Chemistry of Sodium-Affected Soils

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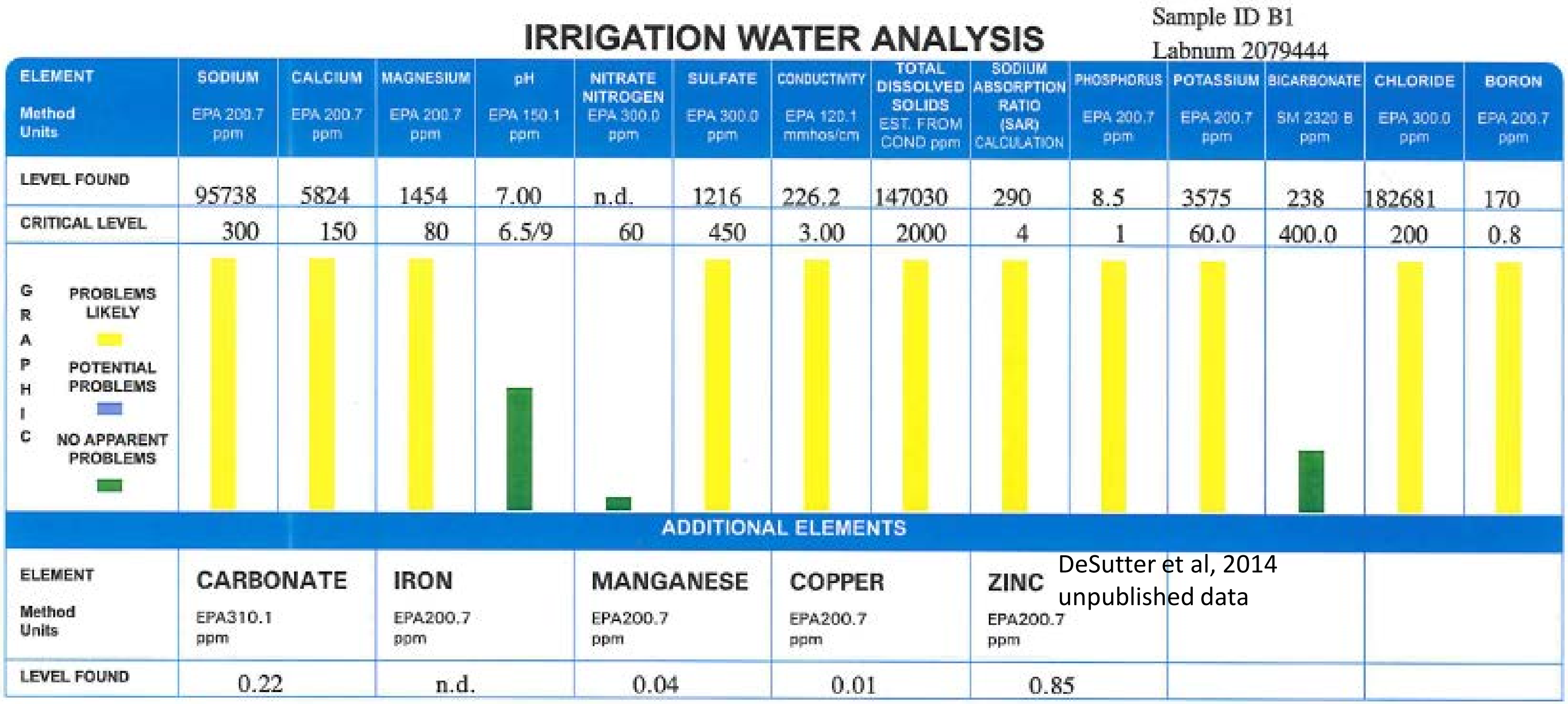


Sample ID B1
Labnum 2079444

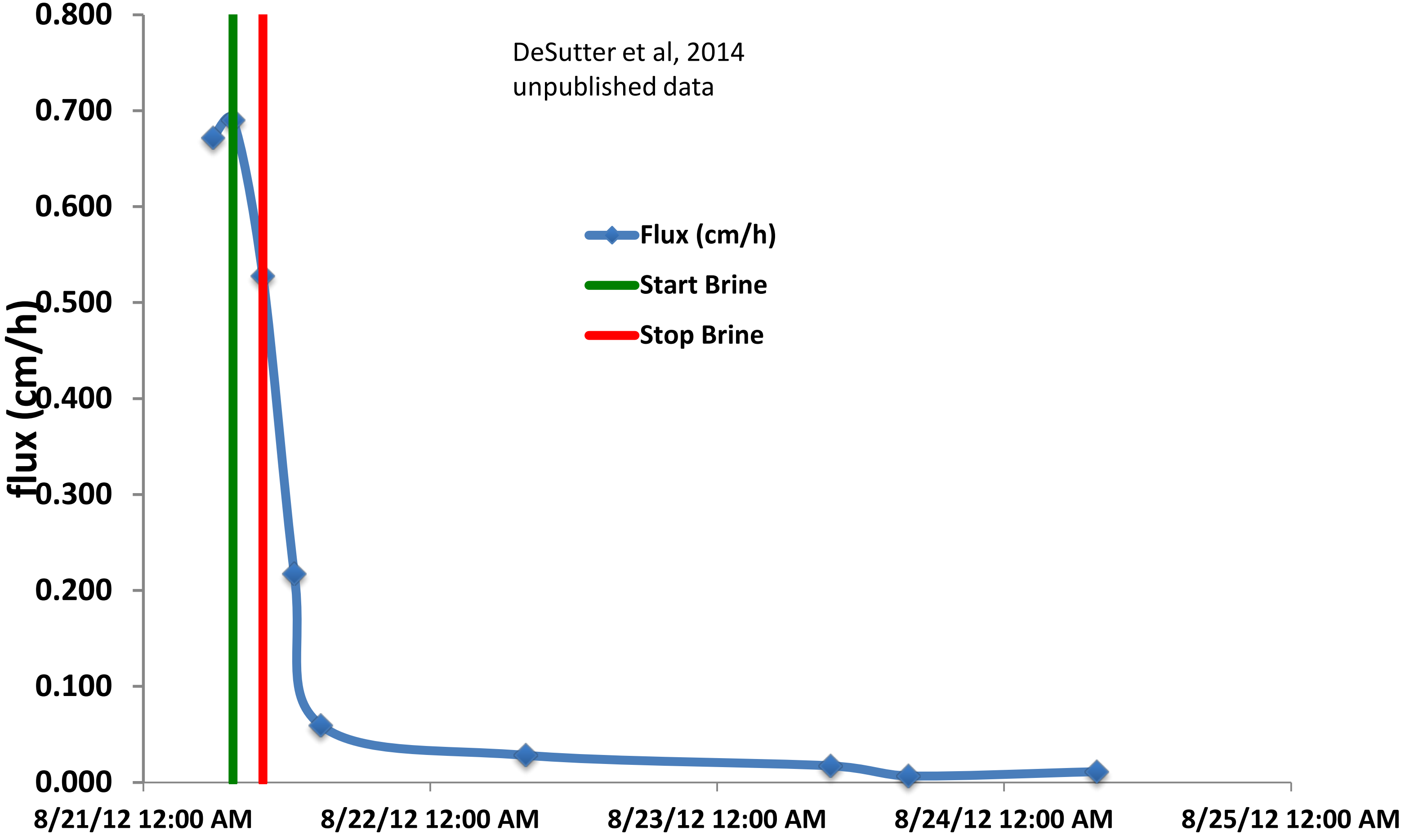
IRRIGATION WATER ANALYSIS

ELEMENT	SODIUM	CALCIUM	MAGNESIUM	pH	NITRATE NITROGEN	SULFATE	CONDUCTIVITY	TOTAL DISSOLVED SOLIDS	SODIUM ABSORPTION RATIO (SAR)	PHOSPHORUS	POTASSIUM	BICARBONATE	CHLORIDE	BORON
Method Units	EPA 200.7 ppm	EPA 200.7 ppm	EPA 200.7 ppm	EPA 150.1 ppm	EPA 300.0 ppm	EPA 300.0 ppm	EPA 120.1 mmhos/cm	EST. FROM COND ppm	CALCULATION	EPA 200.7 ppm	EPA 200.7 ppm	SM 2320 B ppm	EPA 300.0 ppm	EPA 200.7 ppm
LEVEL FOUND	95738	5824	1454	7.00	n.d.	1216	226.2	147030	290	8.5	3575	238	182681	170
CRITICAL LEVEL	300	150	80	6.5/9	60	450	3.00	2000	4	1	60.0	400.0	200	0.8
GRAPHIC PROBLEMS LIKELY 🟨 POTENTIAL PROBLEMS 🟦 NO APPARENT PROBLEMS 🟩	🟨	🟨	🟨	🟩	🟩	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟨	🟨

ADDITIONAL ELEMENTS

ELEMENT	CARBONATE	IRON	MANGANESE	COPPER	ZINC		
Method Units	EPA310.1 ppm	EPA200.7 ppm	EPA200.7 ppm	EPA200.7 ppm	EPA200.7 ppm		
LEVEL FOUND	0.22	n.d.	0.04	0.01	0.85		

DeSutter et al, 2014
unpublished data

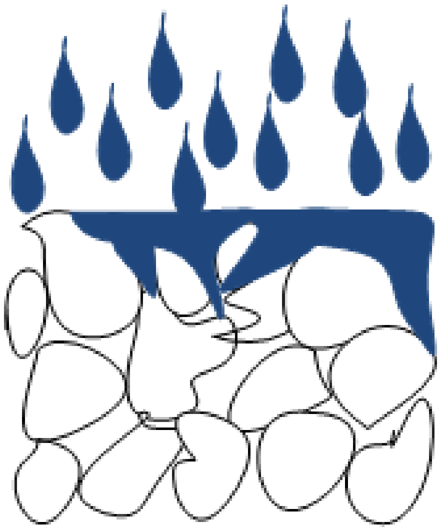


DeSutter et al, 2014
unpublished data

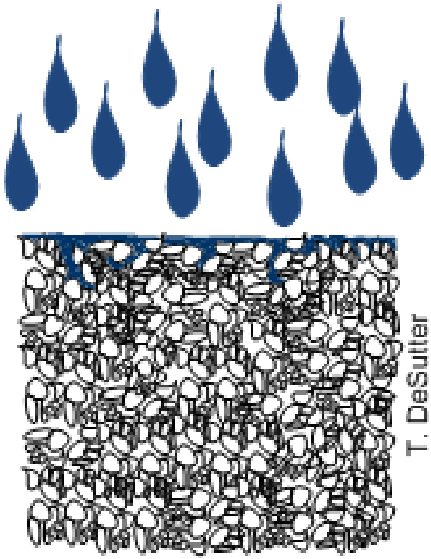
Why does this happen?

- Na inflicts two different possibilities:
  - Dispersion
  - Internal swelling
- Both of these are a function of the concentration of Na and the EC of the soil solution

Flocculation



Swelling



Dispersion

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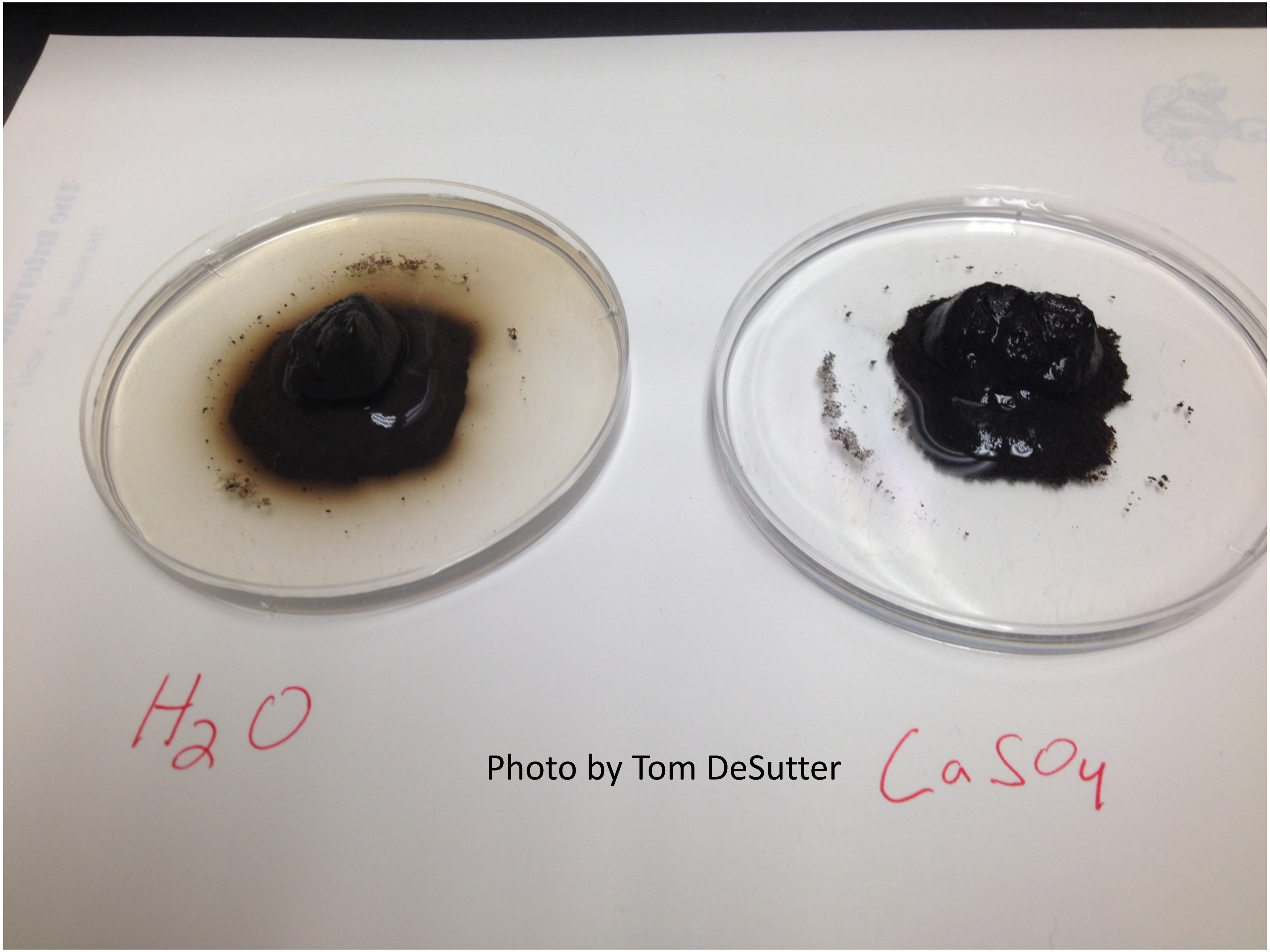
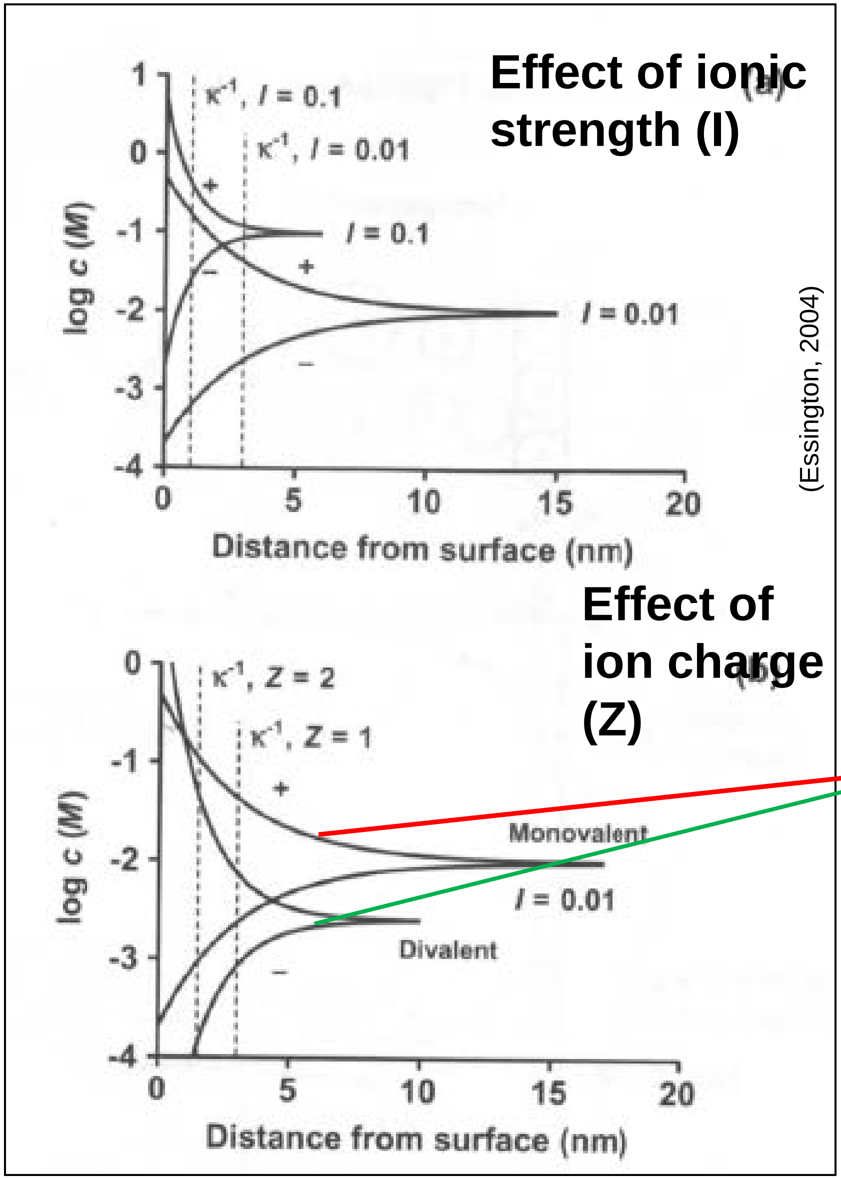


Photo by Tom DeSutter

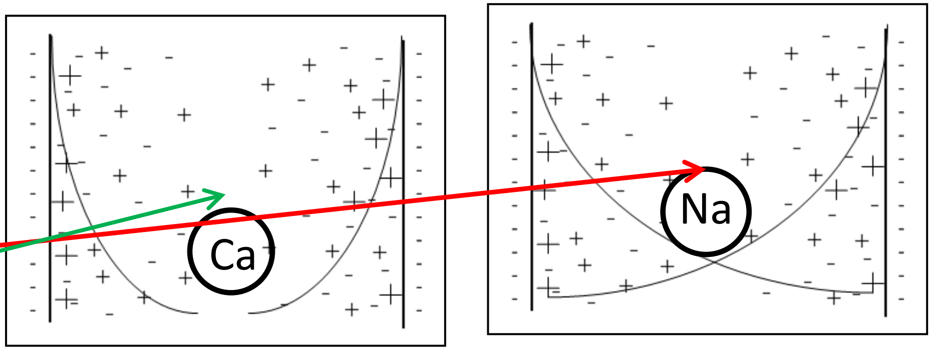
Theory of dispersion



(Essington, 2004)

- Guoy-Chapman theory

$$k^{-1} = \frac{3.042\left(10^{-10}\right)}{Z\sqrt{I}}$$



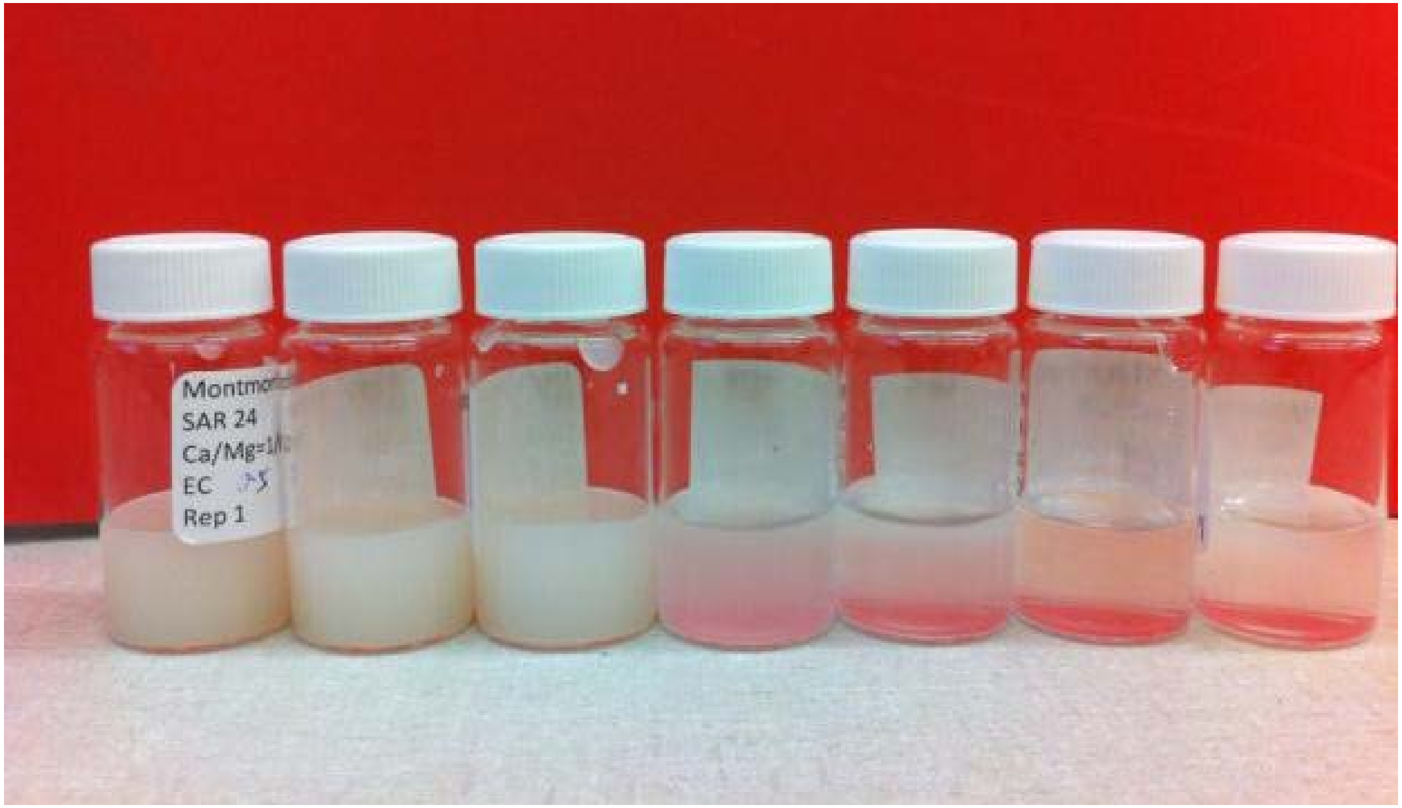
At low EC and monovalent cations, thickness of double layer is large, Double layers of adjacent particles will overlap, causing electrostatic repulsion.

$$\mathrm{SAR_e} = \frac{\mathrm{Na^+}}{\sqrt{\dfrac{\mathrm{Ca^{2+}} + \mathrm{Mg^{2+}}}{2}}}$$

$$ESP = \frac{Na*100}{CEC}$$

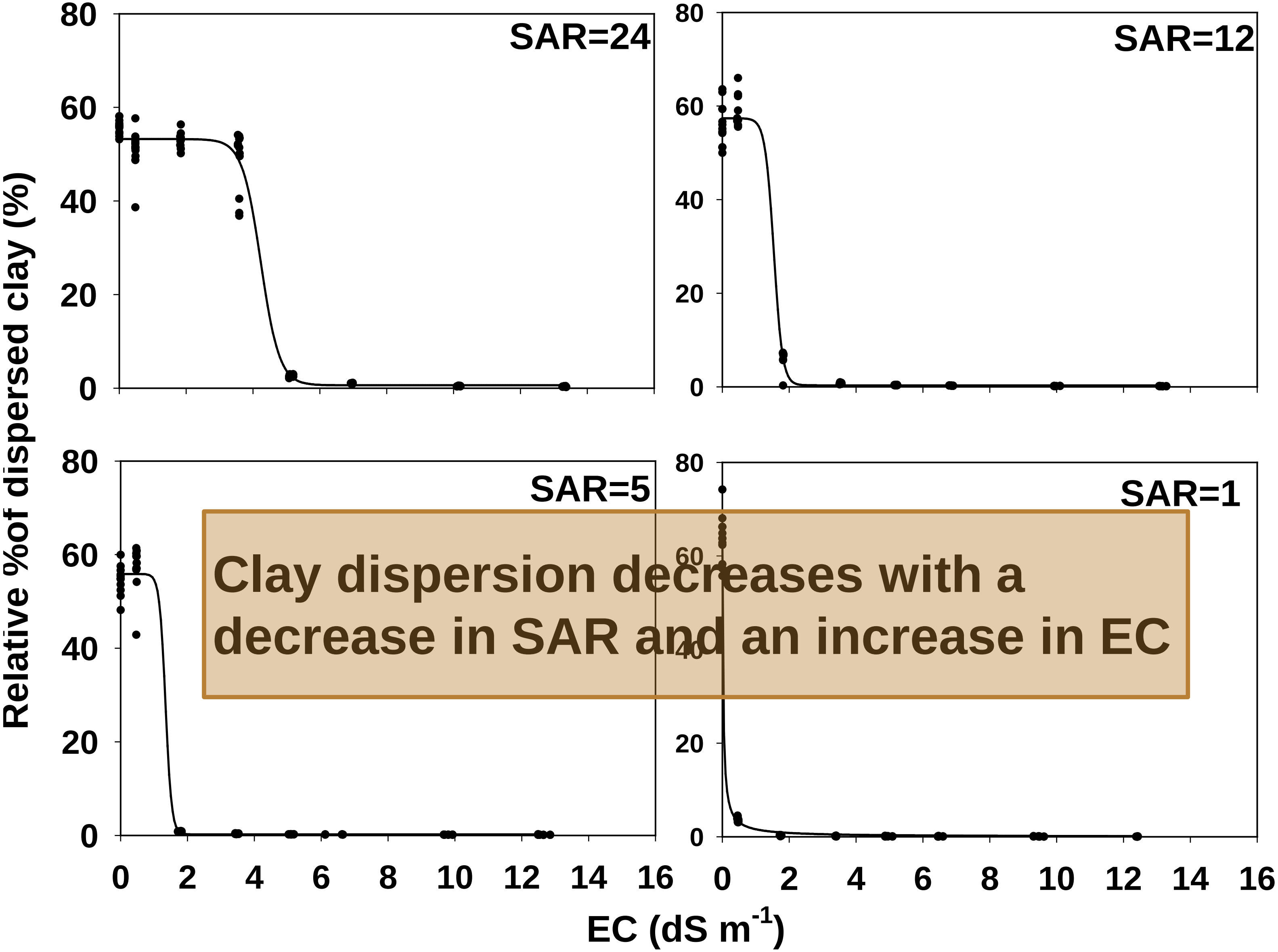
Lab data of dispersion

Montmorillonite SAR =24



EC= 0.5, 2, 4, 6, 8, 12, and 16 dS/m

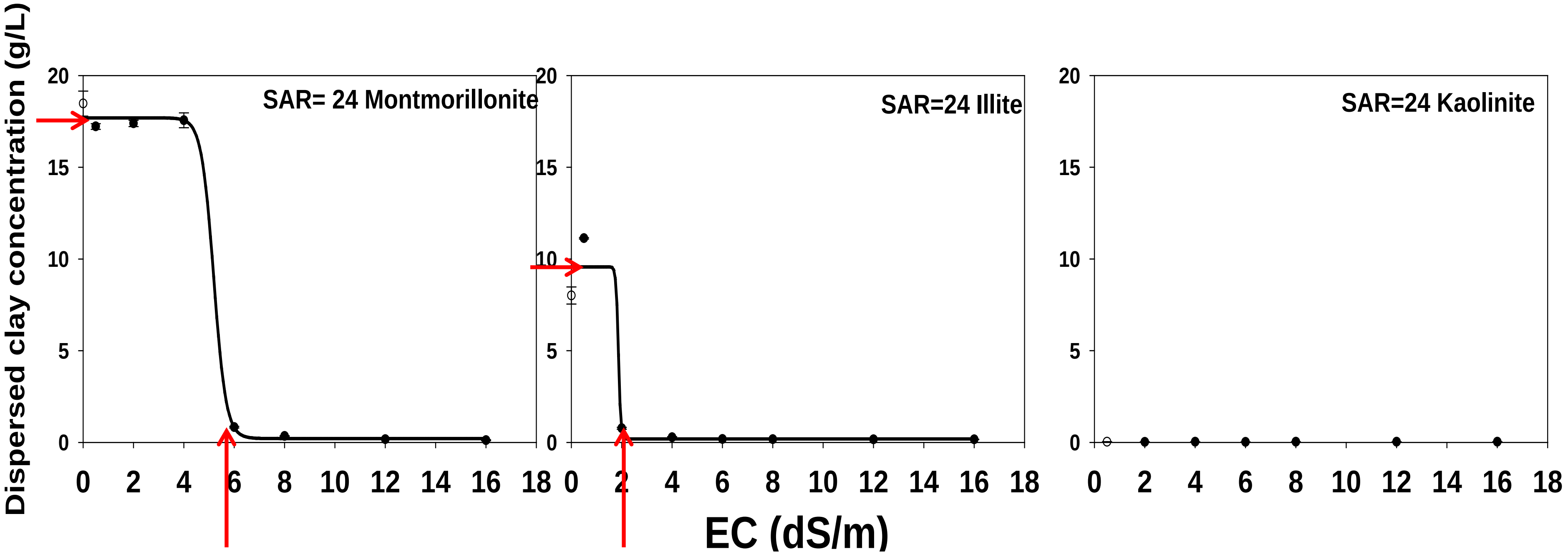
Montmorillonite



Clay dispersion decreases with a decrease in SAR and an increase in EC

He, Y., T. DeSutter, and D. Clay. 2013. Dispersion of pure clay minerals as influenced by Ca to Mg ratios, SAR and EC. Soil Sci. Soc. Am. J. 77:2014-2019.

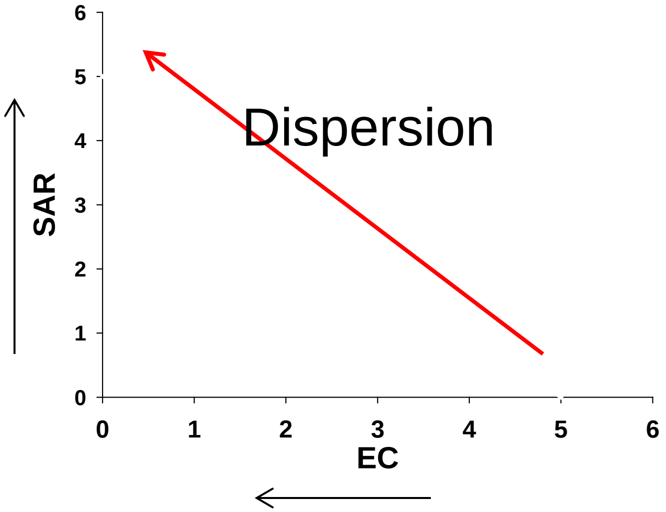
Lab data of dispersion



He, Y., T. DeSutter, and D. Clay. 2013. Dispersion of pure clay minerals as influenced by Ca to Mg ratios, SAR and EC. Soil Sci. Soc. Am. J. 77:2014-2019.

Lab data of dispersion

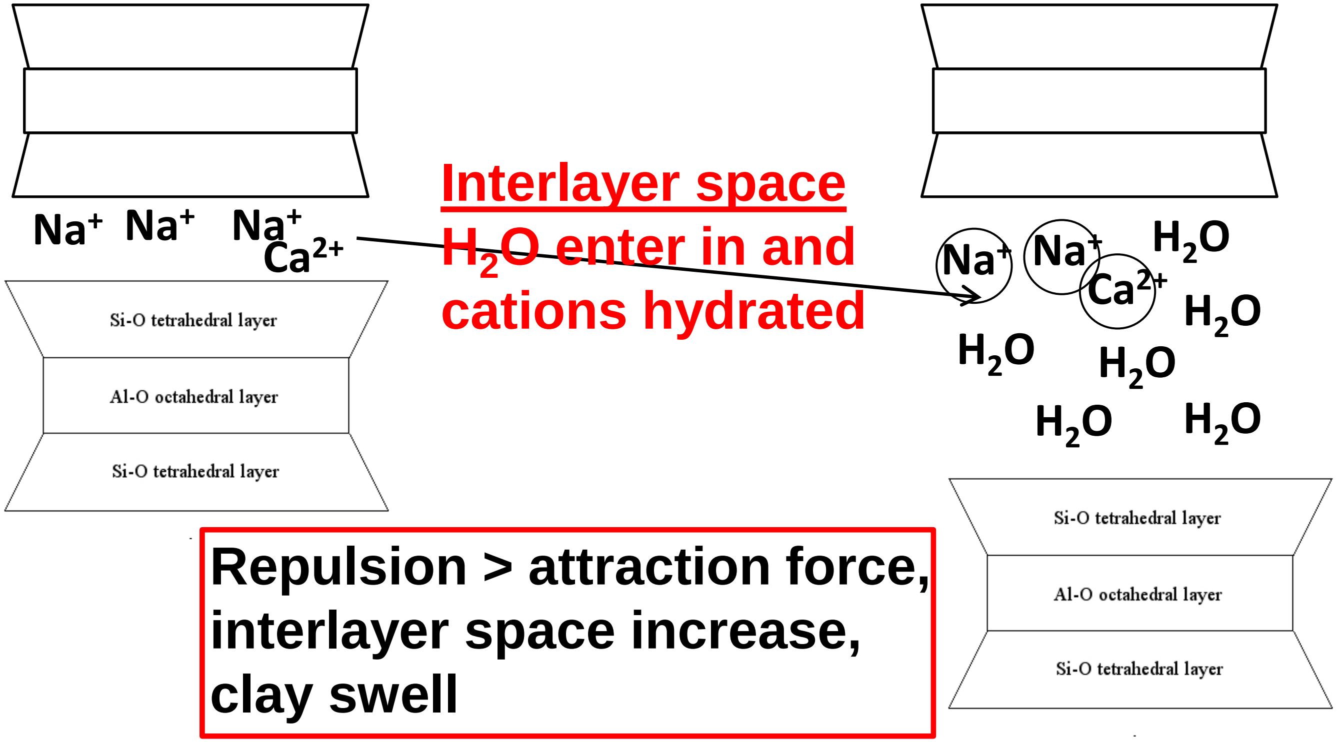
- Dispersion is as a function of both amount of Na and EC
- Dispersion increase with SAR and decrease with increase of EC for 2:1 type clays (Mont. & Illite)



- Adverse effects of dispersion can be alleviated by increasing the solution EC (but plants may suffer)

Swelling theory

- Na^+ has little interruption on water net in interlayer, the water is retained and fluidity is reduced
- Ca^{2+} disrupts water net allowing water to more mobile, reduces overall swelling



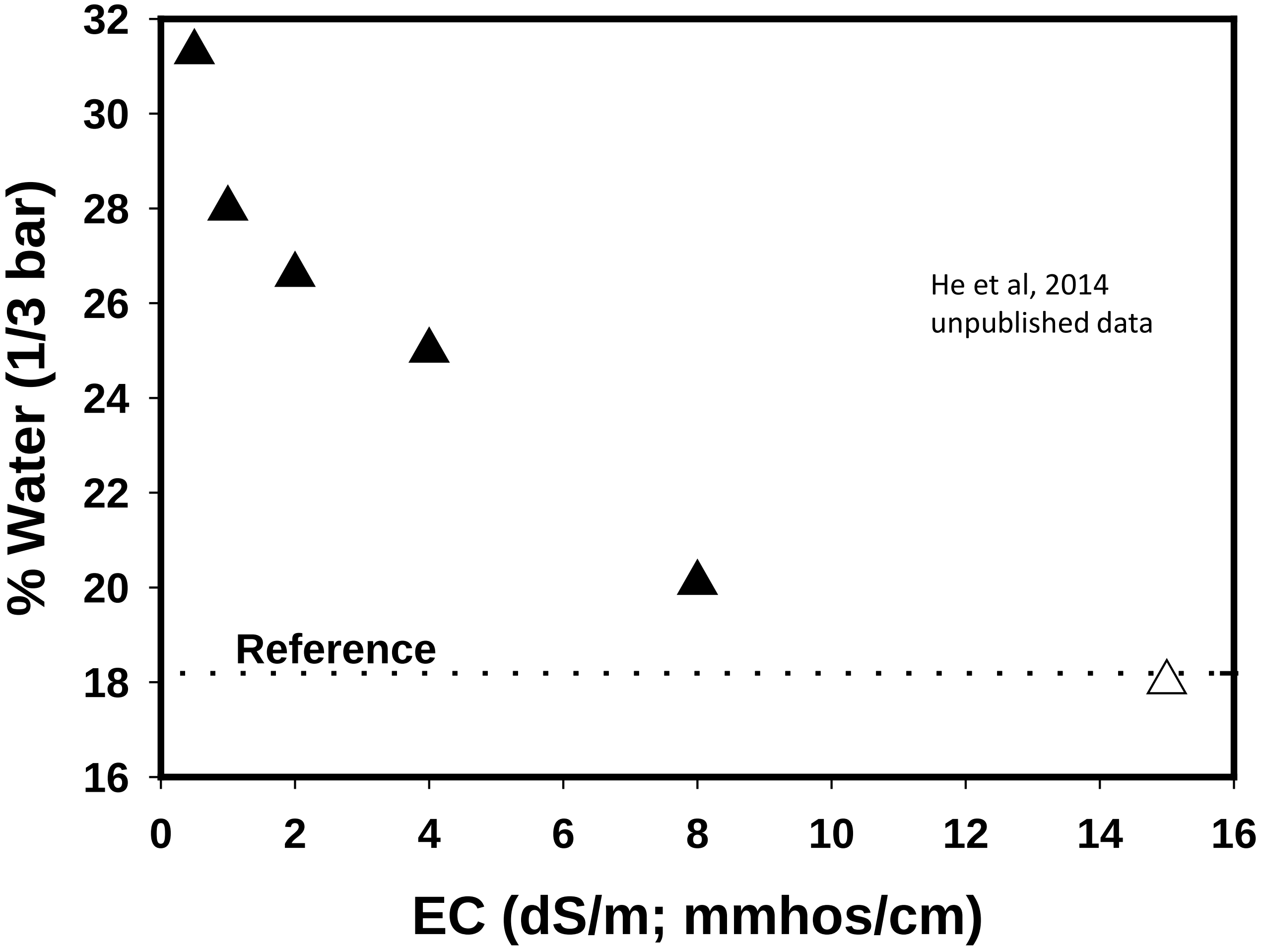
Interlayer space

H_2O enter in and cations hydrated

Repulsion > attraction force, interlayer space increase, clay swell

(Grim, 1968)

Wyndmere CIG Field Soil
SAR = 14



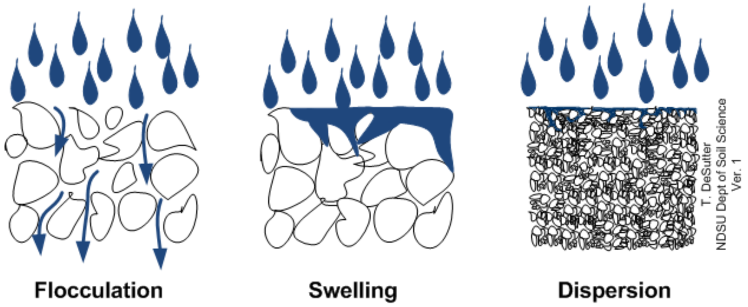
Adverse effects on water movement

Na and EC

Control swelling and dispersion

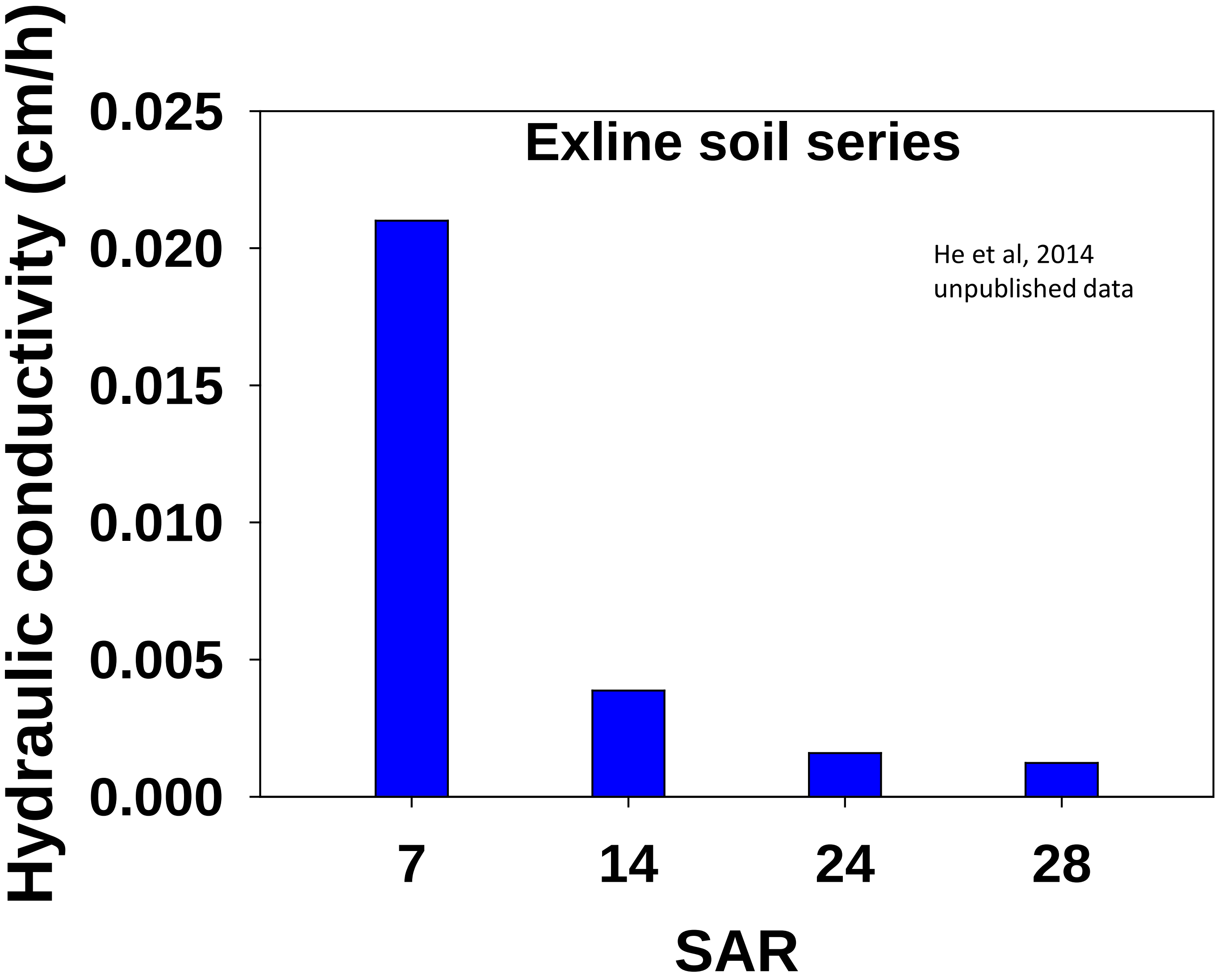
Reduced soil pores and clogged soil pores by clay particles

Slow down water movement (Ksat)



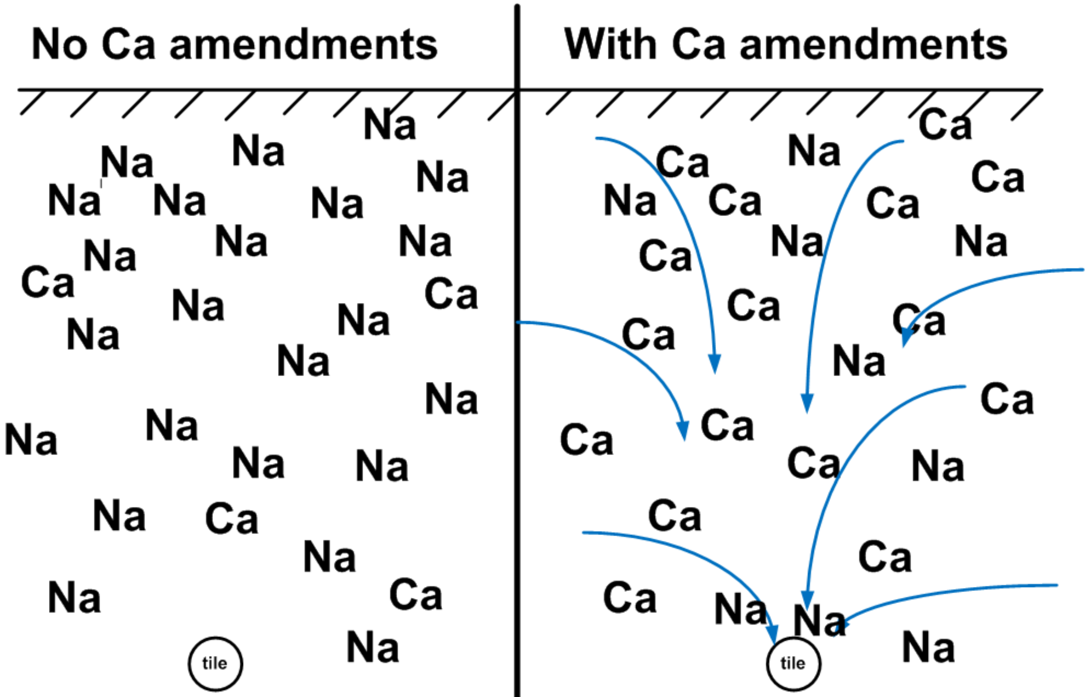
Adverse effects on water movement

- <u>Ksat (Saturated hydraulic conductivity) with water</u>



Now what?

- Steps to remediate/mitigate a Na-affected soil
  - Need Ca amendment (other cations may work too)
  - Need water for leaching
  - Need drainage to get Na out of the system



-Very reduced, or no water movement
-Become 'hard-set' when dry
-Poor trafficability when wet
-Low fertility, soil health

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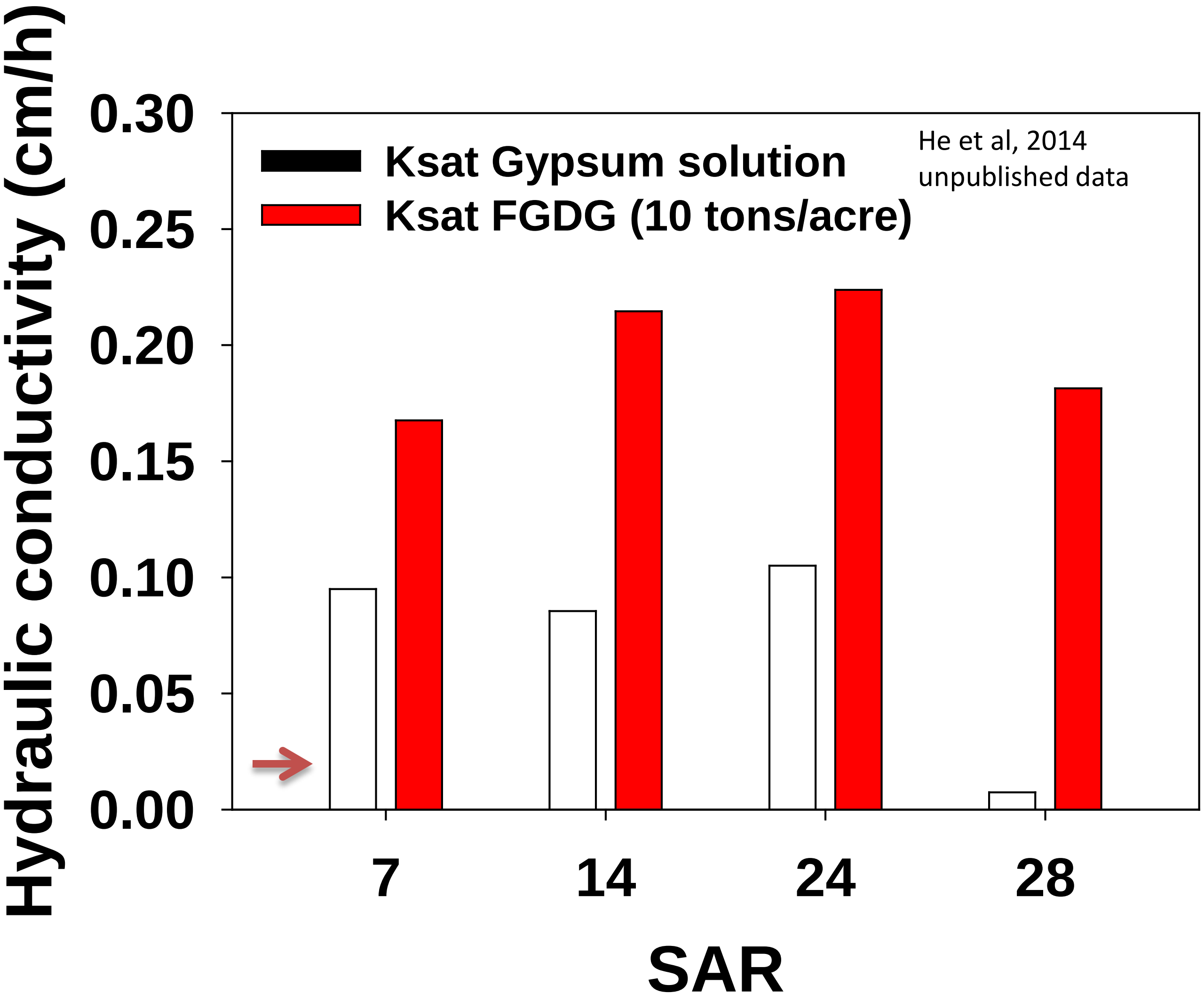
-Increased water movement
-Soil aggregates become established
-Improved trafficability
-Improved fertility, soil health

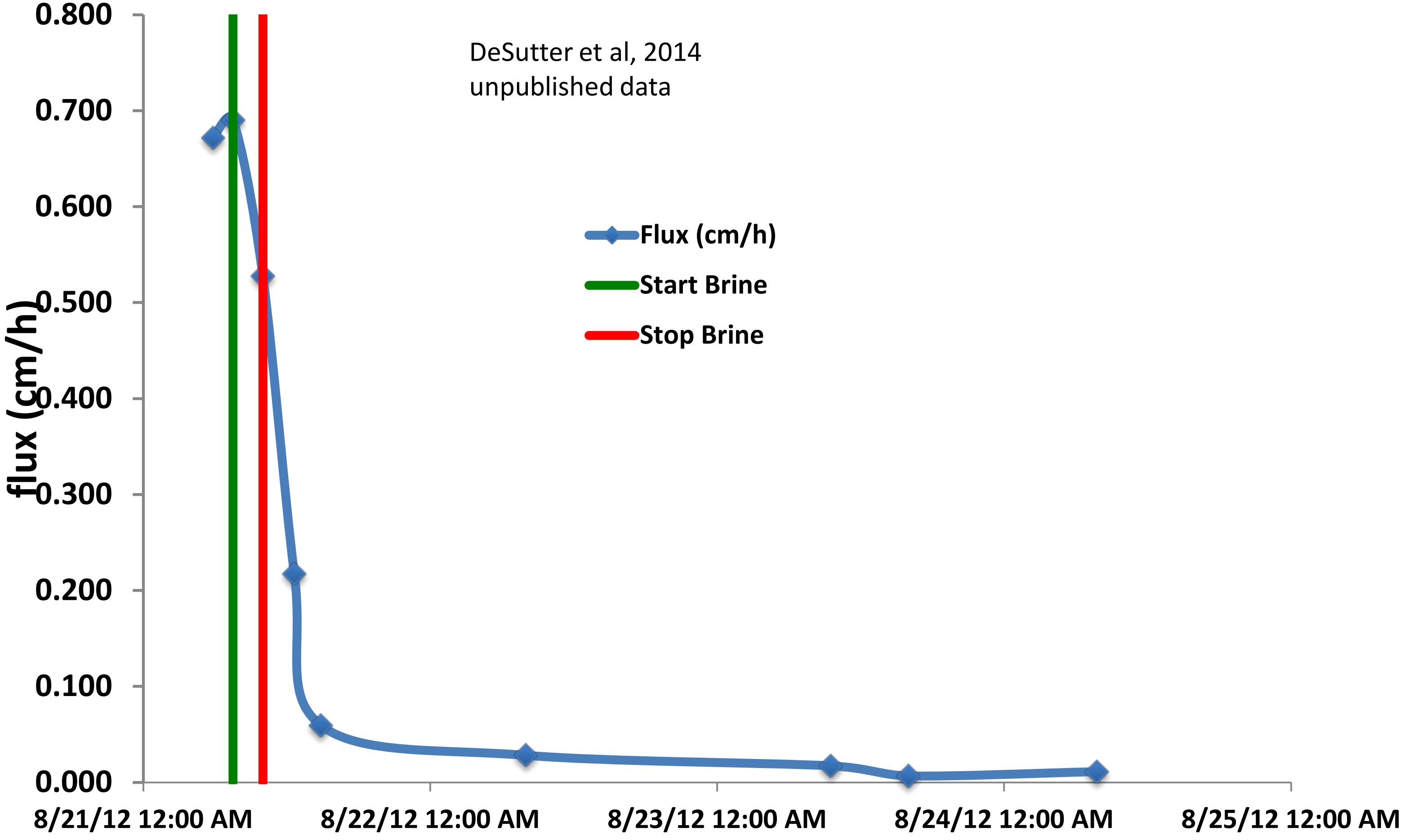
When Ca and EC are provided, water movement improves



He et al, 2014
unpublished data

No treatment

High Ca and EC



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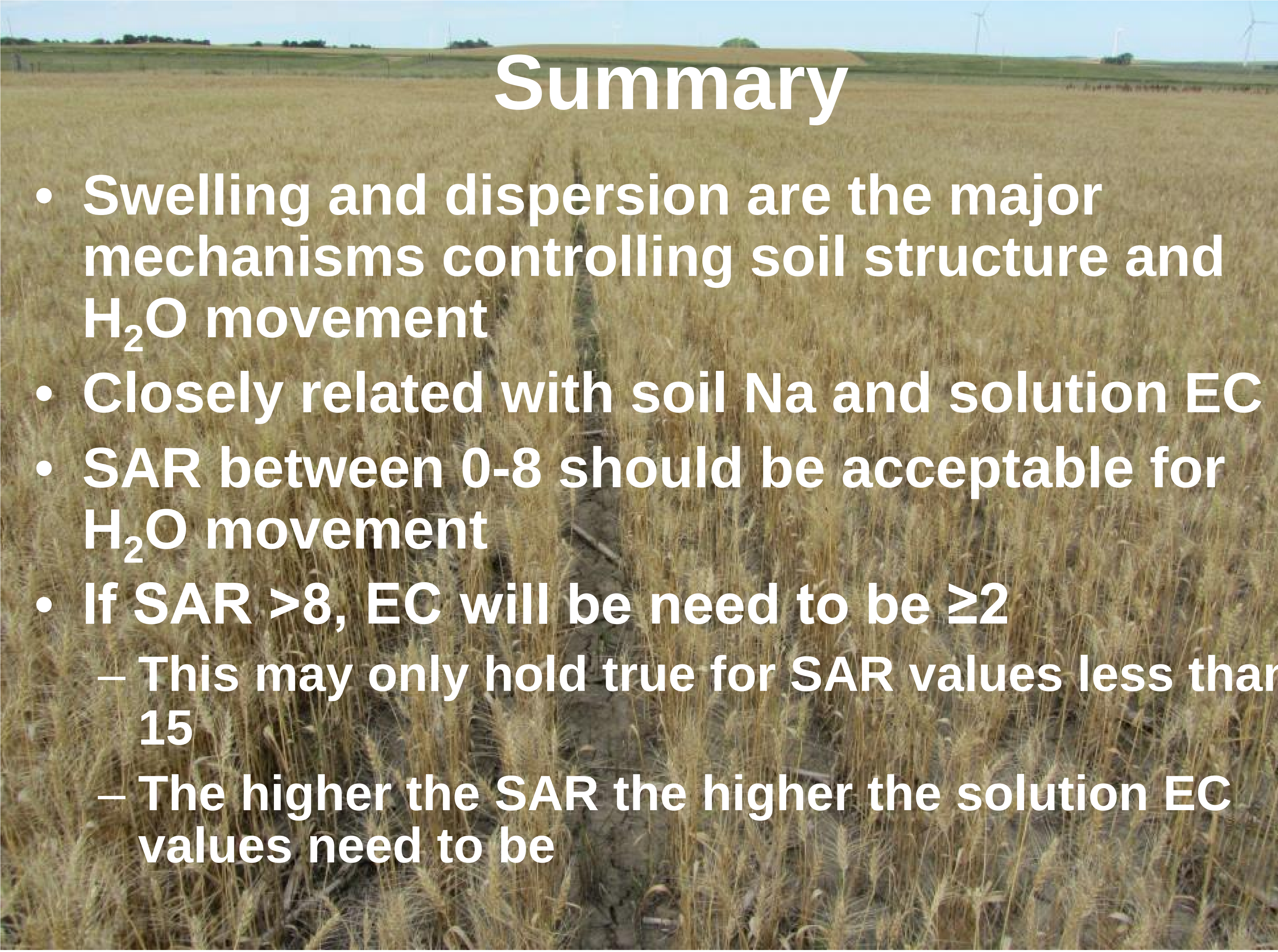

Summary

- Swelling and dispersion are the major mechanisms controlling soil structure and H_2O movement
- Closely related with soil Na and solution EC
- SAR between 0-8 should be acceptable for H_2O movement
- If SAR >8, EC will be need to be ≥2
  - This may only hold true for SAR values less than 15
  - The higher the SAR the higher the solution EC values need to be

Acknowledgements

- ND Water Resources Research Institute
- USDA-NRCS Conservation Innovation Grant
  - Reducing sodification in high risk northern Great Plains soils

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Summary

- **Gypsum (tons/acre-foot) required for SAR to be reduced to 8**

CEC\SAR	SAR → 13	18	30
↓ CEC	Quantity of gypsum	Quantity of gypsum	Quantity of gypsum
10	0.9	1.7	3.5
20	1.7	3.4	6.9
30	2.5	5.1	10.2