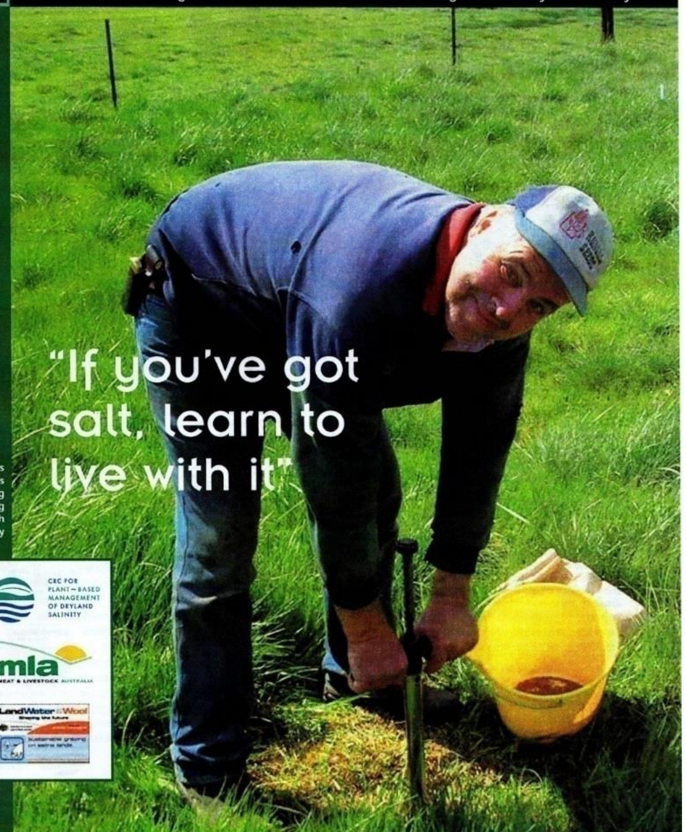
Dispersed attitudes: I'm tiling this country and you can't stop me!

Tom DeSutter
Professor of Soil Science
2020 Agvise Soil Fertility Seminars

salt magazine

The Magazine of the CRC for Plant-based Management of Dryland Salinity

ISSUE No. 15



"If you've got salt, learn to live with it"

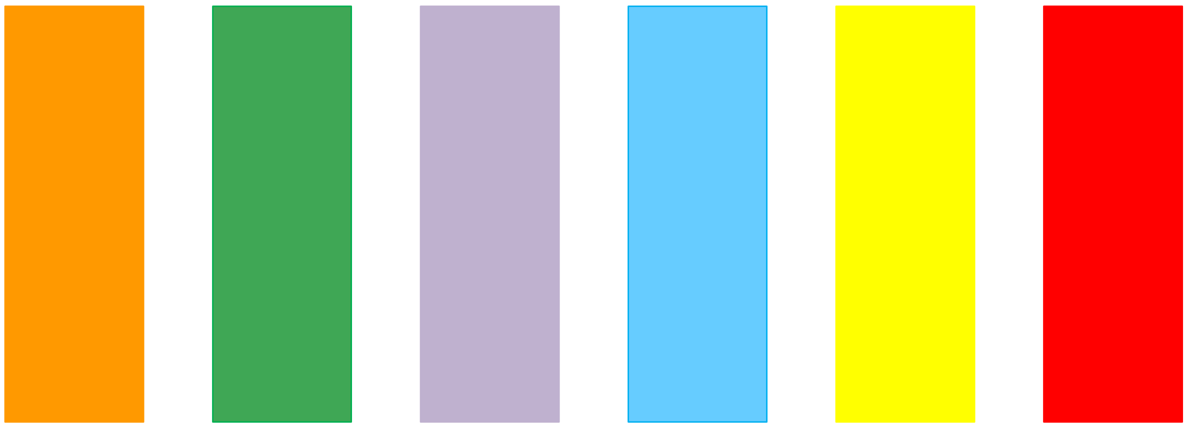
Personal stories of Australians combating and learning to live with dryland salinity

CRC FOR PLANT-BASED MANAGEMENT OF DRYLAND SALINITY

mla MEAT & LIVESTOCK AUSTRALIA

LandWater & Wool
Shaping the future

Today's demonstration: *use of gypsum in sodic soils*



- High SAR, low EC, washed with DI water
- High SAR, low EC, washed with 0.5M $CaCl_2$
- High SAR, low EC, 10 tons flue-gas gypsum (powder)/acre, washed with DI water
- High SAR, low EC, 10 tons commercial gypsum (pellets)/acre, washed with DI water
- High SAR, low EC, 10 tons spent lime/acre, washed with DI water
- NonSodic (low SAR), sandy soil, low EC, washed with 1M NaCl followed by DI water

DeSutter
Sodic Soil Demo Key
Ver. 1

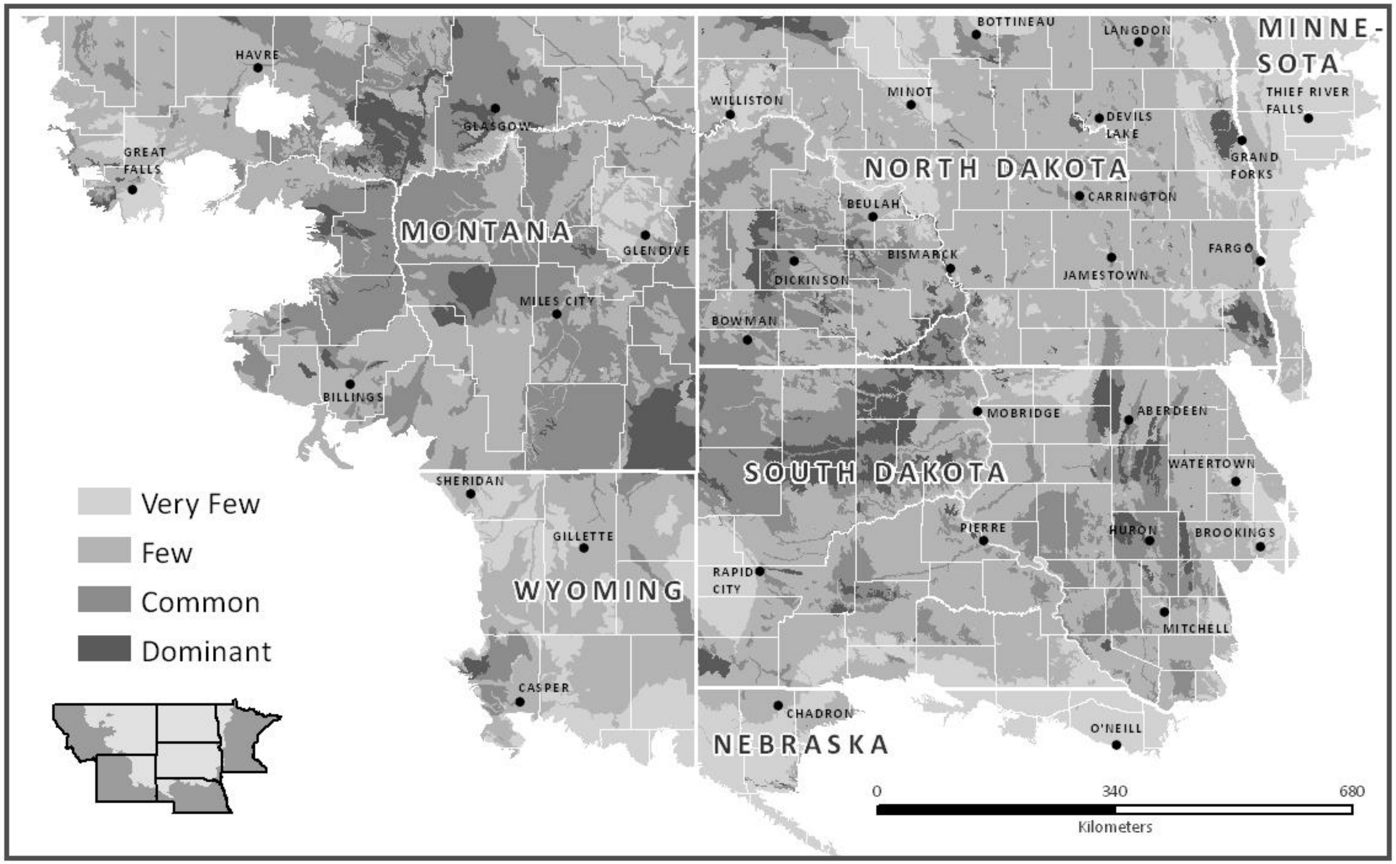
“Saline” vs “Sodic” Soils

- **Saline soils**
  - **Contain elevated levels of the of the chloride and sulfate salts of Na, Ca, Mg, and K**
  - **Salinity is the “total concentration of dissolved mineral solutes that are found in waters and soils” (NRCS)**
  - **Negatively effect plant growth**
- **Sodic soils**
  - **Soils affected by the sodium ion (Na^+)**
  - **Sodicity is the “accumulation of sodium”**
  - **Oftentimes have low salinity**
    - **Soluble salts is a main driver in sodic soil behavior**
  - **Causes soils to become hard-set, crust, restrict root penetration, and may not have a bottom when saturated**

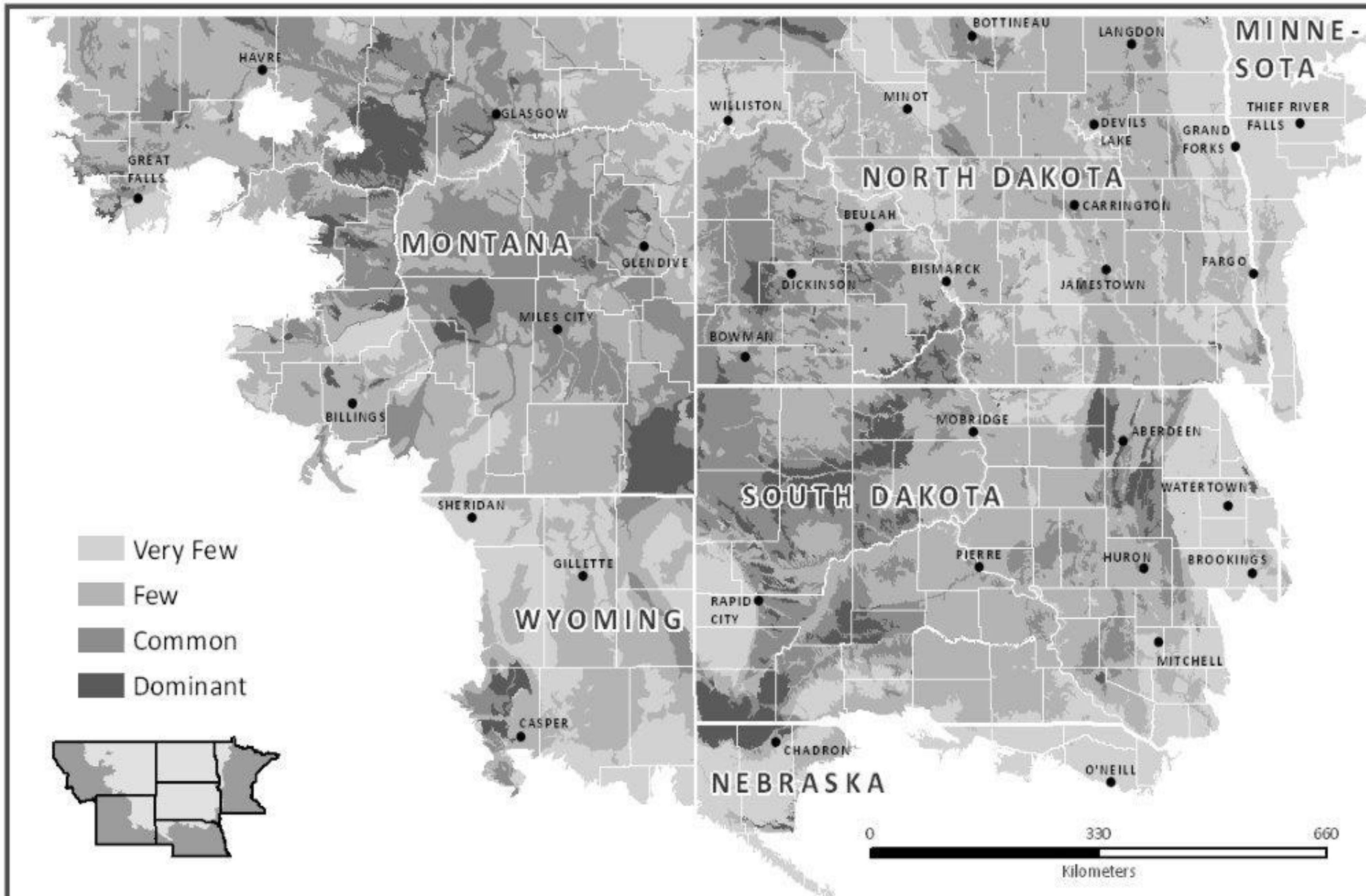
Saline soil (photo by Jay Goos)

Sodic soil (photo by NRCS)

Saline soils, EC > 4 mmhos/cm within 30” (saturated paste extract)



Sodic soils, SAR > 10 within 30” (saturated paste extract)



“Common” Salts in the Soil

Compound	Common Name	Molecular Formula	Solubility (20º C)
			g/L
Calcium carbonate	Lime	$CaCO_3$	0.06†
Magnesium carbonate		$MgCO_3$	2.51‡
Sodium carbonate	Soda	Na_2CO_3	179
Sodium bicarbonate	Baking soda	$NaHCO_3$	87
Calcium sulfate	Gypsum	$CaSO_4$	1.9
Magnesium sulfate	Epsom	$MgSO_4$	252
Sodium sulfate	Glauber’s salt	Na_2SO_4	161
Magnesium chloride		$MgCl_2$	410
Sodium chloride	Table salt	NaCl	264
Calcium chloride		$CaCl_2$	427

Solubility, in general:

$$Cl^{-} > SO_4^{2-} > CO_3^{2-}$$

EC of saturated solutions:

$CaCO_3$___________________

$CaSO_4$___________________

$CaCl_2$____________________

Seawater_______________________

Nutrient In The Soil			Interpretation (VLow / Low / Med / High)
Nitrate	0-6"	5 lb/ac	***
Phosphorus	Olsen	19 ppm	******************************
Potassium		374 ppm	******************************
Chloride	0-6"	1531 lb/ac	******************************
Sulfur	0-6"	120 +lb/ac	******************************
Boron		11.2 ppm	******************************
Zinc		0.94 ppm	******************
Iron		7.4 ppm	**********************
Manganese		3.9 ppm	***********************
Copper		0.84 ppm	******************
Magnesium		991 ppm	******************************
Calcium		4000 ppm	******************************
Sodium		1500 ppm	******************************
Org.Matter		4.2 %	******************
Carbonate(CCE)		9.4 %	**********************
Sol. Salts	0-6"	0.33 mmho/cm	********

	1st Crop Choice		2nd Crop Choice		3rd Crop Choice	
	Corn-Grain		Corn-Grain		Corn-Grain	
	YIELD GOAL		YIELD GOAL		YIELD GOAL	
	160 BU		170 BU		180 BU	
	SUGGESTED GUIDELINES		SUGGESTED GUIDELINES		SUGGESTED GUIDELINES	
	Band		Band		Band	
	LB/ACRE	APPLICATION	LB/ACRE	APPLICATION	LB/ACRE	APPLICATION
N	172		184		196	
P_2O_5	15	Band (2x2) *	15	Band (2x2) *	15	Band (2x2) *
K_2O	10	Band (2x2) *	10	Band (2x2) *	10	Band (2x2) *
Cl		Not Available		Not Available		Not Available
S	0		0		0	
B	0		0		0	
Zn	3	Band	3	Band	3	Band
Fe	0		0		0	
Mn	0		0		0	
Cu	0		0		0	
Mg	0		0		0	
Lime						

Soil pH	Buffer pH	Cation Exchange Capacity	% Base Saturation (Typical Range)				
			% Ca	% Mg	% K	% Na	% H
0-6" 8.4		35.7 meq	(65-75) 56.0	(15-20) 23.1	(1-7) 2.7	(0-5) 18.2	(0-5)

Nutrient In The Soil			Interpretation (VLow / Low / Med / High)
Nitrate	0-6"	81 lb/ac	**
Phosphorus	Olsen	43 ppm	**
Potassium		203 ppm	**
Chloride	0-6"	385 lb/ac	**
Sulfur	0-6"	120 +lb/ac	**
Boron		2.9 ppm	**
Zinc		0.37 ppm	***********
Iron		4.1 ppm	**************************
Manganese		2.5 ppm	*******************************
Copper		0.77 ppm	****************************
Magnesium		2553 ppm	**
Calcium		8652 ppm	**
Sodium		70 ppm	****************
Org.Matter		3.5 %	***********************
Carbonate(CCE)		2.6 %	******************
Sol. Salts	0-6"	4.03 mmho/cm	**

	1st Crop Choice		2nd Crop Choice		3rd Crop Choice	
	Corn-Grain		Corn-Grain		Corn-Grain	
	YIELD GOAL		YIELD GOAL		YIELD GOAL	
	160 BU		170 BU		180 BU	
	SUGGESTED GUIDELINES		SUGGESTED GUIDELINES		SUGGESTED GUIDELINES	
	Band		Band		Band	
	LB/ACRE	APPLICATION	LB/ACRE	APPLICATION	LB/ACRE	APPLICATION
N	81		93		105	
P_2O_5	15	Band (2x2) *	15	Band (2x2) *	15	Band (2x2) *
K_2O	10	Band (2x2) *	10	Band (2x2) *	10	Band (2x2) *
Cl		Not Available		Not Available		Not Available
S	0		0		0	
B	0		0		0	
Zn	5	Band	5	Band	5	Band
Fe	1	Band	1	Band	1	Band
Mn	0		0		0	
Cu	0		0		0	
Mg	0		0		0	
Lime						

Soil pH	Buffer pH	Cation Exchange Capacity	% Base Saturation (Typical Range)				
			% Ca	% Mg	% K	% Na	% H
0-6" 8.1		65.4 meq	(65-75) 66.2	(15-20) 32.6	(1-7) 0.8	(0-5) 0.5	(0-5)

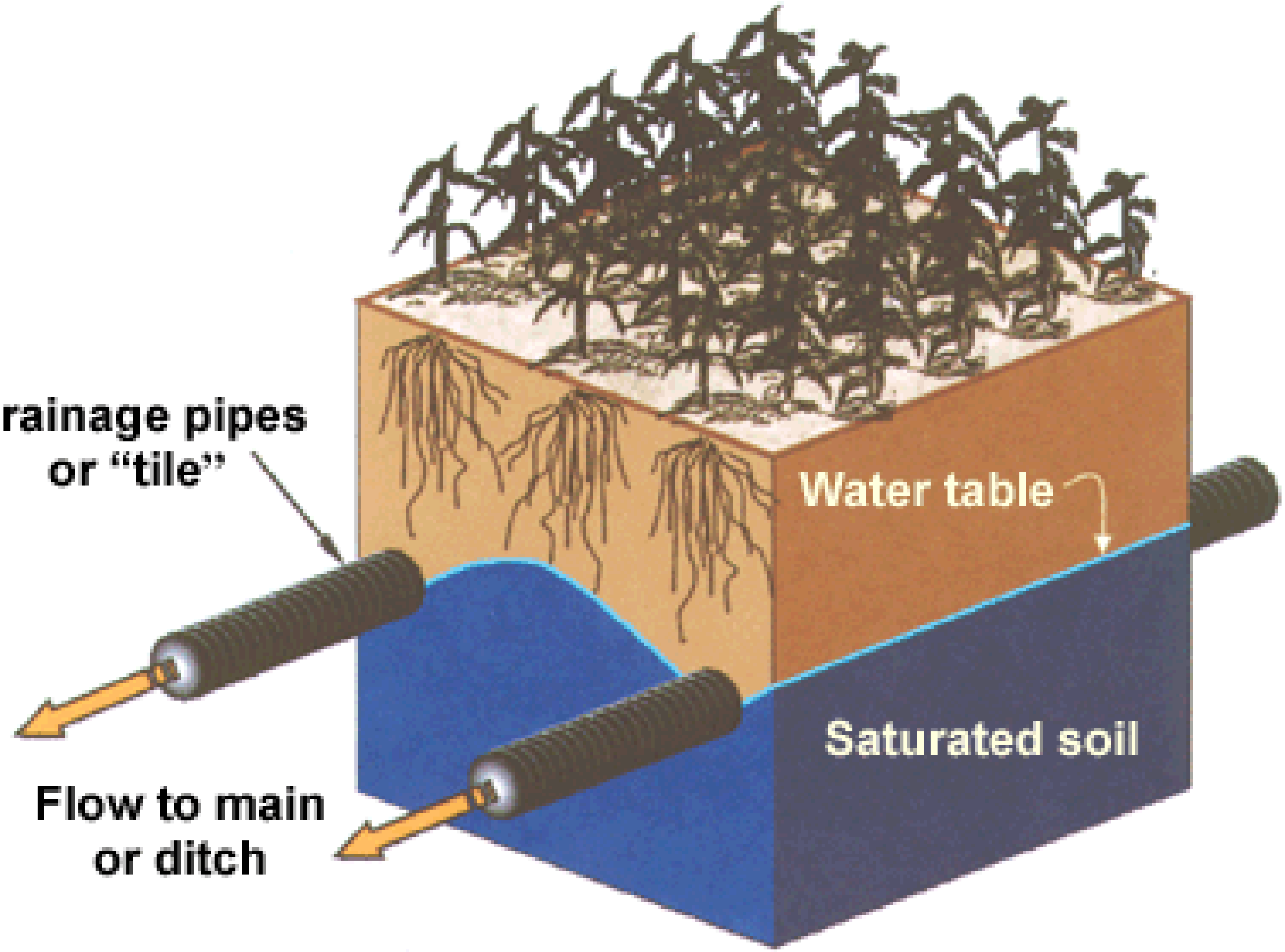
So, which salts will likely move faster in soils?

Depends on:

1) Water flow in soils

-Saturated flow vs unsaturated flow

2) Solubility of the salts



http://www.extension.umn.edu/distribution/cropsystems/images/7740f04.gif

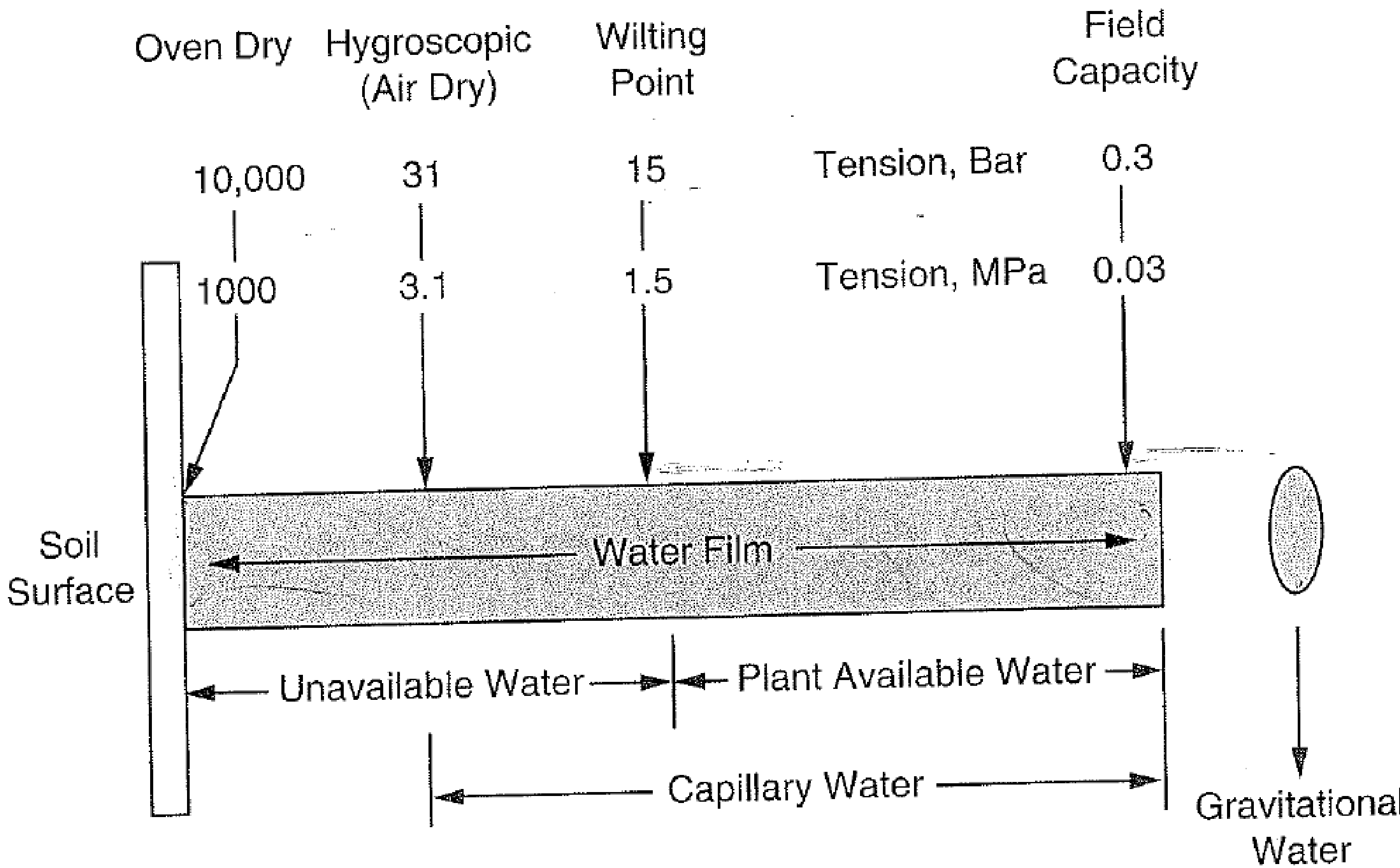


FIGURE 7–1 Types of water in soil (*adapted from Thein & Graveel, 1997*).

Won’t the salts leach by themselves?

Yes, more or less, but it will take time.

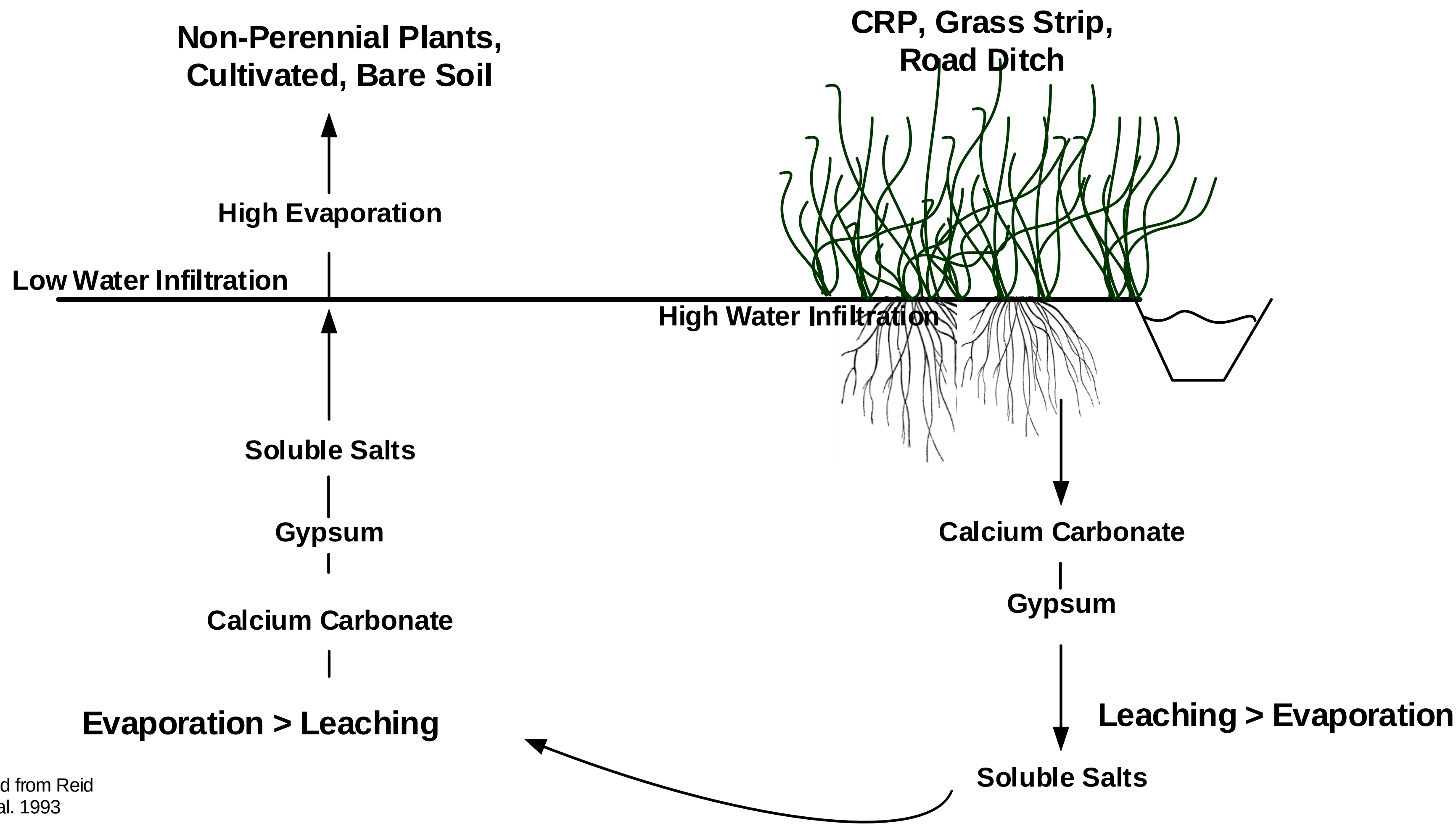
What has to happen to leach salts?

- More fishing?
- Leaching > Evaporation
- Ground water level must be below the capillary fringe
- The downward moving water must have a place to go

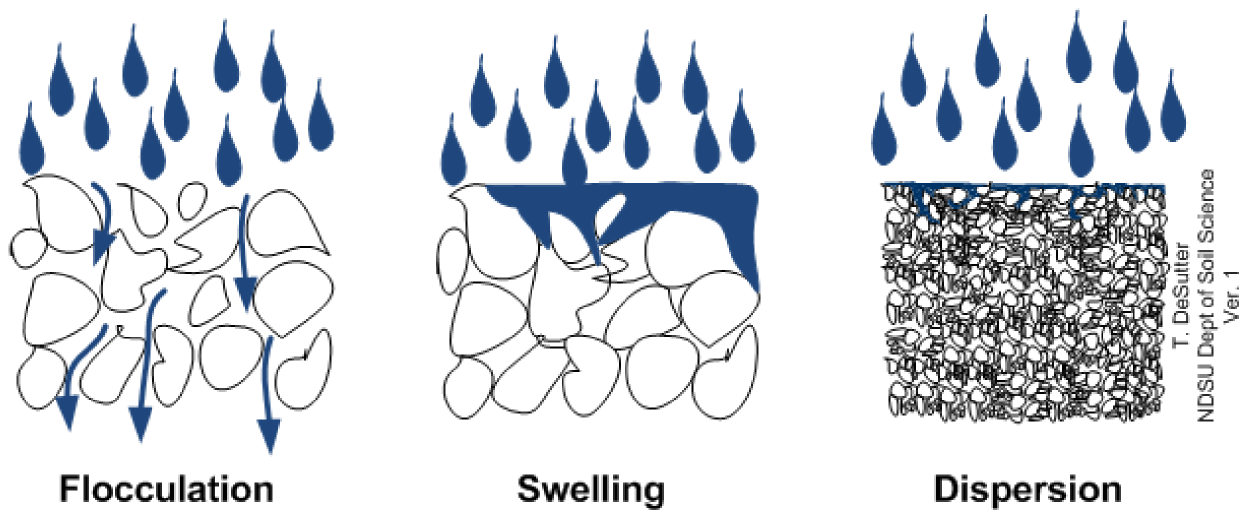
Sources of water to leach soils with

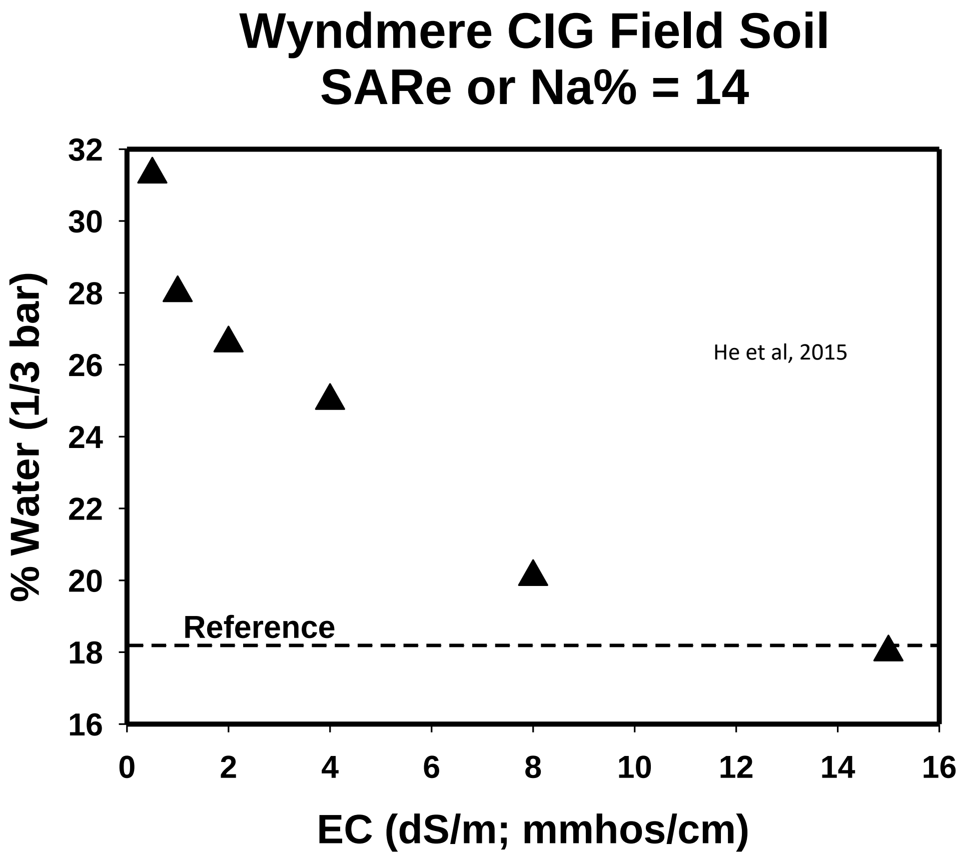
- Best case scenarios:
  - Slow and steady rainfall
  - Melting snow.
  - You can’t make more water but you can concentrate it

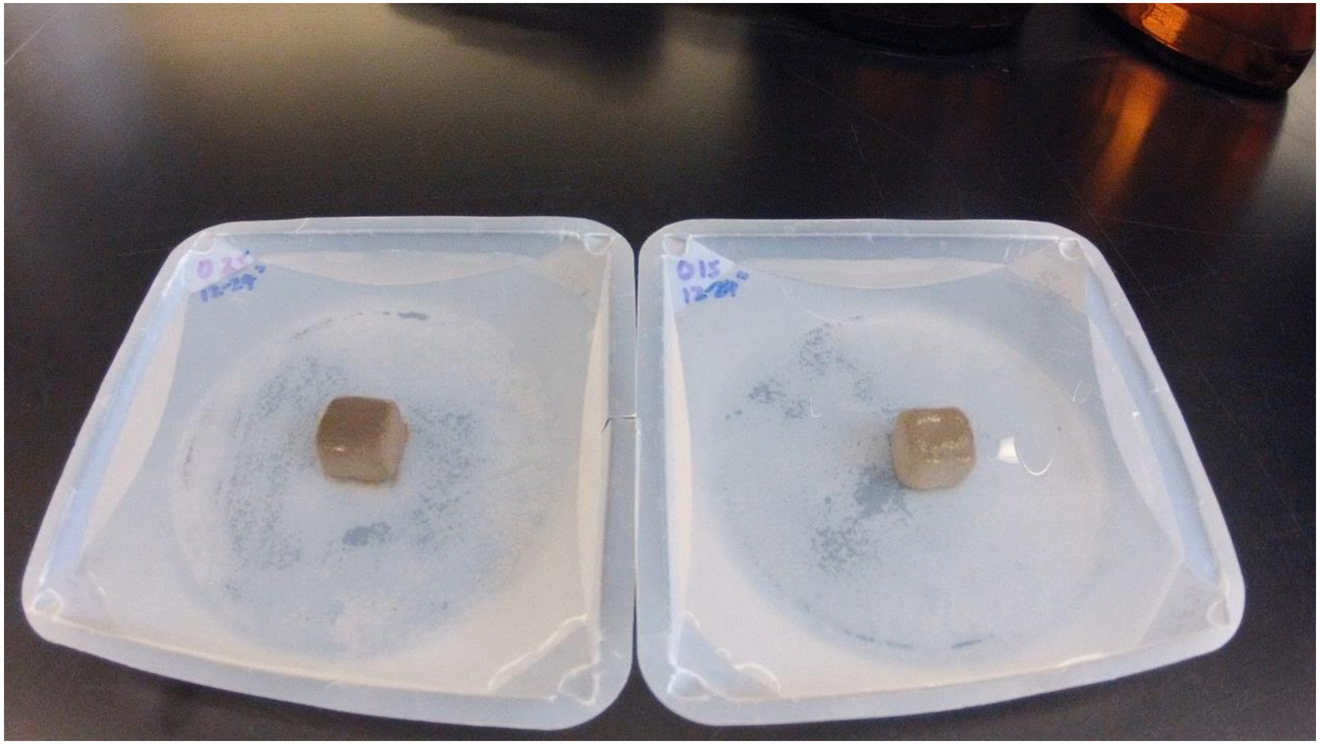
Example of "road ditch salinity"



Adapted from Reid et al. 1993

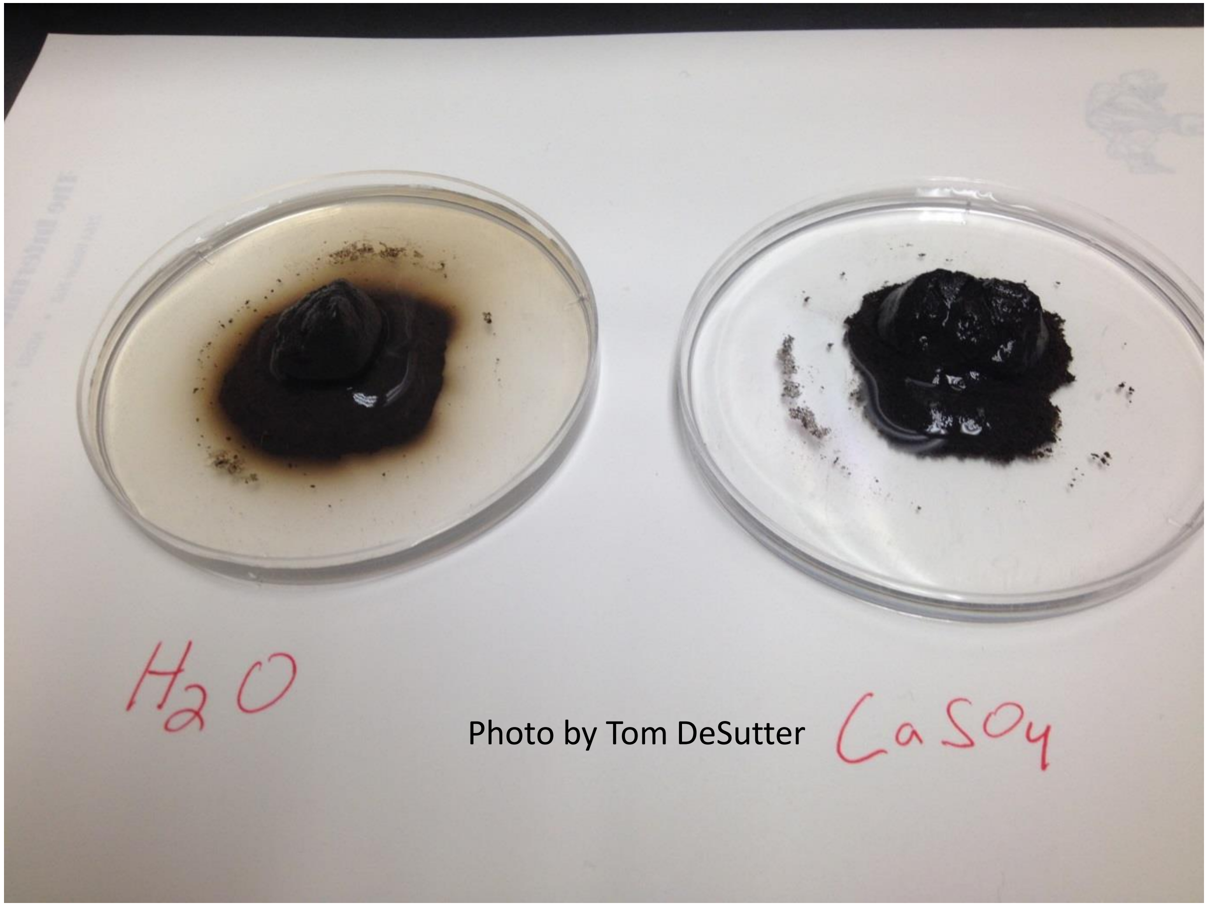

Flocculation
Swelling
Dispersion
T. DeSutter
NDSU Dept of Soil Science
Ver. 1


Wyndmere CIG Field Soil
SARe or Na% = 14
He et al, 2015
Reference
% Water (1/3 bar)
EC (dS/m; mmhos/cm)
32
30
28
26
24
22
20
18
16
0
2
4
6
8
10
12
14
16



Two main reasons that this occurs:

1) **Sodium concentrations are elevated**
2) **The salinity is low**


H2O
Photo by Tom DeSutter
CaSO4

$$2NaX + CaSO_4 \rightleftharpoons CaX_2 + Na_2SO_4$$

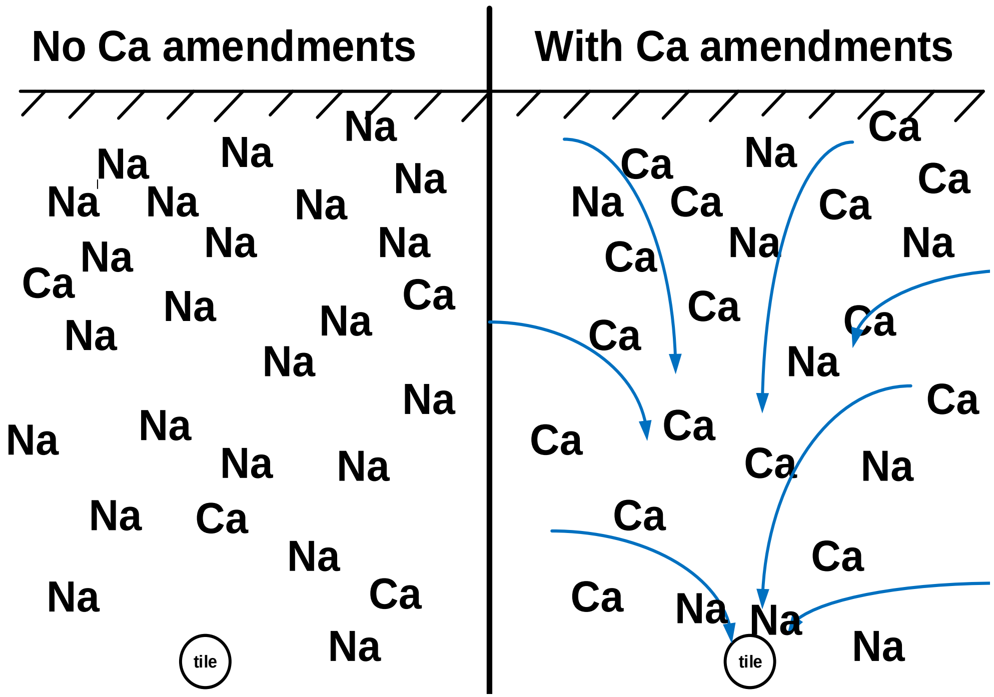


Figure by Thomas DeSutter and Maria Breker

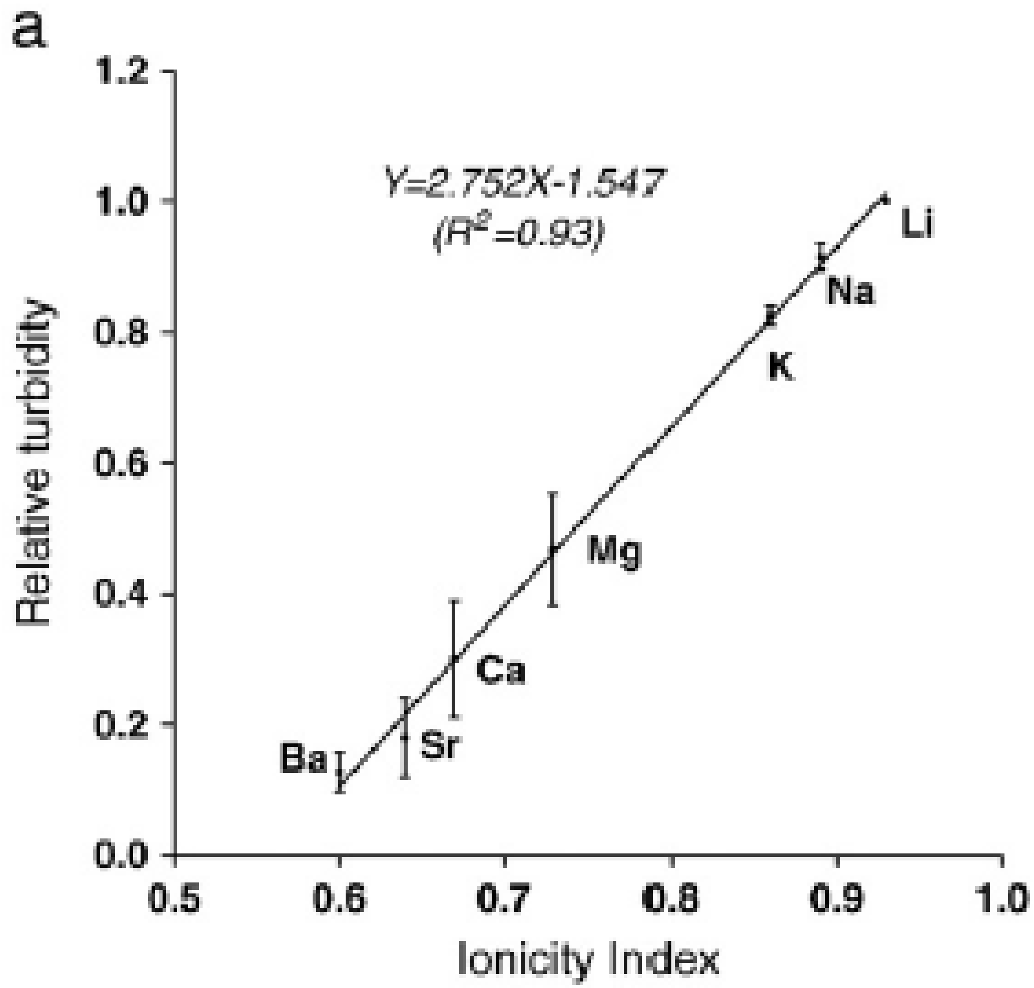
Recent NDSU research has found that swelling and/or dispersion can occur when the %Na is greater than 5 when the $EC_{1:1}$ is less than 1.0 mmhos/cm.

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

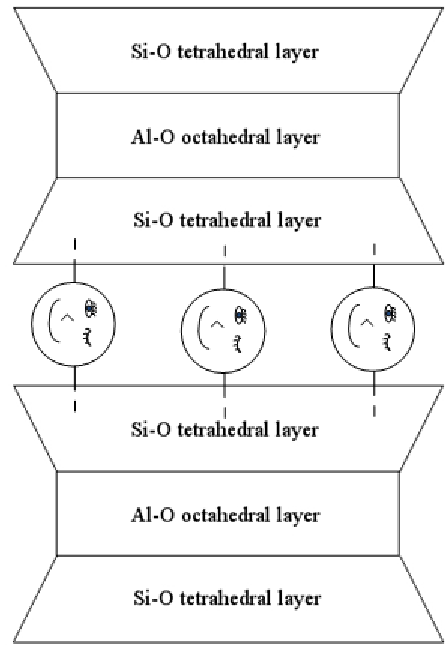
Historically, Ca and Mg have been treated as equals with respect to their ability to flocculate clays

The story of Mg…

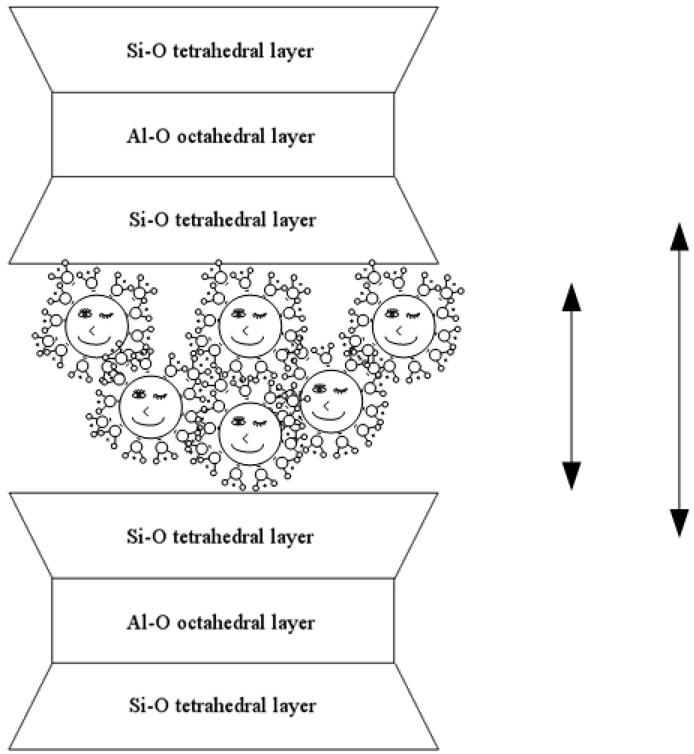
- **In fact, as far back as 1935, Ellis and Caldwell, suggested dividing soils as “solonetz” into “sodium solonetz” and “magnesium solonetz” soils.**
- **In 2006, the Food and Agriculture Organization of the United Nations set out a definition of a sodic soil as “having 15 % or more exchangeable Na plus Mg on the exchange complex within 50 cm of the soil surface throughout”**



Marchuk and Rengasamy, 2011



When Ca is present it does not matter if EC is high or not



When repulsion becomes greater than attraction dispersion will occur

This happens when Na is on exchange sites and when EC is low

Keep in mind that just knowing the level of Na, Ca, Mg, or K is not the whole story:

-the level of soluble salts greatly controls swelling and dispersion

Sources of Calcium

- Gypsum ($CaSO_4 \cdot 2H_2O$)
  - Mined
    - Most likely pelletized
    - About $200/ton
  - Synthetic
    - Byproduct from coal combustion
    - Powder form
    - Now available, less than $15/ton
- Both are very pure and are good sources of S too

Sources of Calcium

- Sugar beet spent lime
  - Lots of beneficial uses for ag
  - Very low solubility, so not ideal for sodic soils
  - Organic compounds within it are very degradable and can improve microbial respiration
- Calcium nitrate
  - High solubility
  - Often used in reclamation of brine spills

So, how much gypsum should one apply?

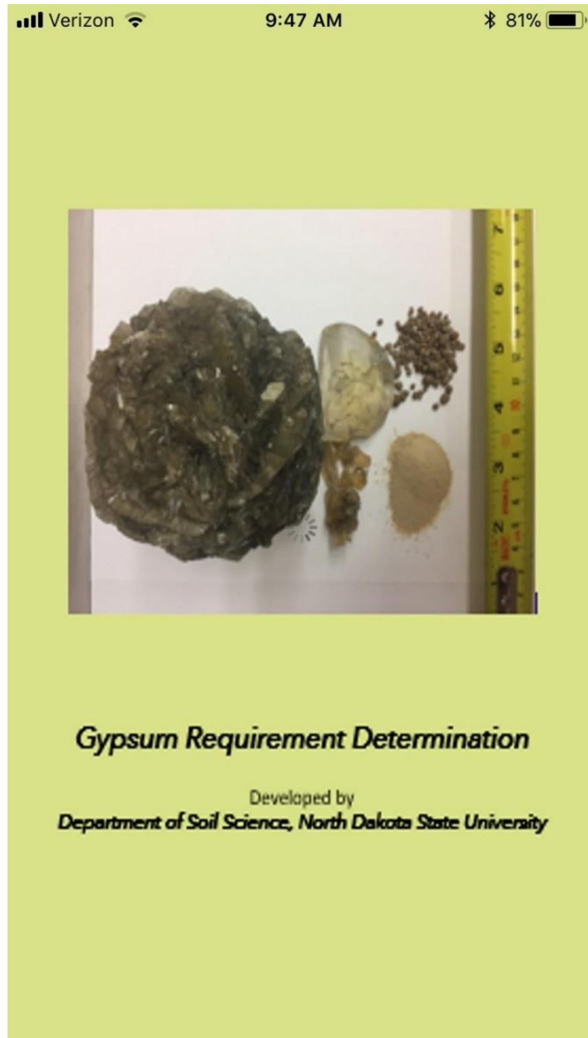
- Need to know, or assume, some basic soil parameters
  - Soil density
  - Actual cation exchange capacity (CEC)
  - What level of Na you are starting with?
  - What level of Na doing you want end with?
  - What is the thickness of soil that needs treating?
  - How pure is your gypsum?

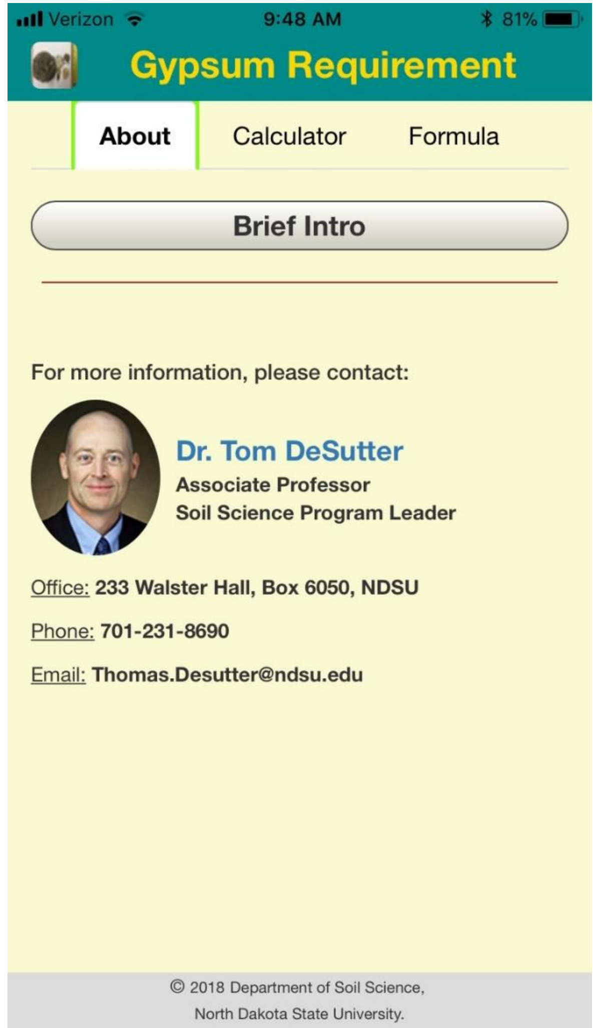
$$GR = 0.86(F)(D)(\rho_b)(CEC)(ESP_i - ESP_f)(100/\%purity)$$

GR = gypsum requirement (Mg/ha)
F = Ca-Na exchange efficiency; 1.1 for ESP of 15, 1.3 for ESP of 5
D = depth of soil to treat (m)
ρ_b = soil bulk density (Mg/m^3), typically ranges from 1.1 to 1.6
CEC = soils' actual cation exchange capacity ($mmol_c/kg$)
ESP*i* = soils' initial exchangeable sodium percentage (%)
ESP*f* = soils' final exchangeable sodium percentage (%)
Purity = the actual purity of the gypsum that you are using (%)

0.86 is derived from the mass of $CaSO_4{*}2H_2O$ required to replace one Na^+

Download now, its free!




Verizon
9:48 AM
81%
Gypsum Requirement
About
Calculator
Formula
Brief Intro
For more information, please contact:
Dr. Tom DeSutter
Associate Professor
Soil Science Program Leader
Office: 233 Walster Hall, Box 6050, NDSU
Phone: 701-231-8690
Email: Thomas.Desutter@ndsu.edu
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North Dakota State University.

Verizon LTE 9:22 AM 91%

Gypsum Requirement

About | Calculator | Formula

Brief Intro

Welcome to the NDSU gypsum requirement (GR) mobile app. The calculations are based on the equation of Oster et al. (1999). To determine GR (in Mg/ha; e.g. 1 Mg/ha = 1.1 tons/acre) the equation requires knowledge of the 1) depth, D, (in meters; e.g. 0.15 m = 6 inches) to which the gypsum will be applied, 2) the bulk density, Bd, of the soil (in Mg/m3; e.g. 1 Mg/m3 = 1 g/cm3; default value in the calculator is 1.47 Mg/m3), 3) the cation exchange capacity, CEC, of the soil (in mmolc/kg; e.g. 100 mmolc/kg = 10 cmolc/kg = 10 meq/kg), 4) the reaction efficiency factor, F, which is unitless (e.g. choose 1.3 if the final ESP is 5 and 1.1 if the final ESP is 15 or greater), 5) the initial ESP, ESPi, which is determined by a qualified laboratory (ESP is a % of the Na ions on the soil's exchange sites), 6) the target, final ESP, ESPf, and 7) the purity of the gypsum being used (in %).

You will need to adjust the final mass of gypsum

$$GR = 0.86(F)(D)(\rho_b)(CEC)(SAR_i - SAR_f)(100/\%purity)$$

Where SAR is the sodium adsorption ratio.

When ESP<50 then ESP≈SAR.

So, what about %Na?

GR = 0. 86(F)(D)(ρ_b)(CEC)(%Na*i* - %Na*f*)(100/%purity)

SAR = 1.04%Na- 0.35; r^2 = 0.92

So, just replace SAR or ESP with %Na.

Verizon LTE 9:23 AM 91%

Gypsum Requirement

About | Calculator | **Formula**

You can use either

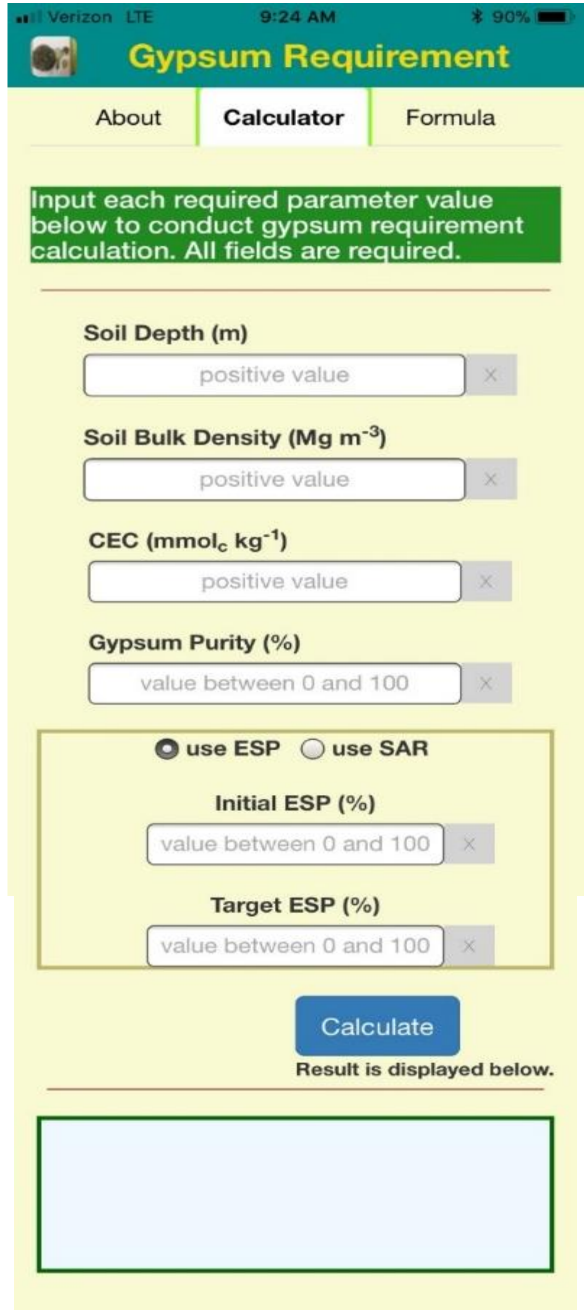
$$GR_{adj}=0.86*F*D*\rho_b*CEC*(ESP_i-ESP_f)/p$$

or

$$GR_{adj}=0.86*F*D*\rho_b*CEC*(SAR_i-SAR_f)/p$$

Note: The second formula requires that the ESP value is less than 50.

Symbol	Definition
GR_{adj}	Amount of gypsum needed. Adjusted by its purity. unit: Mg ha^{-1}
ESP	exchangeable sodium percentage, unit: %
ESP_i	initial *ESP* level
ESP_f	final or target *ESP* level
SAR	sodium adsorption ratio, unit: %
SAR_i	initial *SAR* level


Verizon LTE
9:24 AM
90%
Gypsum Requirement
About
Calculator
Formula
Input each required parameter value below to conduct gypsum requirement calculation. All fields are required.
Soil Depth (m)
positive value
Soil Bulk Density (Mg m^{-3})
positive value
CEC (mmol$_c$ kg^{-1})
positive value
Gypsum Purity (%)
value between 0 and 100
use ESP
use SAR
Initial ESP (%)
value between 0 and 100
Target ESP (%)
value between 0 and 100
Calculate
Result is displayed below.

Recommendations:

- **Saline soils**
  - **Soil sample to monitor changes over time**
  - **May need to use salt-tolerant crops in certain areas of the field**
  - **Leaching lots of water is essential**
  - **Tile drainage will eventually help, takes time**
- **Sodic soils**
  - **Soil sampling is the only real way of determining the Na and EC levels**
  - **If tiling, 1’ increments to 4’ is recommended**
  - **Gypsum will only be useful to depth at which it is applied**
- **Unknown?**
  - **Soil sample!**

Demo results:

- **Water did not move in sodic soil**
- **Addition of ‘salt’ to the sodic soil allowed the water to move**
- **The powder gypsum was more effective than the pelletized gypsum**
- **Spent lime may work, eventually, but don’t expect short term success (less than 5 yr)**
  - **May never work in soils having pH >7.5**
- **Be careful of using poor irrigation water**

Dispersed attitudes: I'm tiling this country and you can't stop me!

Tom DeSutter
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2020 Agvise Soil Fertility Seminars