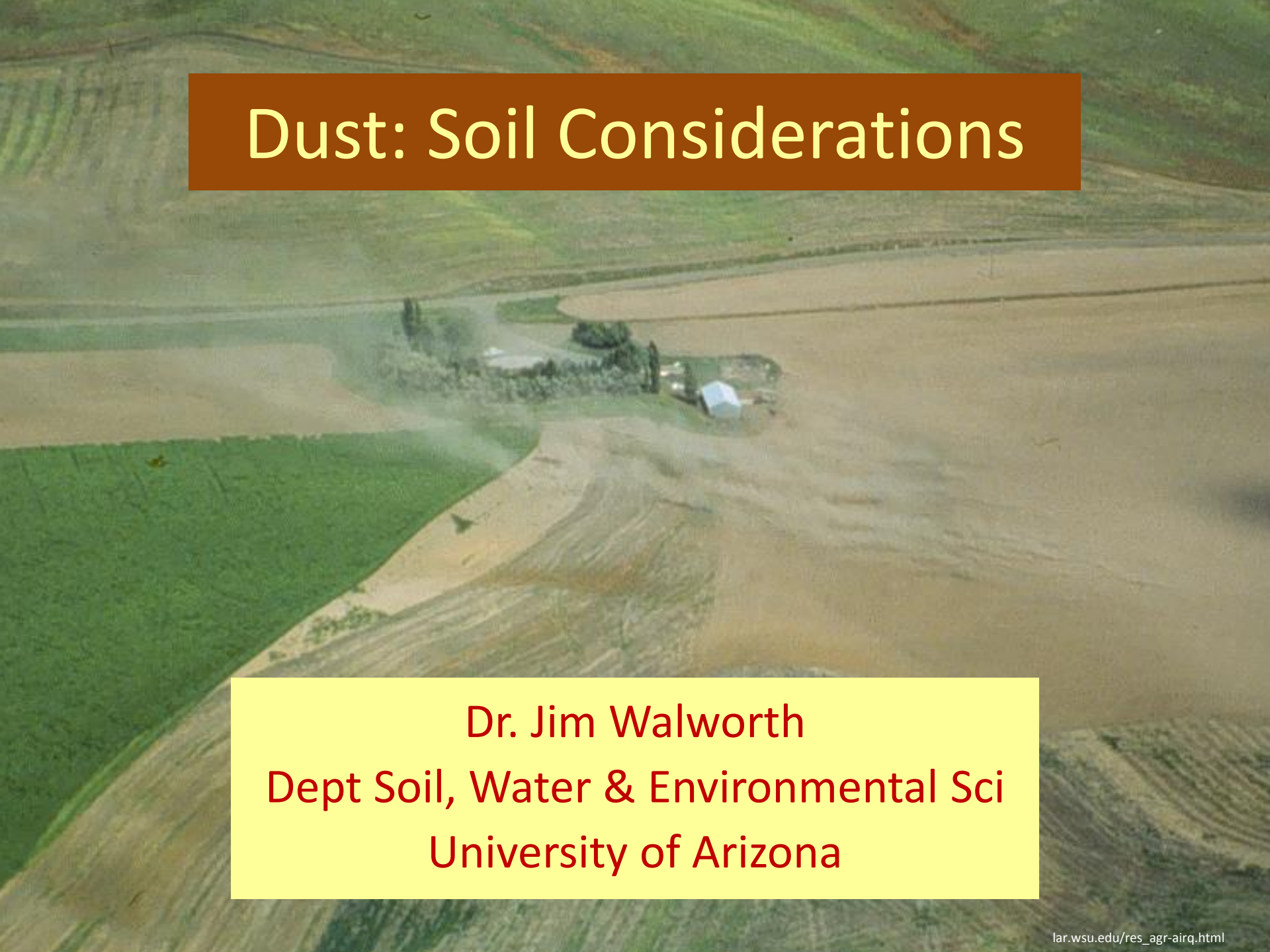
Dust: Soil Considerations



Dr. Jim Walworth
Dept Soil, Water & Environmental Sci
University of Arizona

lar.wsu.edu/res_agr-airq.html

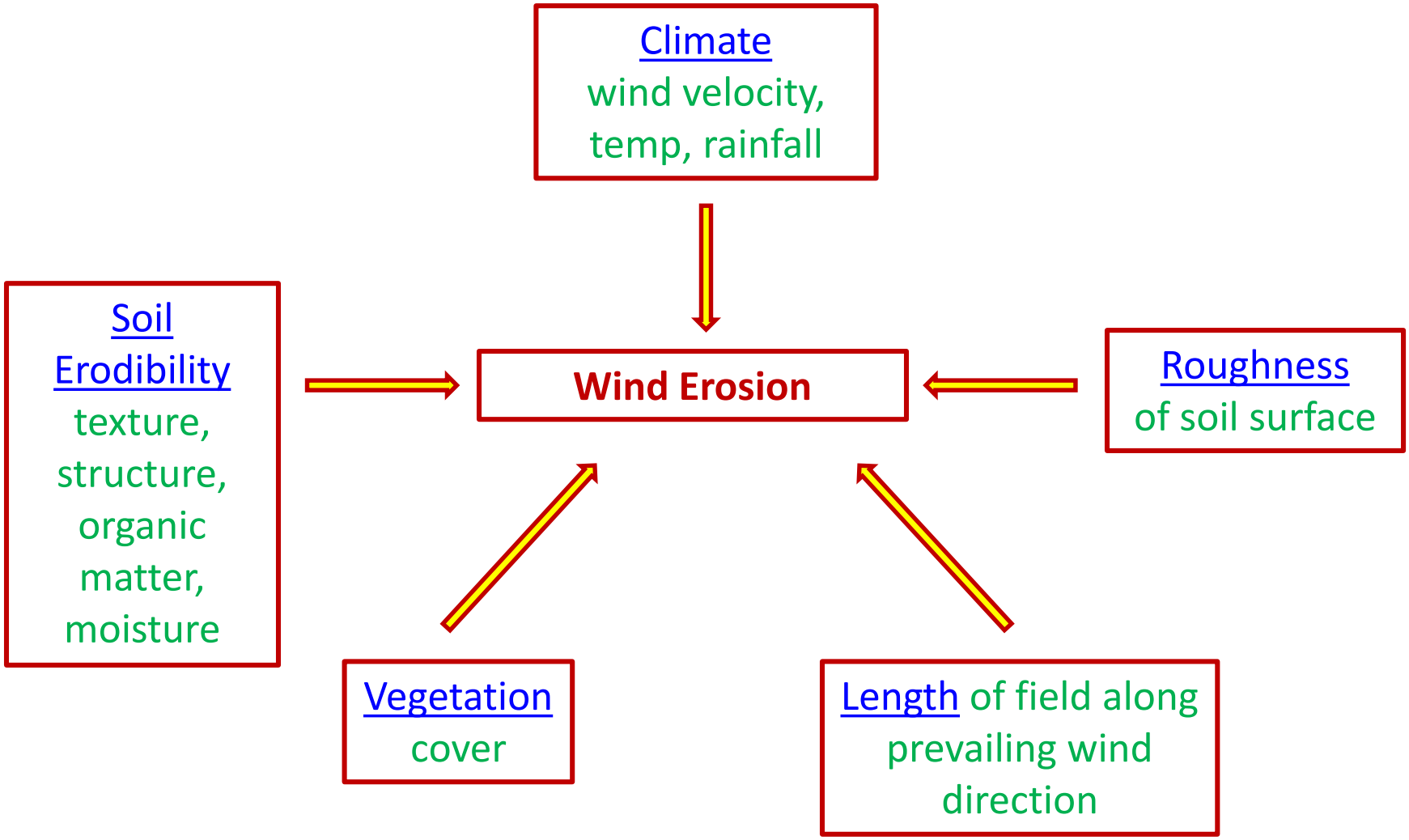
Wind Erosion Prediction Equation (WEP)

$$E = f(ICKLV)$$

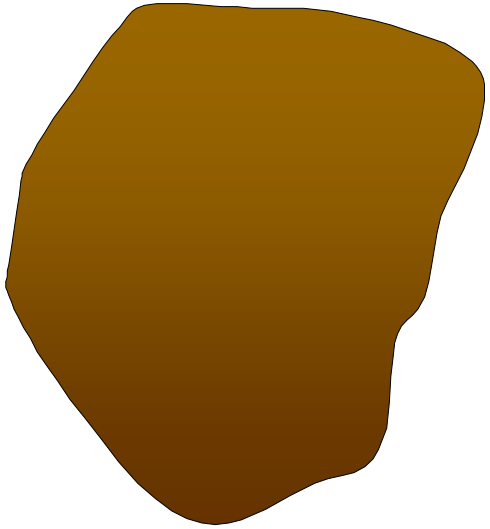
- E = erosion

- I = soil erodibility factor
- C = climate factor (wind velocity, temp, rainfall)
- K = soil-ridge-roughness factor (roughness of soil surface)
- L = length of field factor
- V = vegetative cover factor

Factors controlling the process of soil dust production

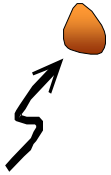


Soil Particles

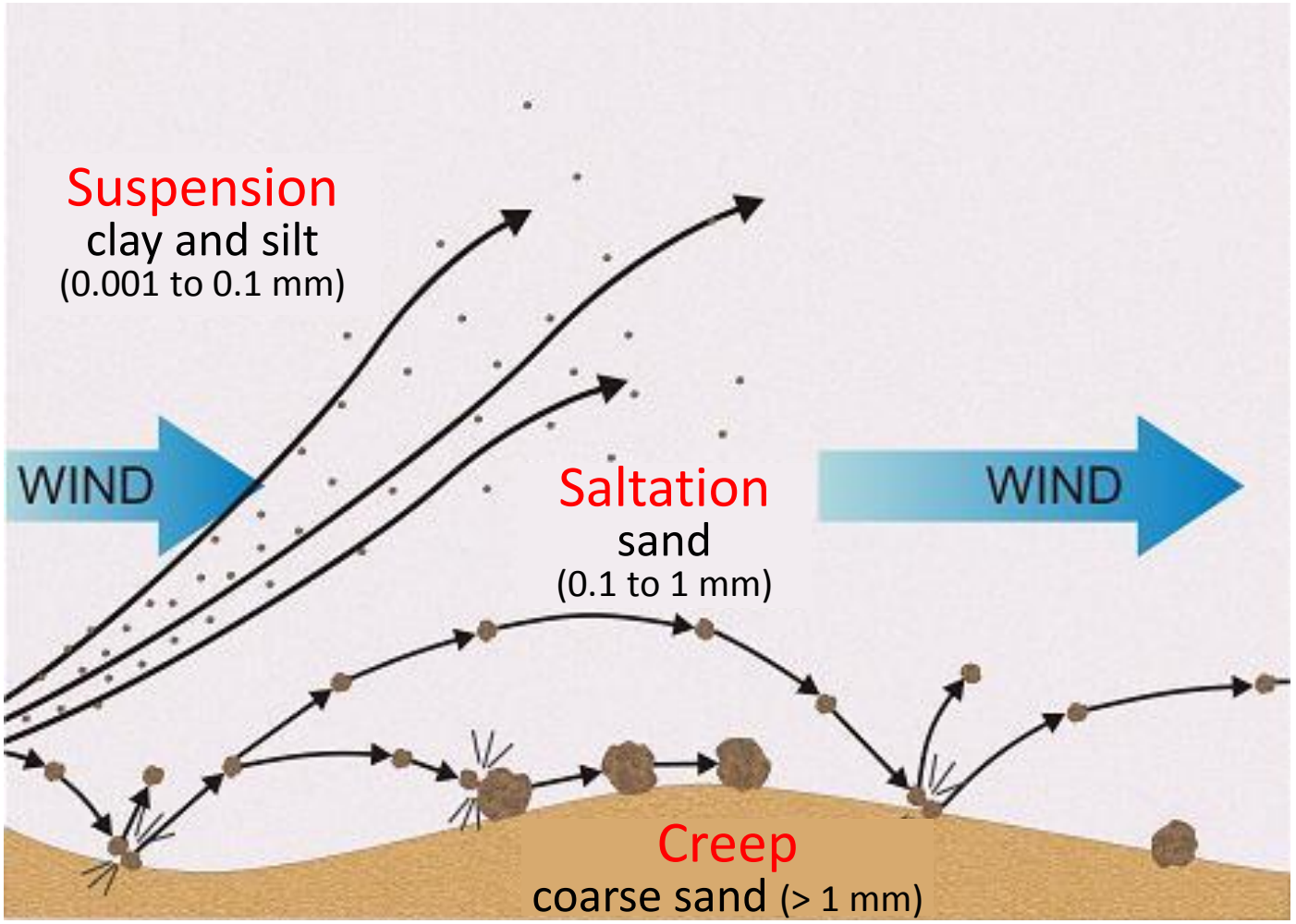


Sand 2.0 to 0.05 mm

Clay less than 0.002 mm



Silt 0.05 to 0.002 mm



http://cmg.soton.ac.uk/assets/people/gtj104/gallery/saltation-small.JPG

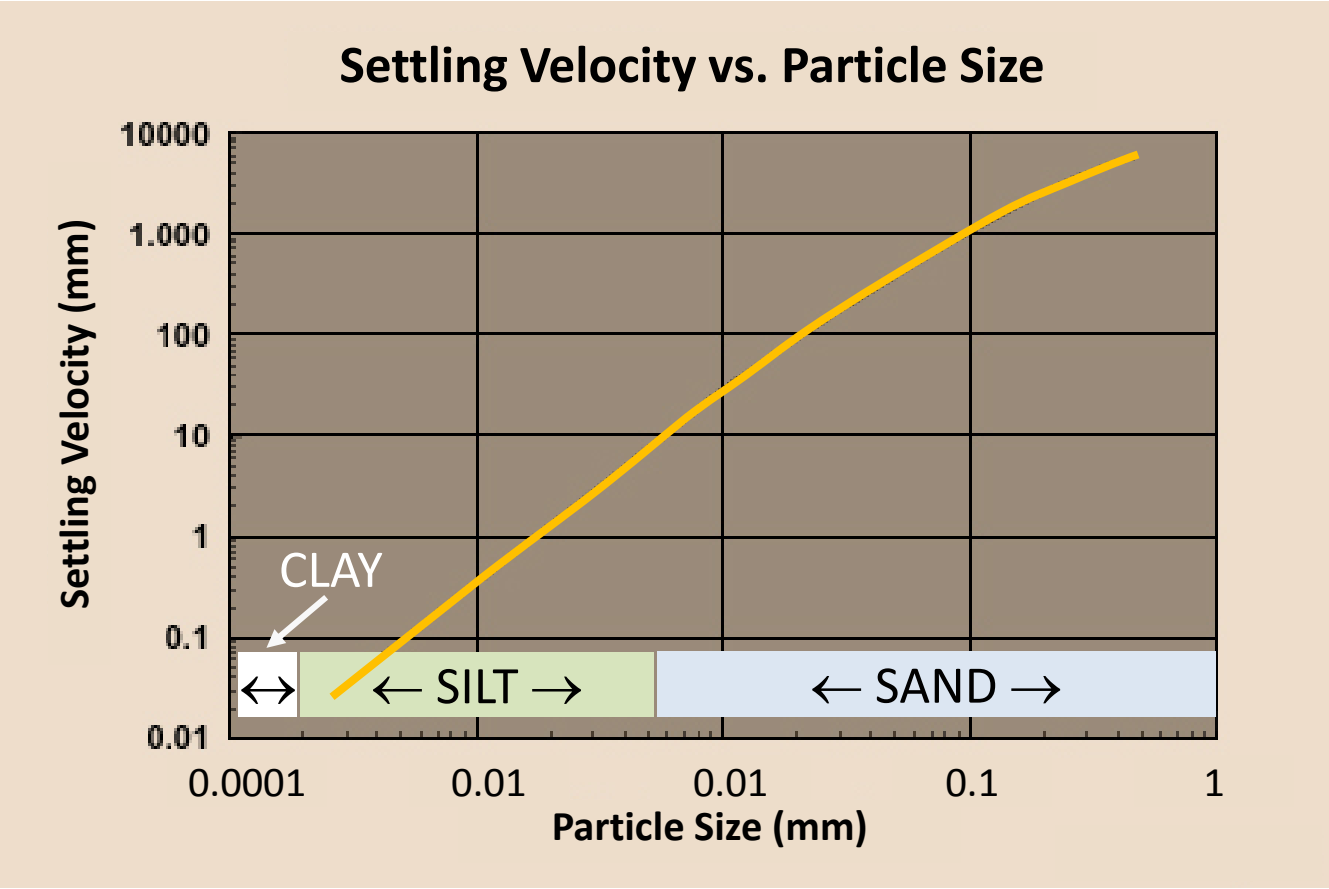
Stokes' Law

Velocity of settling (V) is proportional to the square of the particle's diameter (d).

$$V = kd^2$$

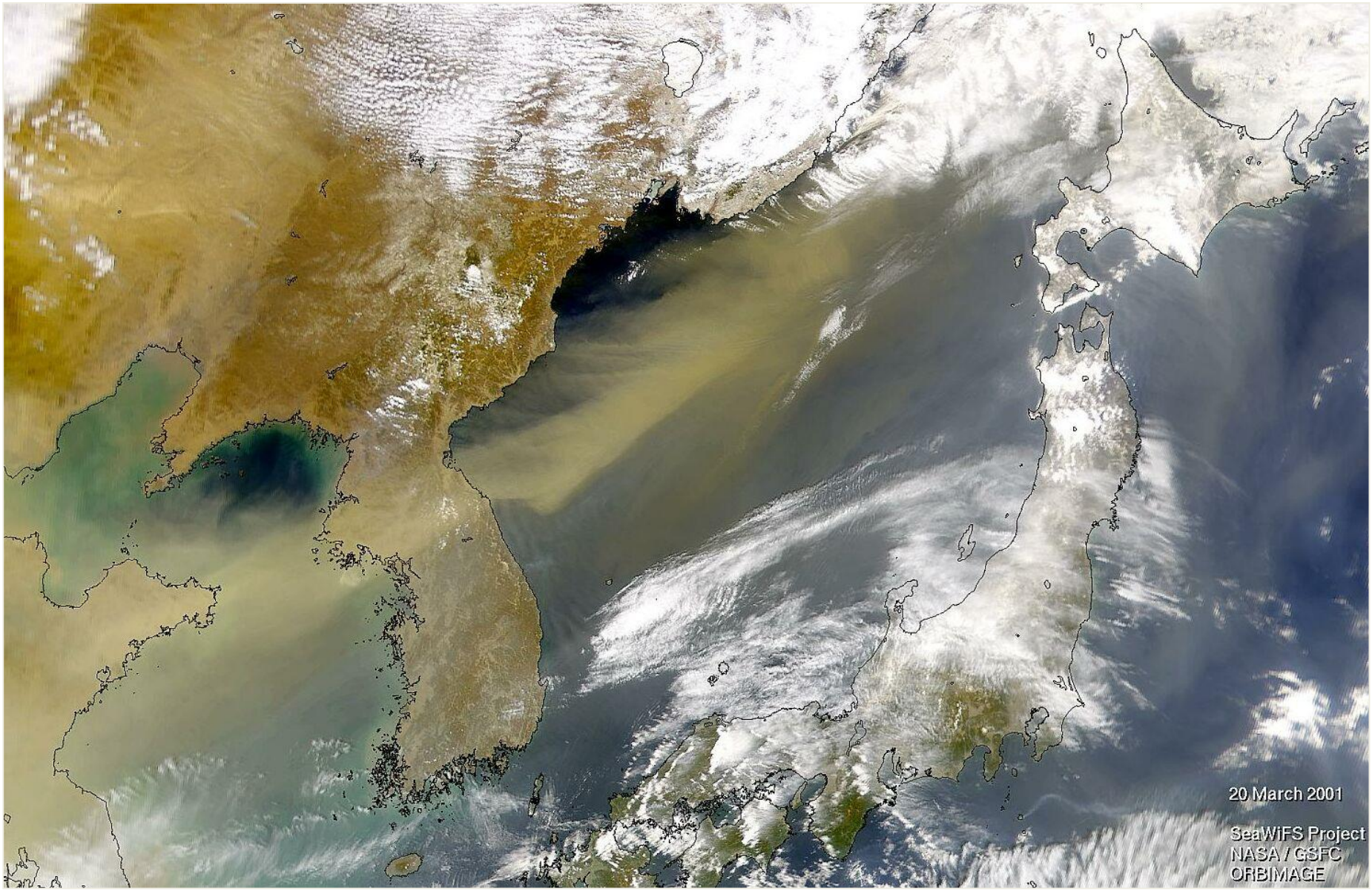
Where: k = constant related to the acceleration due to gravity and the density and viscosity of the settling medium (air or water).

Rate of settling of soil particles in air



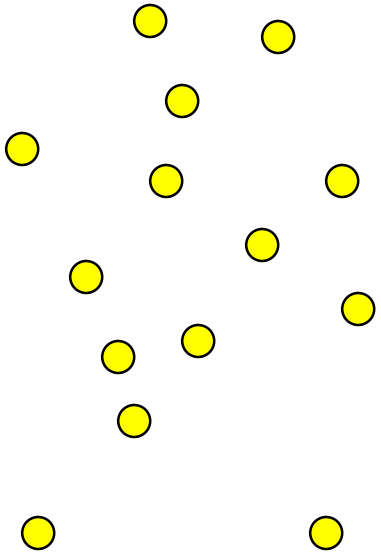
Zender, 2004

Clay particles can remain suspended, travel long-distances

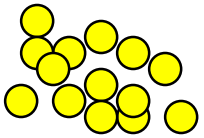


- Soil particles can be unattached to one another (*dispersed*) or clumped together (*flocculated*) in aggregates.
  - *Structure* is the arrangement of soil particles in stable secondary units called aggregates.
  - Aggregates are composed sand, silt, and clay particles, cemented together by clays or organic matter.

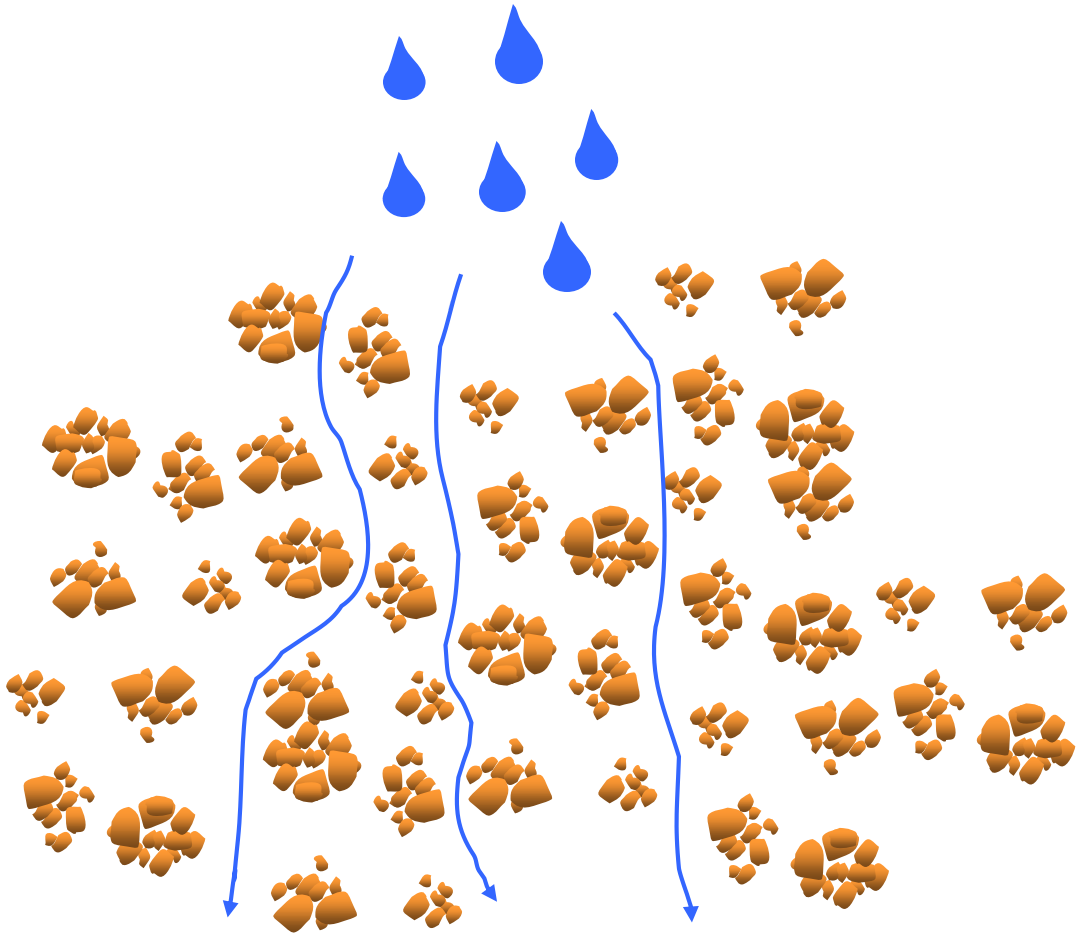
Dispersed Particles



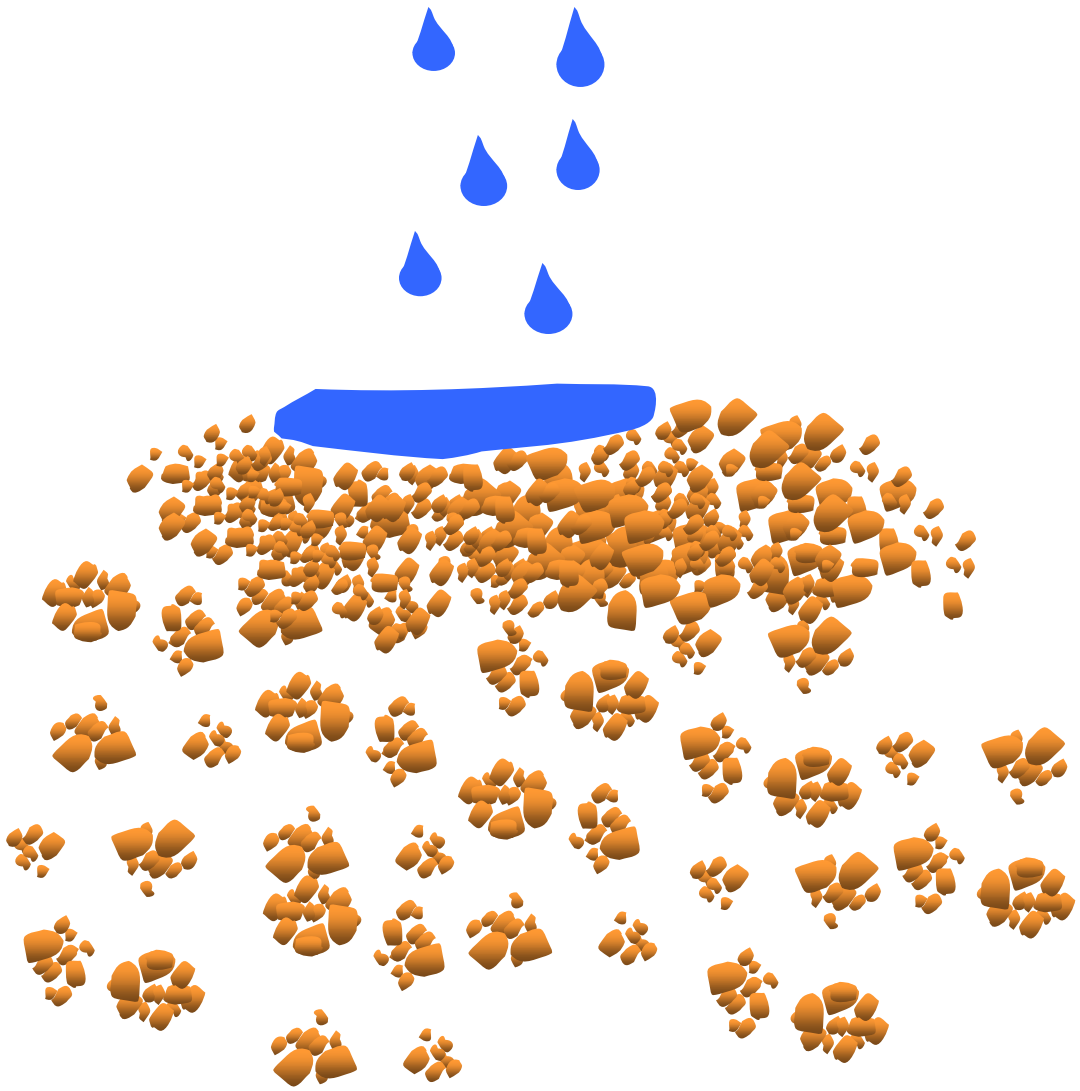
Aggregated or Flocculated Particles



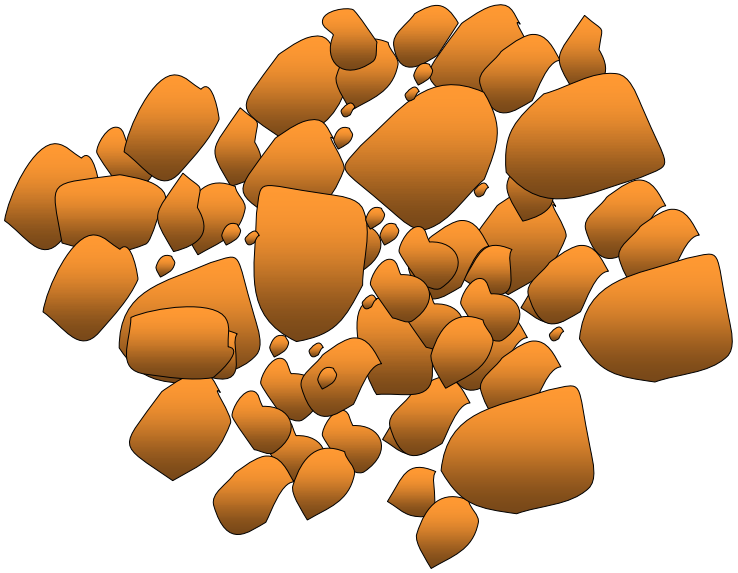
- Aggregates are larger than soil particles
- Pores between aggregates are much larger than intra-aggregate pores
  - Macropores are critical for water infiltration, soil drainage and aeration



Dispersed soil particles plug macropores, preventing water infiltration & drainage




Lordsburg Playa, NM

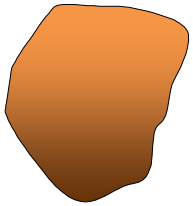


Aggregates

less than 0.25 to more than 10 mm

Clay

less than 0.002 mm



Silt

0.05 to 0.002 mm

Sand

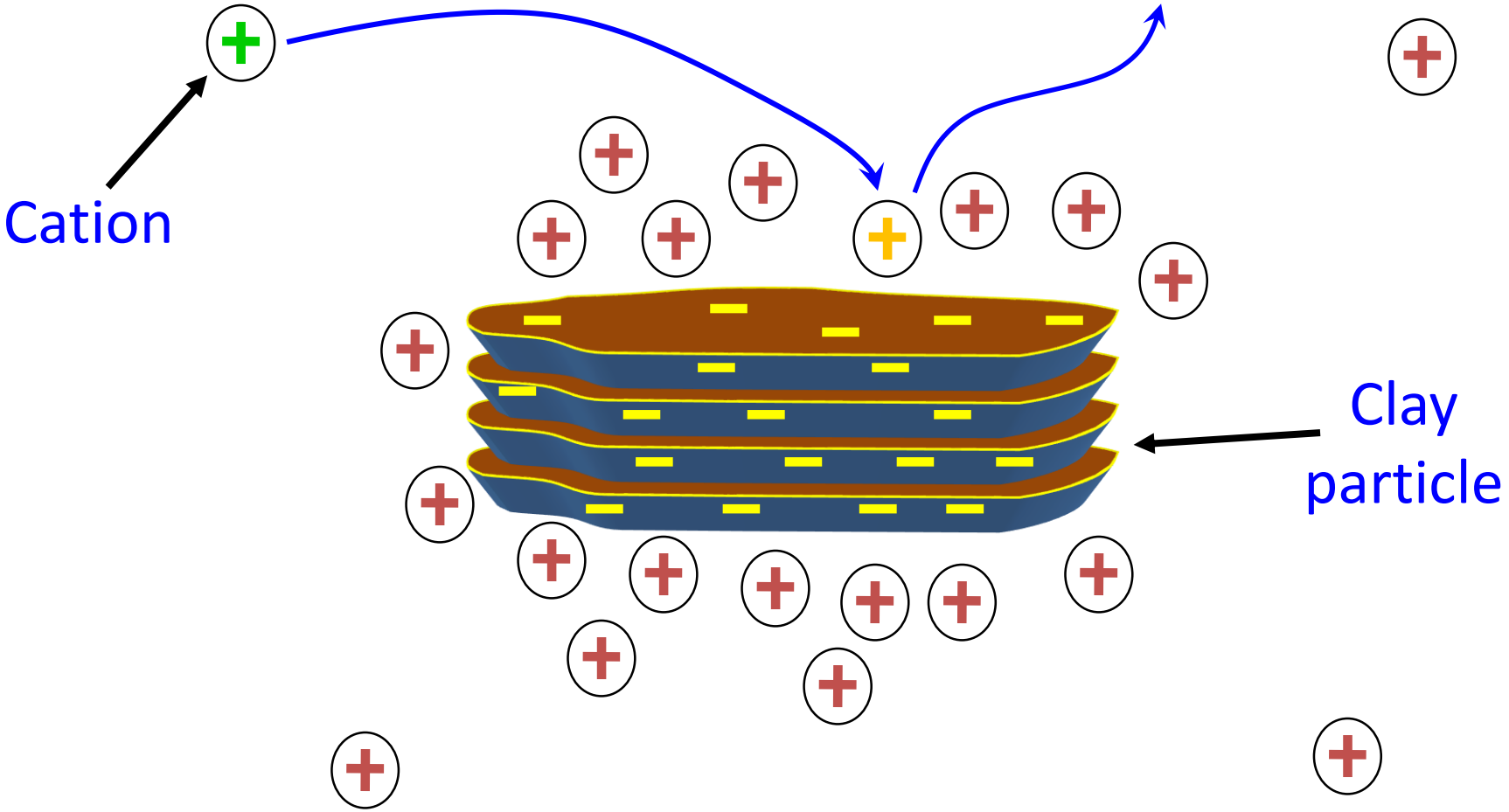
2.0 to 0.05 mm

Cation Exchange

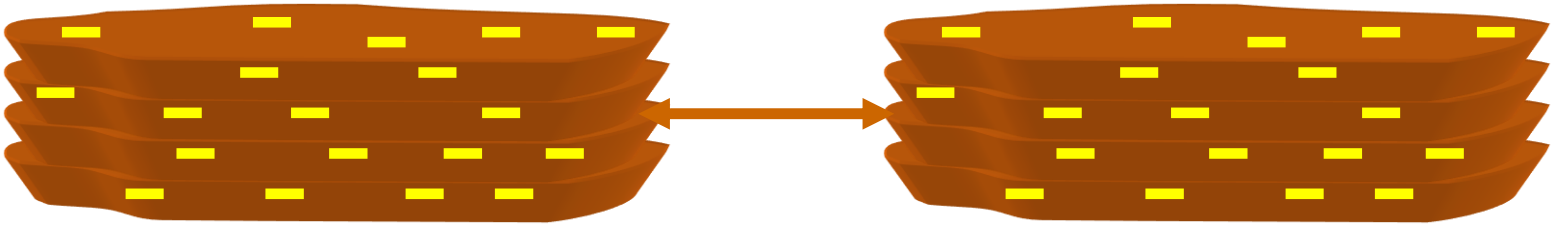
- Clay particles are mostly negatively charged. The negative clay charge attracts positively-charged soil ions (cations).
  - These are ‘exchangeable cations’
  - Major exchangeable cations in desert soils are

Element	Charge	Chemical Symbol
Calcium	++	Ca^{2+}
Magnesium	++	Mg^{2+}
Potassium	+	K^{+}
Sodium	+	Na^{+}

Cation Exchange



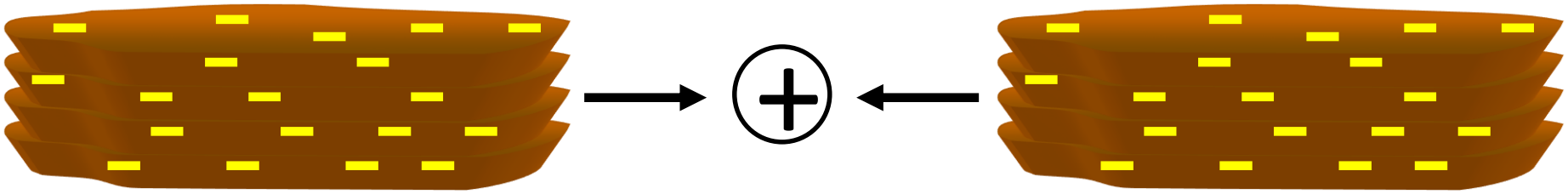
Because each clay particle carries a negative charge, clay particles are repelled by one another's negative charge.



Negatively charged clay particle

Negatively charged clay particle

Soil cations can promote clay particle flocculation.



Negatively charged clay particle

Negatively charged clay particle

Flocculating Cations

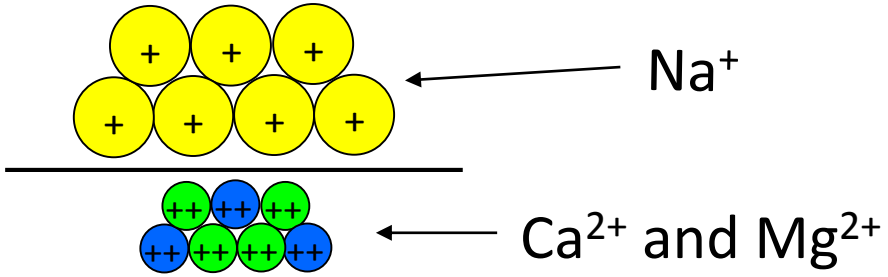
- We can divide cations into two categories
  - Weak flocculators
    - Sodium
  - Strong flocculators
    - Calcium
    - Magnesium
- SAR (sodium adsorption ratio) is used to describe soil cation composition

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

Sumner and Naidu, 1998

Sodium Adsorption Ratio

The ratio of ‘strong’ to ‘weak’ flocculators gives an indication of the relative status of these cations:



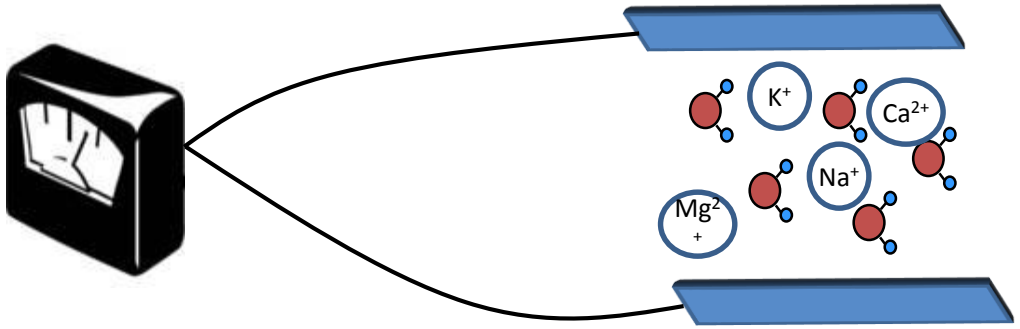
Mathematically, this is expressed as the ‘sodium adsorption ratio’ or SAR:

$$SAR = \frac{[Na^+]}{\sqrt{[Ca^{2+}] + [Mg^{2+}]}}$$

where concentrations are expressed in mmoles/L

Quantity of soil salts is also important

- Salt ions dissolved in water conduct electricity, so the total amount of soluble soil salts can be detrmined by measuring the electrical conductivity (EC) of a soil water extract.
- Soil EC is measured in a soil-water mixture
  - Units are deci-Siemens per meter (dS/m), older units are mmhos/cm



Soil Salts

- Common soil cations
  (positively charged molecules)

  Calcium: Ca^{2+}

  Magnesium: Mg^{2+}

  Sodium: Na^{+}

  Ammonium: NH_4^{+}

  Potassium: K^{+}

- Common soil anions
  (negatively charged molecules)

  Chloride: Cl^{-}

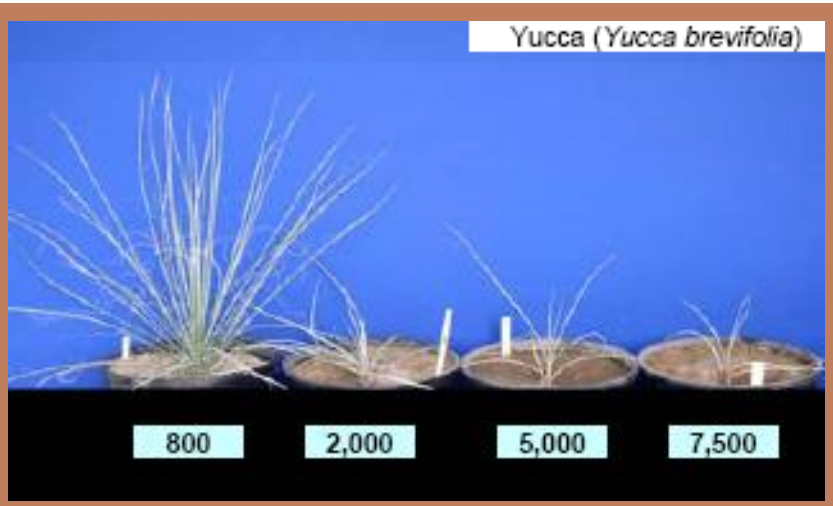
  Sulfate: SO_4^{2-}

  Bicarbonate: HCO_3^{-}

  Carbonate: CO_3^{2-}

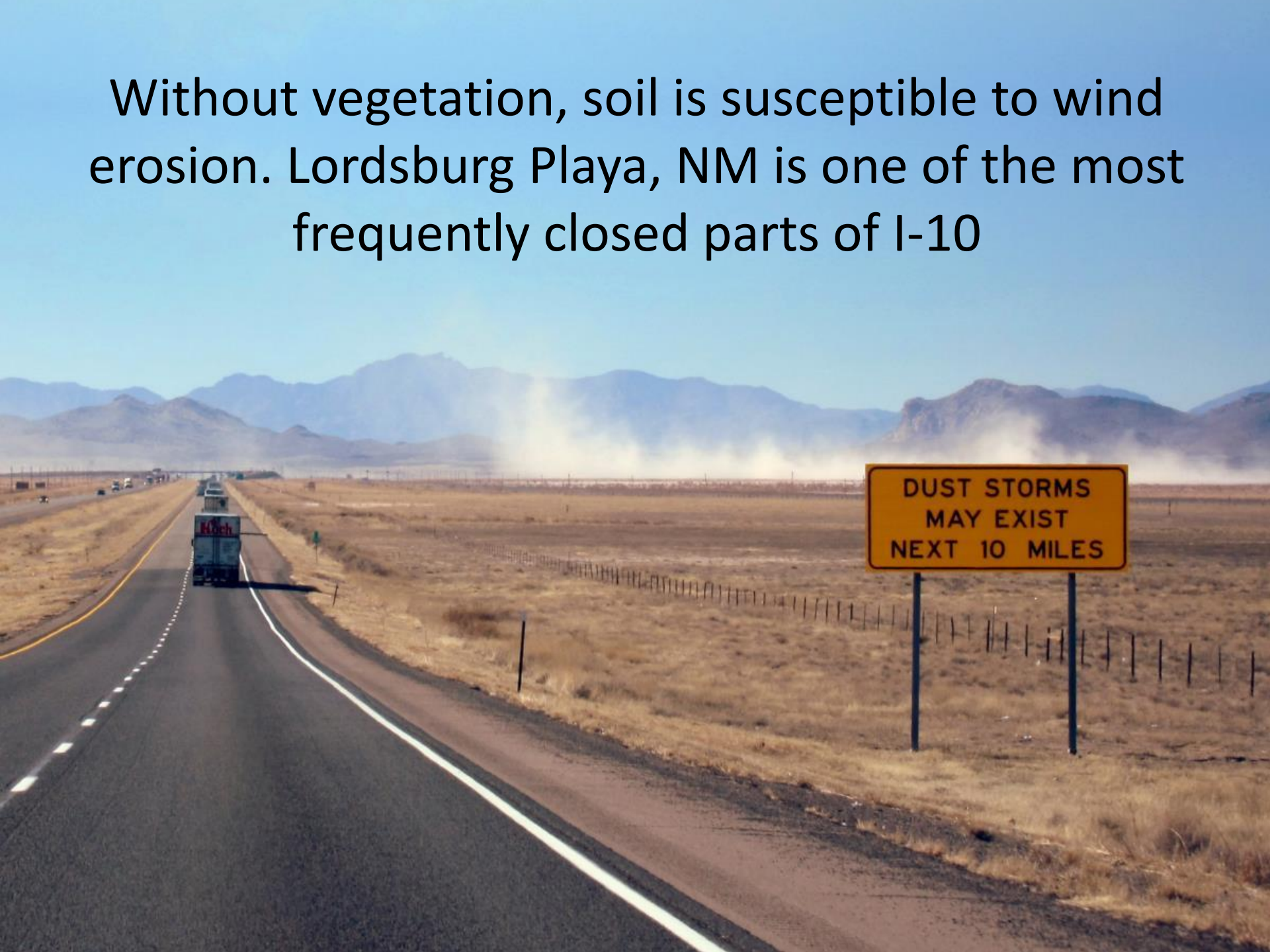
  Nitrate: NO_3^{-}

Salts can damage, and even kill plants

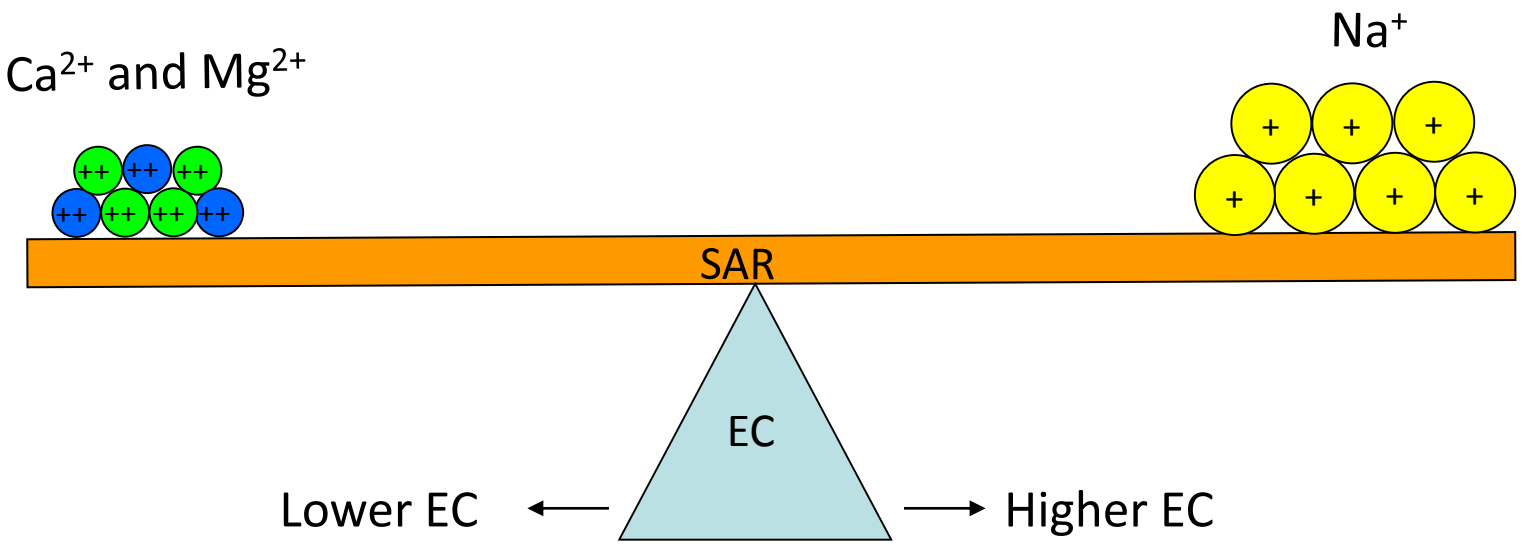



Willcox Playa – a natural evaporite basin that is too saline to support plant life

Without vegetation, soil is susceptible to wind erosion. Lordsburg Playa, NM is one of the most frequently closed parts of I-10



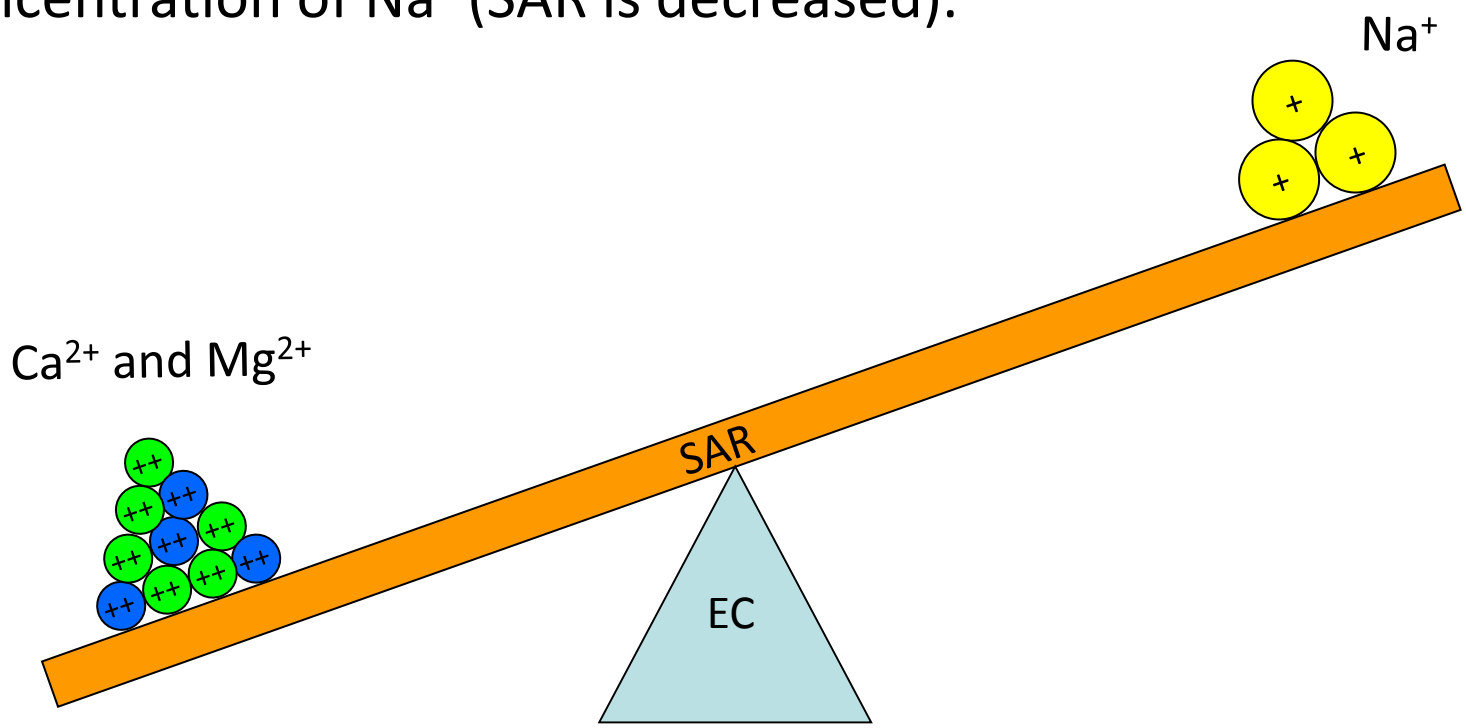
Aggregate stability (dispersion and flocculation) depends on the balance (SAR) between (Ca^{2+} and Mg^{2+}) and Na^{+} as well as the amount of soluble salts (EC) in the soil.



Flocculated soil

Dispersed soil

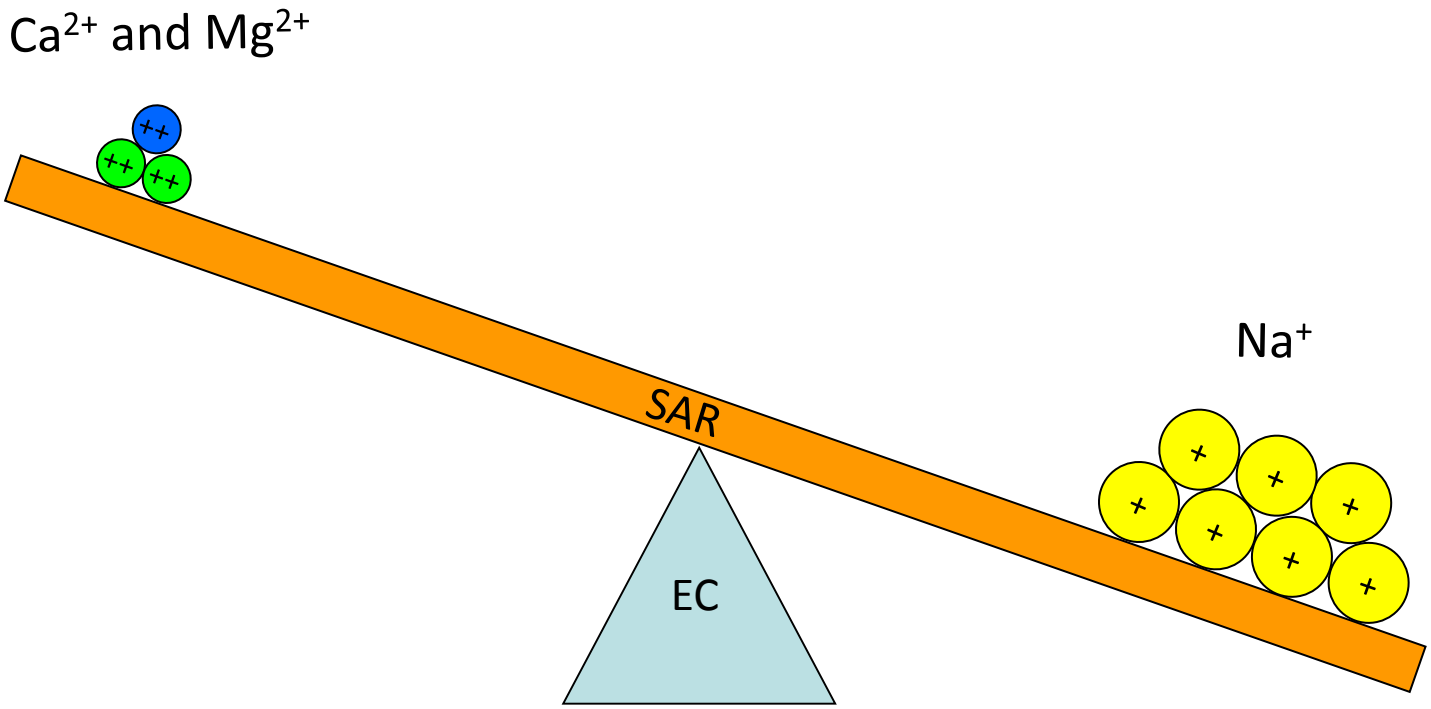
Soil particles will flocculate if concentrations of (Ca^{2+} + Mg^{2+}) are increased relative to the concentration of Na^{+} (SAR is decreased).



Flocculated soil

Dispersed soil

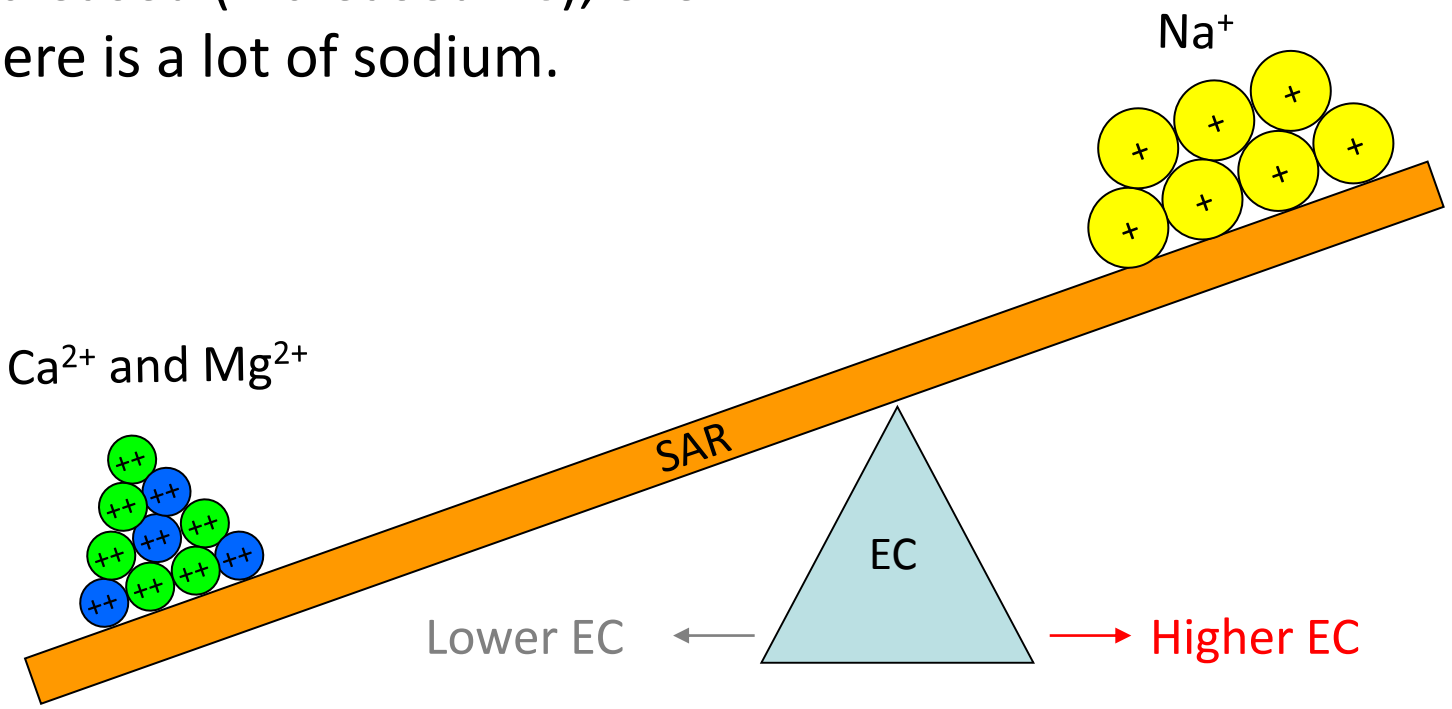
Soil particles will disperse if concentrations of (Ca^{2+} + Mg^{2+}) are decreased relative to the concentration of Na^{+} (SAR is increased).



Flocculated soil

Dispersed soil

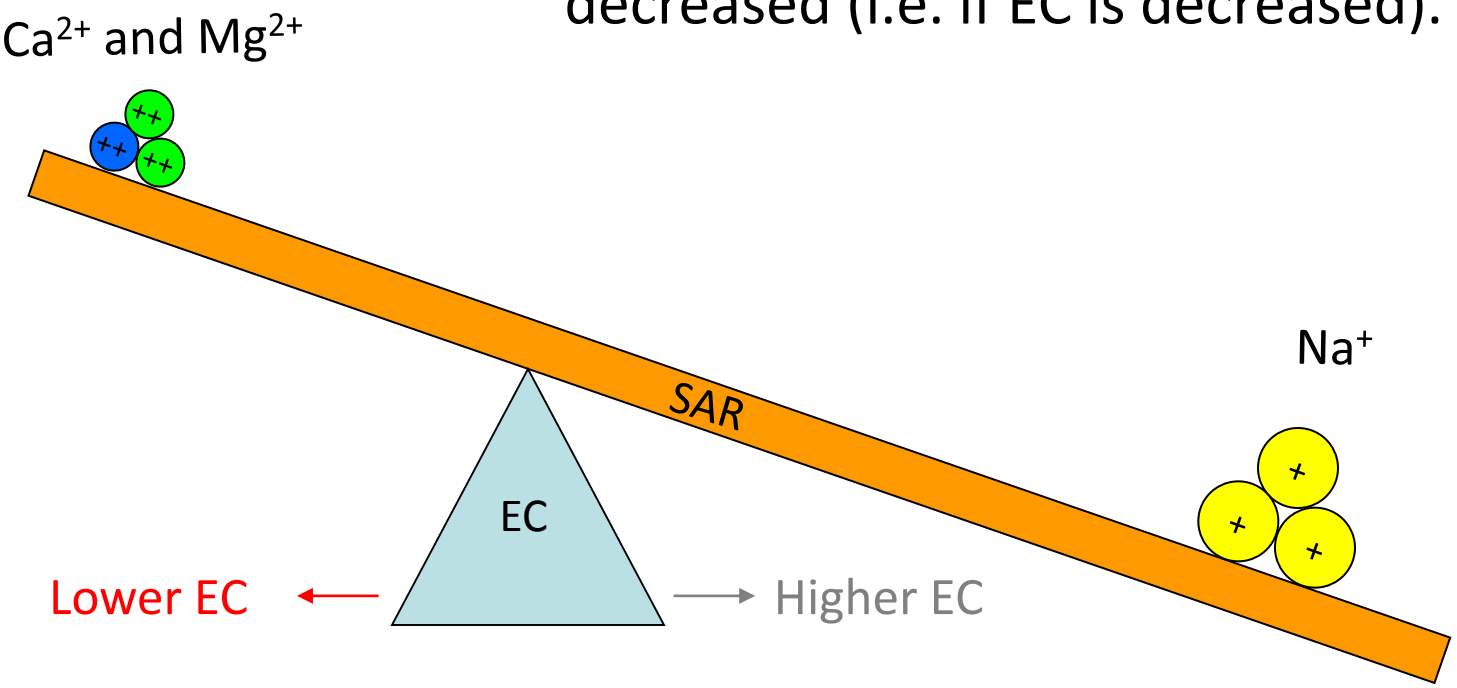
Soil particles will flocculate if the amount of soluble salts in the soil is increased (increased EC), even if there is a lot of sodium.



Flocculated soil

Dispersed soil

Soil particles may disperse if the amount of soluble salts in the soil is decreased (i.e. if EC is decreased).



Flocculated soil

Dispersed soil

http://imgc.artprintimages.com/images/art-print/joel-sartore-swirling-wind-kicks-up-a-dust-devil-near-the-pan-american-highway_i-G-27-2705-4OGND00Z.jpg