Saline and Sodic Soils: Characteristics and Properties

DOUGLAS D. MALO, PRESENTING TODAY

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SALINE/SODIC SOIL MANAGEMENT WORKSHOP

REDFIELD, SD

JULY 9, 2015

Outline

- Definition of the problem
- Causes of the problem
- Salt affected classes of soils
- Lab tests used to identify salt and sodicity problems
- Current research results

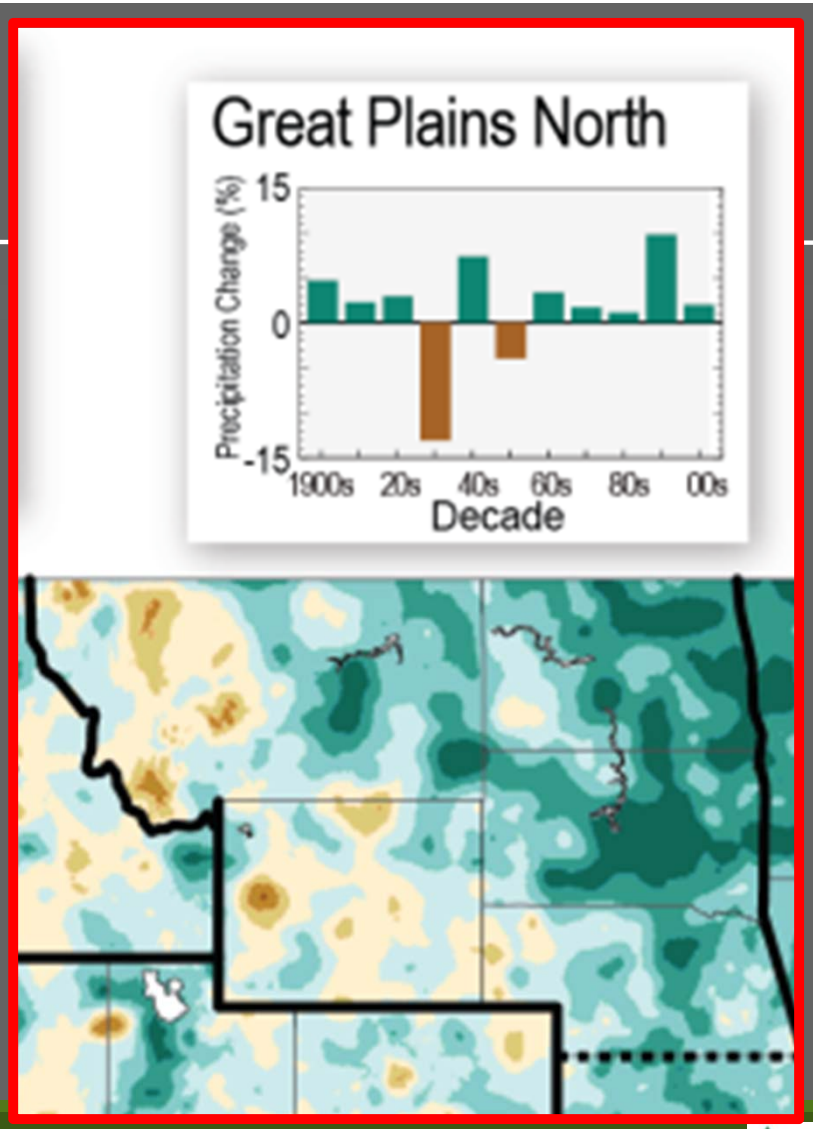
Why Salt Problems Now?

- Changes in climate
- Changes in management
  - More corn and soybeans
  - No-till adoption
- Source of the salts - the soil parent materials
- In typical, normal conditions salts are deeper in soil profiles

Climate Changes

- Changes in precipitation from 1900 to 2010 in the Northern Great Plains

Source - http://nca2014.globalchange.gov/report/our-changing-climate/precipitation-change



Next factor that adds to problem:
Seasonal water use of tall grass prairie greater than that of corn, soybeans, or wheat.

Deep roots of the tall grass that remove water from deeper in the soil profile.

Photo, Jim Millar

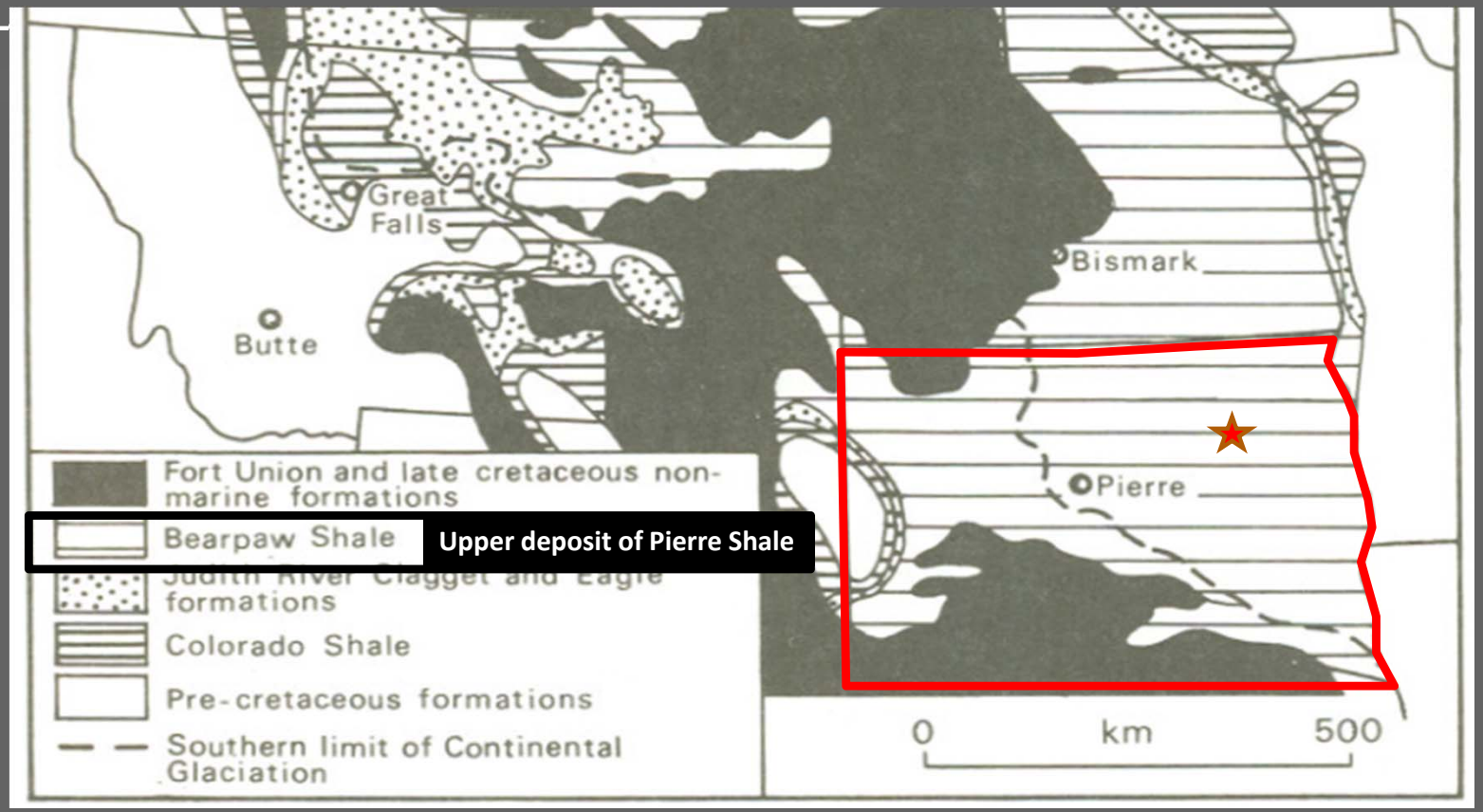
Changes in Tillage Practices

- Shift from Conventional to No-till
- Impacts

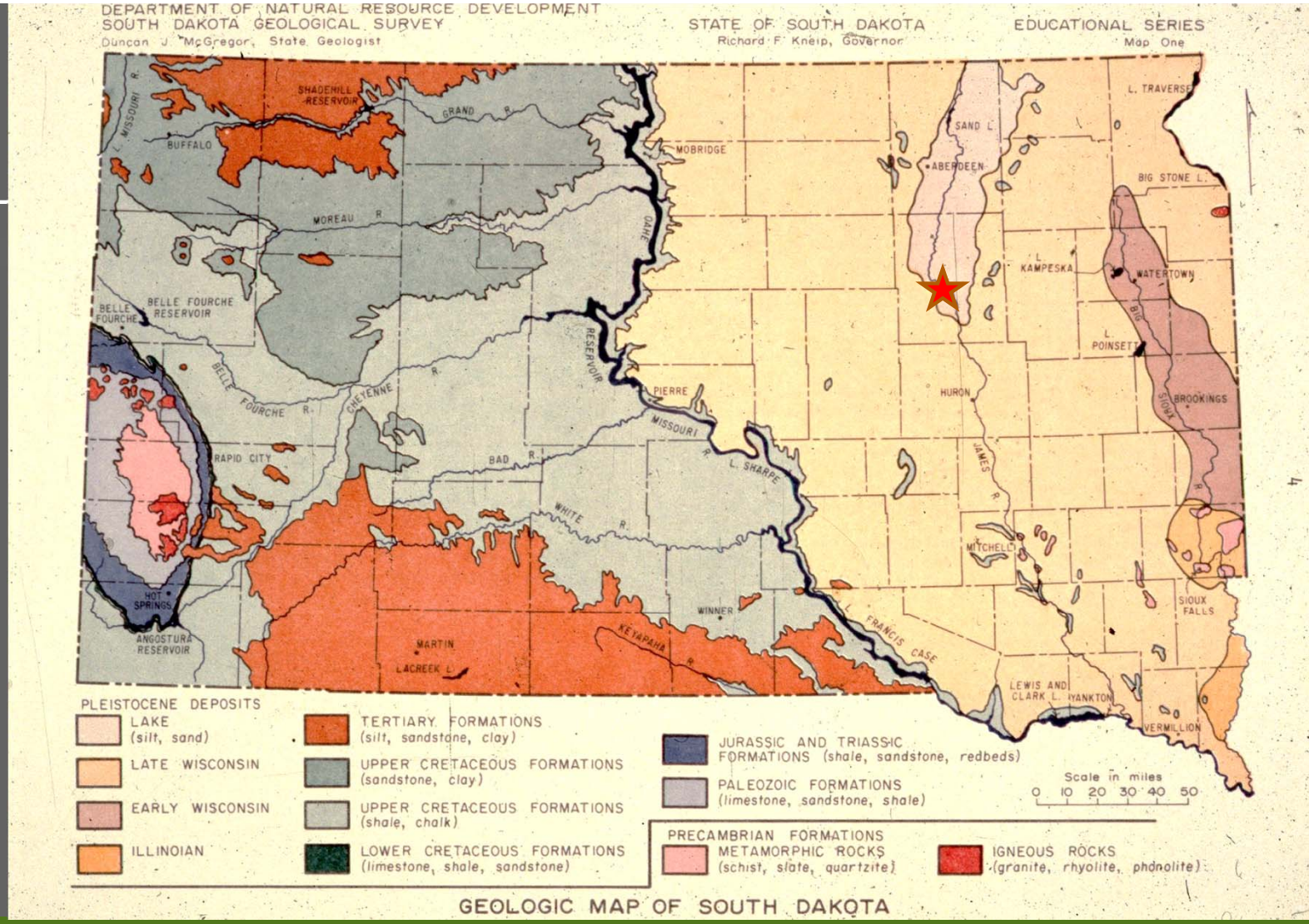
Source of the Salts

Spink County: Areas with till, and lacustrine deposits from Pierre shale

Daniels 1987

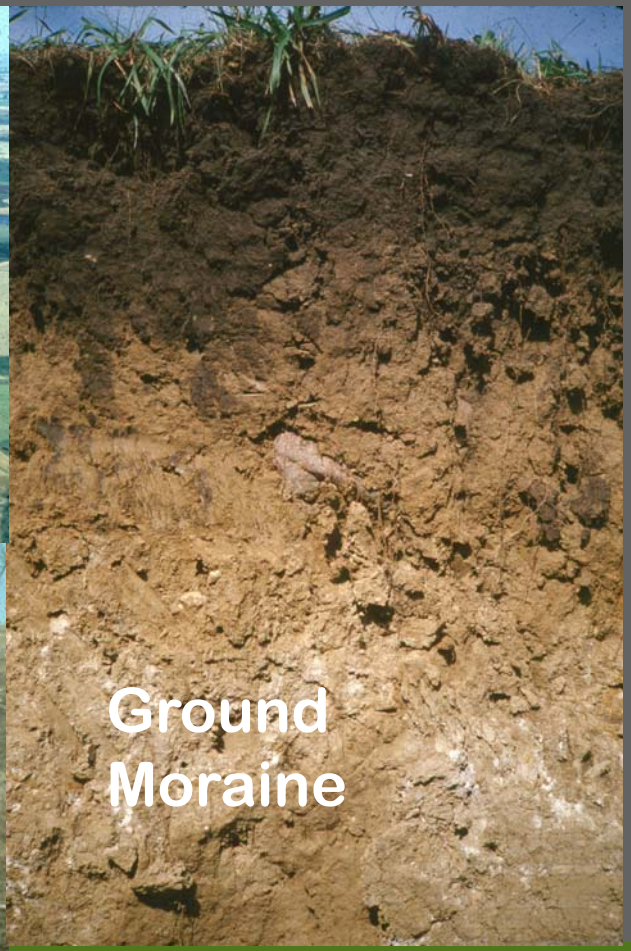


SD Geology


DEPARTMENT OF NATURAL RESOURCE DEVELOPMENT
SOUTH DAKOTA GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist
STATE OF SOUTH DAKOTA
Richard F. Kneip, Governor
EDUCATIONAL SERIES
Map One
SHADEHILL RESERVOIR
GRAND R.
L. MISSOURI R.
BUFFALO
MOREAU R.
MOBRIDGE
OAHE
SAND L.
ABERDEEN
L. TRAVERSE
BIG STONE L.
KAMPESKA
WATERTOWN
POINSETT
BIG SIOUX R.
BROOKINGS
BELLE FOURCHE
BELLE FOURCHE RESERVOIR
BELLE FOURCHE R.
CHEYENNE R.
RESERVOIR
PIERRE
MISSOURI R.
L. SHARPE
HURON
JAMES R.
RAPID CITY
BAD R.
WHITE R.
MITCHELL
HOT SPRINGS
ANGOSTURA RESERVOIR
WINNER
L. FRANCIS CASE
SIOUX FALLS
MARTIN
LACREEK L.
KEYAPAHA R.
LEWIS AND CLARK L.
YANKTON
VERMILLION
PLEISTOCENE DEPOSITS
LAKE (silt, sand)
LATE WISCONSIN
EARLY WISCONSIN
ILLINOIAN
TERTIARY FORMATIONS (silt, sandstone, clay)
UPPER CRETACEOUS FORMATIONS (sandstone, clay)
UPPER CRETACEOUS FORMATIONS (shale, chalk)
LOWER CRETACEOUS FORMATIONS (limestone, shale, sandstone)
JURASSIC AND TRIASSIC FORMATIONS (shale, sandstone, redbeds)
PALEOZOIC FORMATIONS (limestone, sandstone, shale)
PRECAMBRIAN FORMATIONS
METAMORPHIC ROCKS (schist, slate, quartzite)
IGNEOUS ROCKS (granite, rhyolite, phonolite)
Scale in miles
0 10 20 30 40 50
GEOLOGIC MAP OF SOUTH DAKOTA

Glacial Impacts

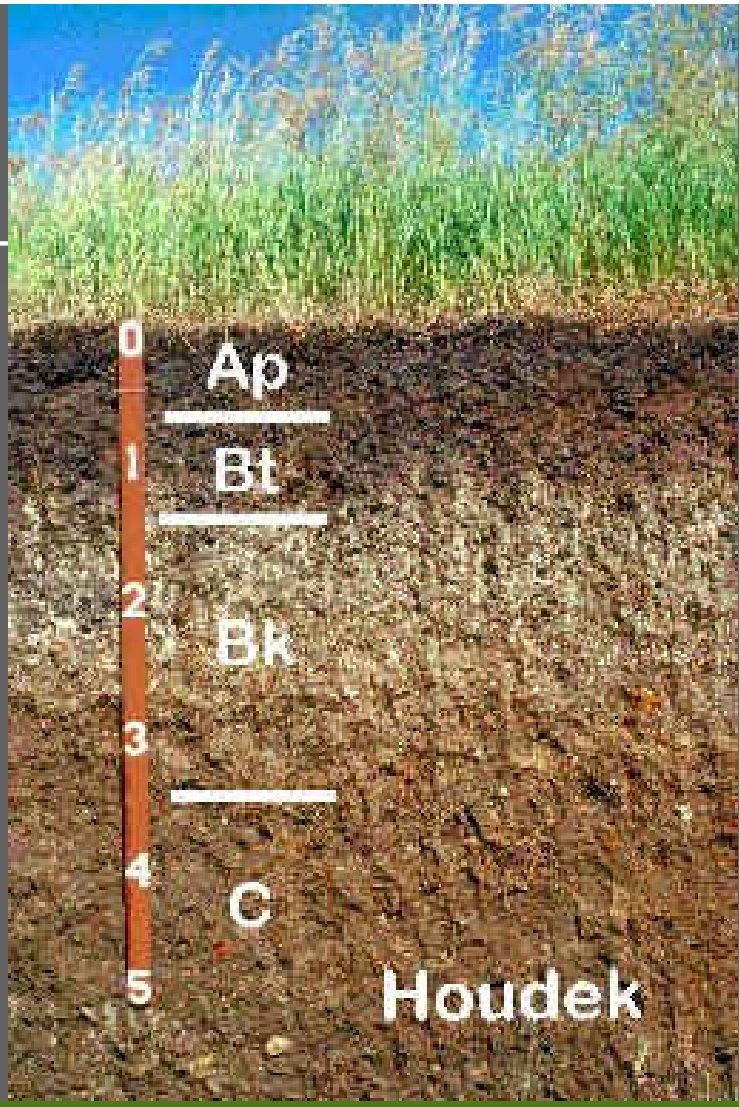
Glacial Soils



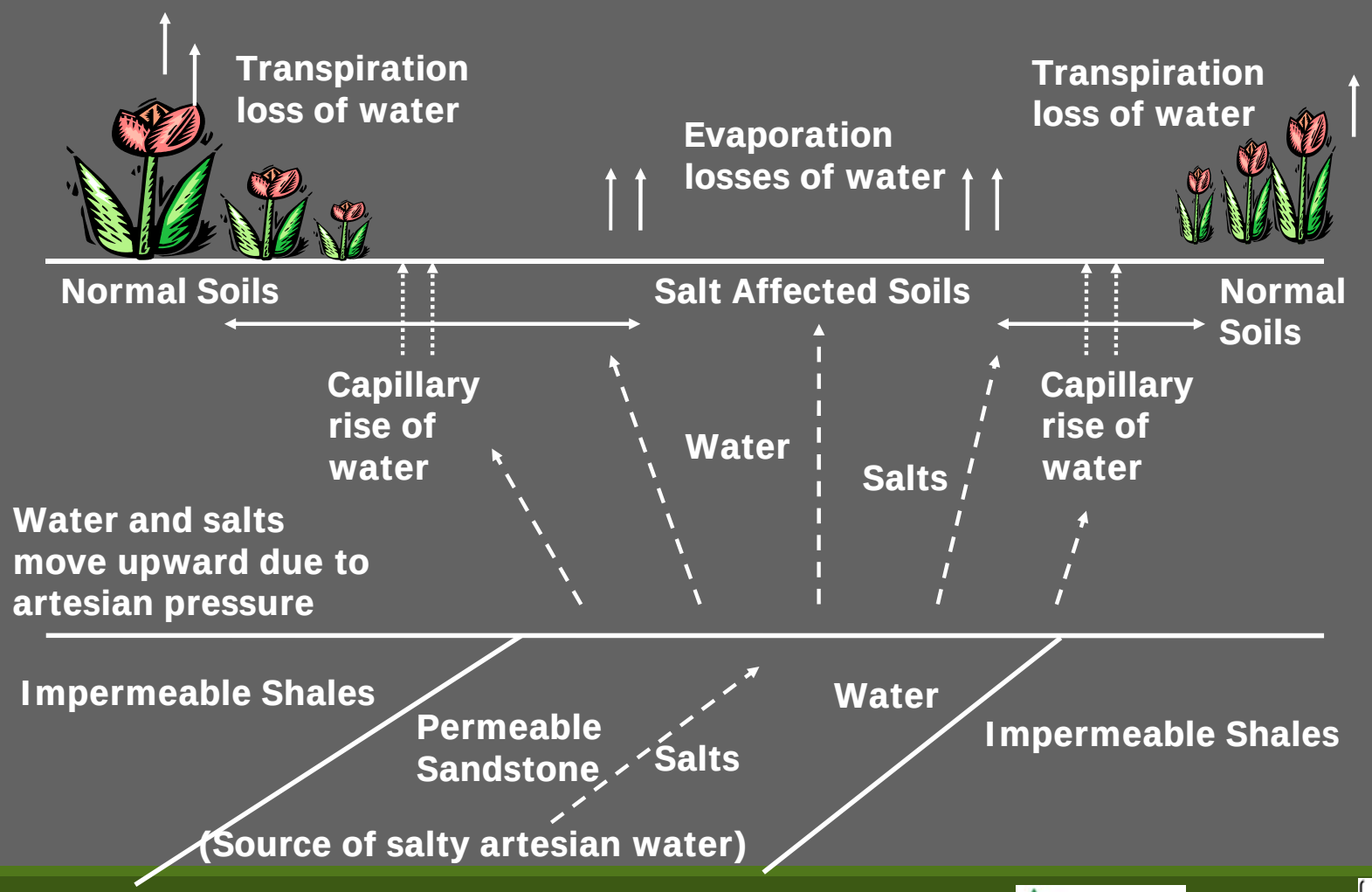
Glacial Lake Plain

Typical Eastern SD Soil

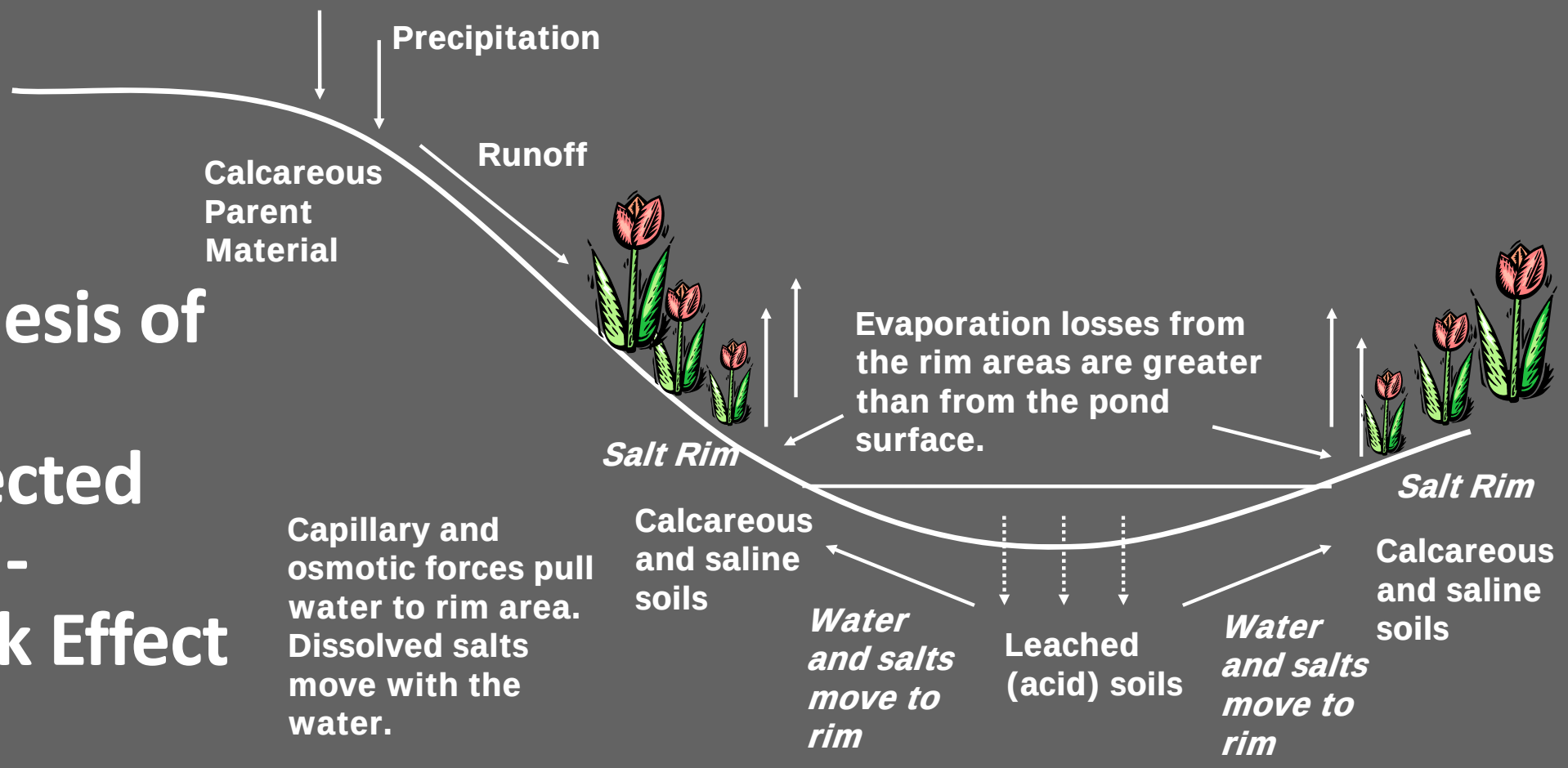
- Appearance
- Horizons
- Organic Matter distribution
- Salt location



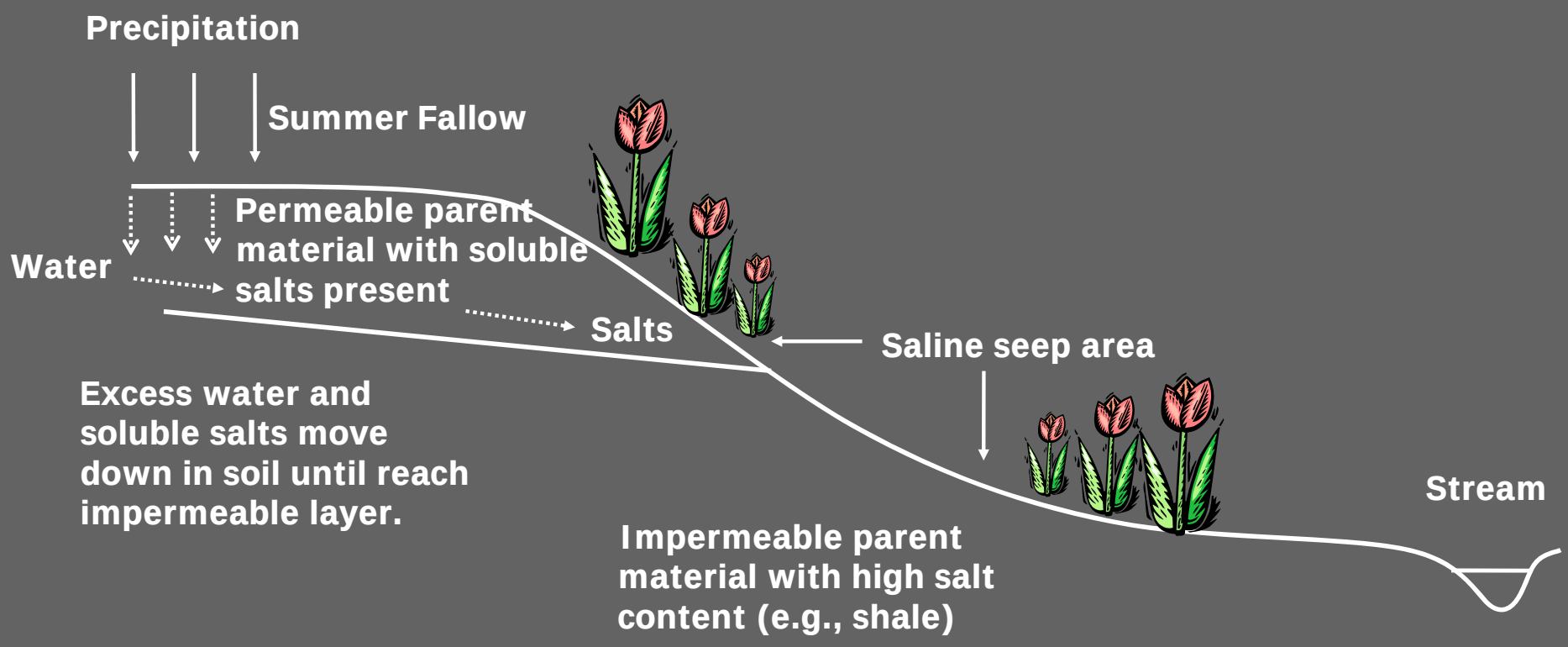
Genesis of Salt Affected Soils - Artesian Water



Genesis of Salt Affected Soil - Wick Effect



Genesis of Salt Affected Soils – Saline Seep



Development of Salt Sites in Fields

- 1. Abundance of precipitation in the 1980's and throughout the 2010's.
- 2. Water tables have risen bringing deep old geologic salt concentrations to the surface.

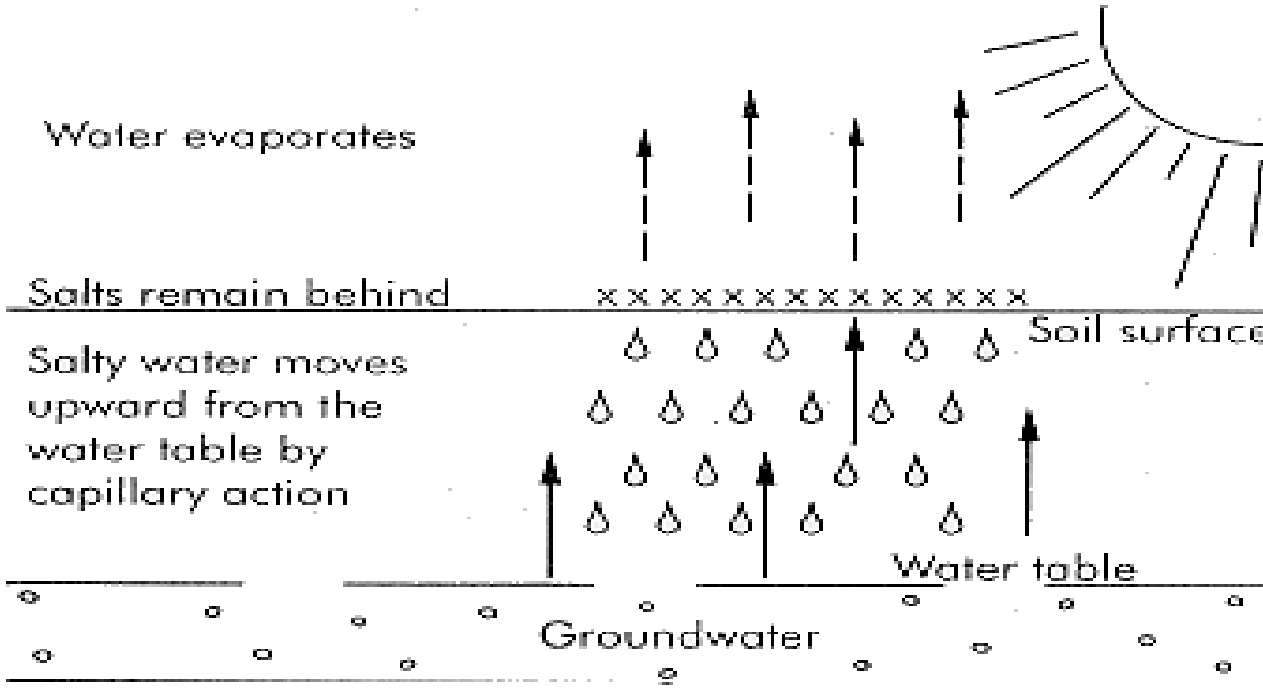


Figure 2. Salts build up by capillary action and evaporation.

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex167

High Water Table and Salts

- Saline = Calcium / Magnesium Salts → Plants will not grow

- Sodic = Sodium Salts → Plants will not grow and soil is dispersed.

- Commonality between saline and sodic problems is a high water table.

Source – Reese, 2015

Saline or Sodic?

- Note solubility
- Saline –

Calcium (Ca) or Magnesium (Mg) Salts (2+) dominate

- Sodic –

Sodium Salts (1+) dominate

Table 1. Composition and solubility of some common evaporite minerals (salts).

Mineral	Composition	Solubility (moles/liter)	Chemical Name
Calcite (lime)	$CaCO_3$	0.00014	Calcium Carbonate
Gypsum	$CaSO_4 \cdot 2H_2O$	0.0154	Calcium Sulfate
----	$CaCl_2 \cdot 6H_2O$	7.38	Calcium Chloride
Magnesite	$MgCO_3$	0.001	Magnesium Carbonate
Hexahydrite	$MgSO_4 \cdot 6H_2O$	4.15	Magnesium Sulfate
Epsomite	$MgSO_4 \cdot 7H_2O$	3.07	Magnesium Sulfate
Bischofite	$MgCl_2 \cdot 6H_2O$	5.84	Magnesium Chloride
(Washing soda)	$Na_2CO_3 \cdot 10H_2O$	2.77	Sodium Carbonate
(Baking soda)	$NaHCO_3$	1.22	Sodium Bicarbonate
Mirabilite	$Na_2SO_4 \cdot 10H_2O$	1.96	Sodium Sulfate
Thenardite	$NaSO_4$	3.45	Sodium Sulfate
Halite	NaCl	6.15	Sodium Chloride

Source – Reese, 2015

Saline Stress: Calcium (Ca) + Magnesium (Mg)

- Moderately high pH
- Drought like conditions

- Poor germination and growth
- Low nutrient availability

Sodic Stress: Sodium (Na)

- Dispersion
- High pH >8.4

- No water movement
  - Erosion
  - Root limitation

Source – Reese, 2015

Terms to Know

- **EC (Electrical Conductivity):**
  - Measurement of total salts, critical value is 4 dS/m
- **CEC (Cation Exchange Capacity):**
  - Soils' ability to hold positively charged cations
- **ESP (Exchangeable Sodium Percentage):**
  - Sodium (Na+) on soil exchange sites *(% Na+ compared to Ca^{2+} + Mg^{2+} on CEC)*
- *ESP > 5 = is considered sodic in SD (previously ESP >15)*
- **SAR (Sodium Adsorption Ratio):**
  - Measurement of the relative amount of sodium, when compared to total amount of salts *(from saturated extracts)*
- *Attention – SAR > 4 is considered sodic in SD! (previously > 13)*
- *NOTE ABOUT SAR: Not as commonly used as ESP because more difficult to do*

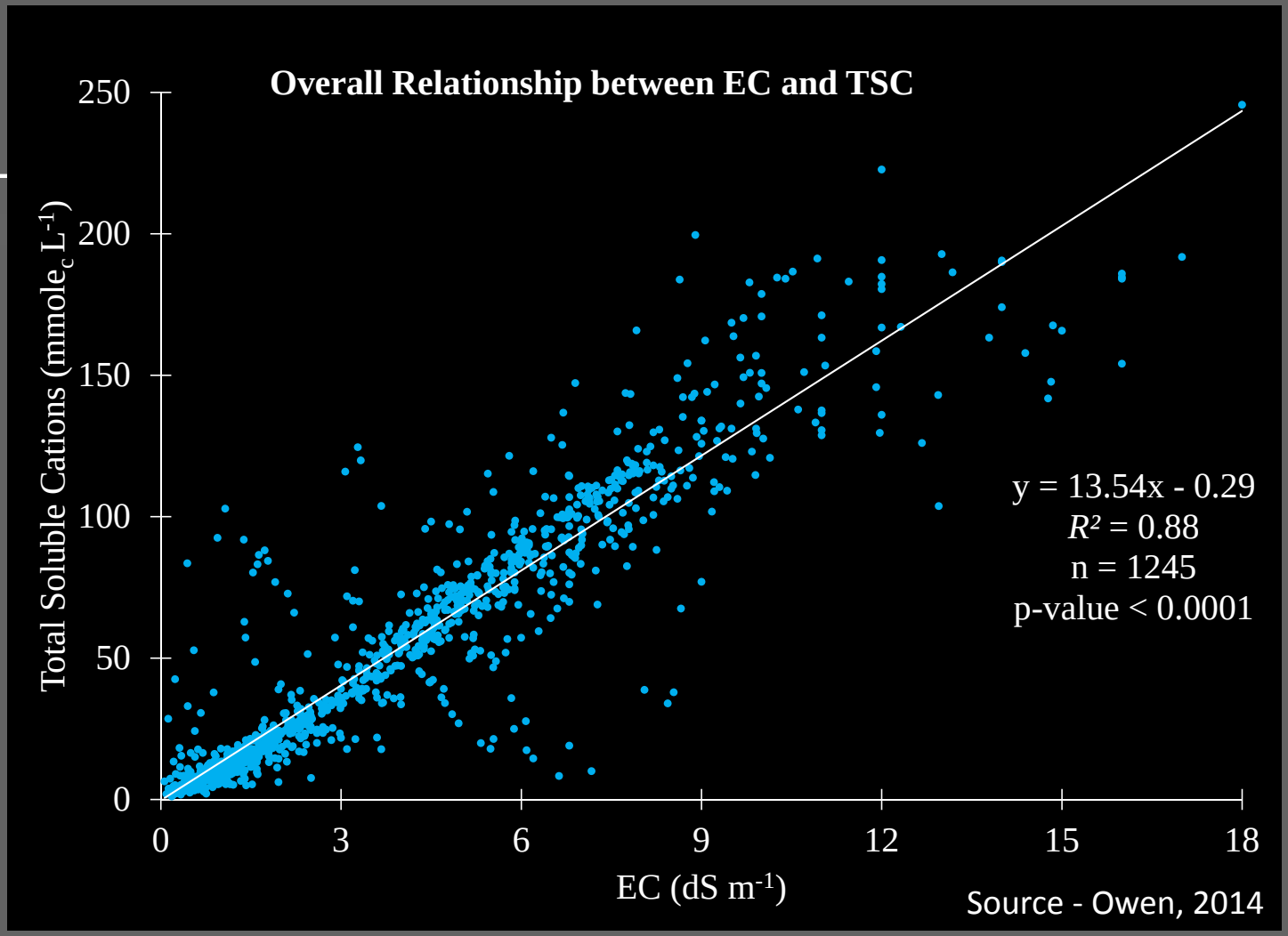
Source – Reese, 2015

Soil Testing Lab Survey

Testing Lab	Location	EC	Cation Concentration	Sodium Index
Iowa State University	Ames, IA	SP	NH_4OAc	SAR
North Dakota State University	Fargo, ND	1:1	NH_4OAc	SAR
University of Minnesota	St. Paul, MN	1:1	NH_4OAc	SAR
AgLab Express	Sioux Falls, SD	1:1	NH_4OAc	ESP
AgVise Laboratory	Northwood, ND	1:1	NH_4OAc	ESP
Minnesota Valley Testing Lab	New Ulm, MN	1:1	NH_4OAc	ESP
Ward Laboratories	Kearney, NE	1:1	NH_4OAc	ESP
ServiTech	Hastings, NE	1:1	NH_4OAc	SAR

Source - Owen, 2014

Results



Source - Owen, 2014

Results

Established a linear relationship between EC and TSC:

- **TSC = 13.5*EC**

Provides a simple way to relate EC to TSC and allows users to more efficiently assess salt-affected soils.

Allows users to calculate SAR using only EC and Na^+.

$$[(EC*13.5) - Na^+] = [Ca^{2+} + Mg^{2+}]$$

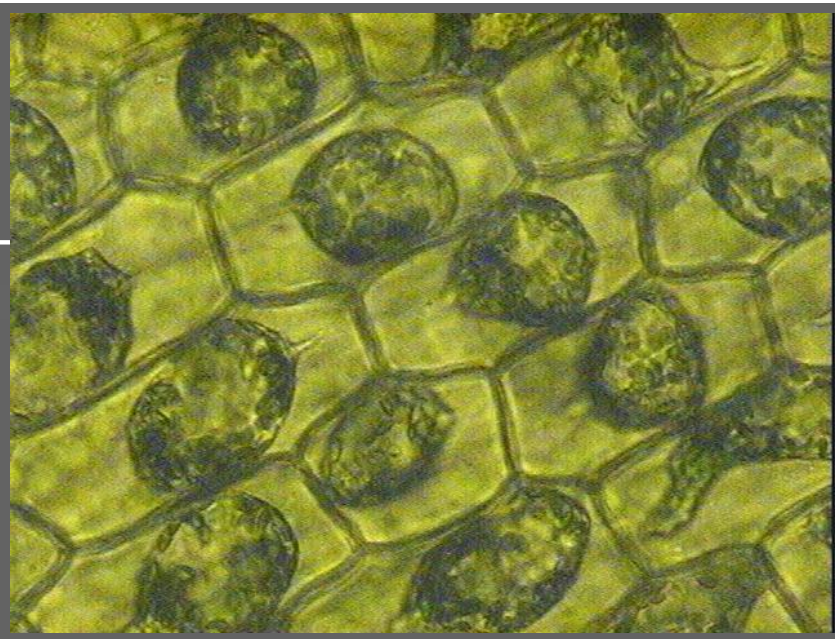
Source - Owen, 2014

Question to ask a soil testing lab

- How is sodium determined?
  - Saturated paste (SAR) or Ammonium Acetate Extraction (ESP)
- How was EC determined?
  - Saturated paste or 1:1 extract?
- Why is this important?
- Because the EC is used to estimate the total soluble cations (TSC).
- The TSC is required for the SAR calculation.

Source – Reese, 2015

Salt Affected Soil Classes

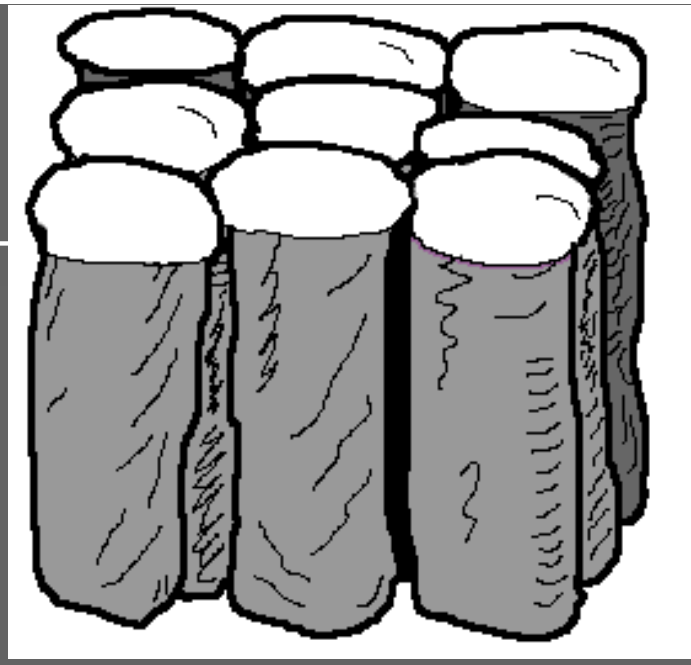


www-pub.naz.edu:9000/~bwwitz/ElodeaafterER.jpg

- Saline
  - pH<8.4
  - EC >4 mmhos cm^{-1}
  - SAR<13, ESP<15% (Arid)
  - SAR <4, ESP <5% (Midwest/Great Plains)*
  - Problem – excess soluble salts, reduce water/nutrient availability, plasmolysis, and osmotic forces

Salt Affected Soil Classes

- Sodic
  - pH>8.4
  - EC<4 mmhos cm^{-1}
  - SAR>13, ESP>15% (arid)
  - SAR >4, ESP >5% (Midwest/Great Plains)*
  - Problem is high pH due to excess sodium, soluble salts are low, dispersion, reduced air and water movement and reduced nutrient availability



Ltpwww.gsfc.nasa.gov/globe/pvg/columnar.gif

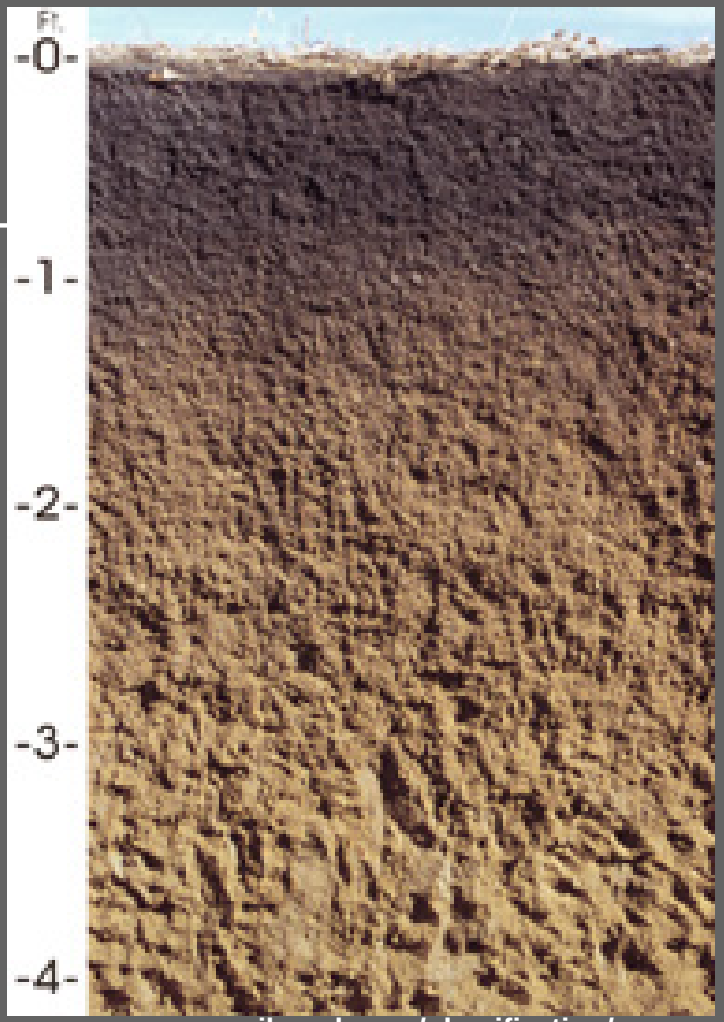
Salt Affected Soil Classes

- Saline-sodic
  - EC>4mmhos cm^{-1}
  - pH<8.4 (excess soluble salts keep pH low)
  - SAR>13, ESP>15% in arid areas
  - SAR >4, ESP >5% (Midwest/Great Plains)
  - Soil has both high soluble salts and sodium. Soil will become sodic if excess soluble salts are removed.

www.r5.fs.fed.us/ecoregions/ photos/cd1-031.jpg

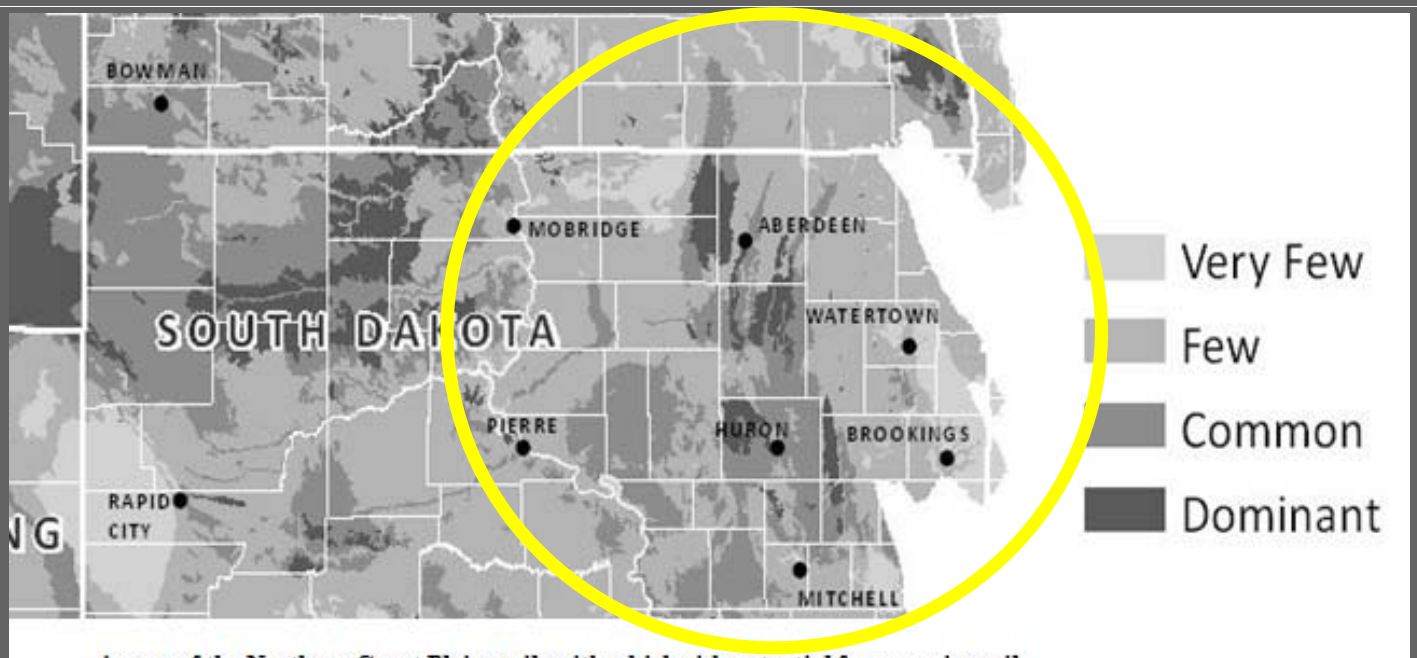
Salt Affected Soil Classes

- Normal
  - pH<8.4
  - EC<4 mmhos cm
  - SAR<13, ESP<15% (arid)
  - SAR <4, ESP <5% (Midwest/Great Plains)
  - No salt problems for most crop and other plants



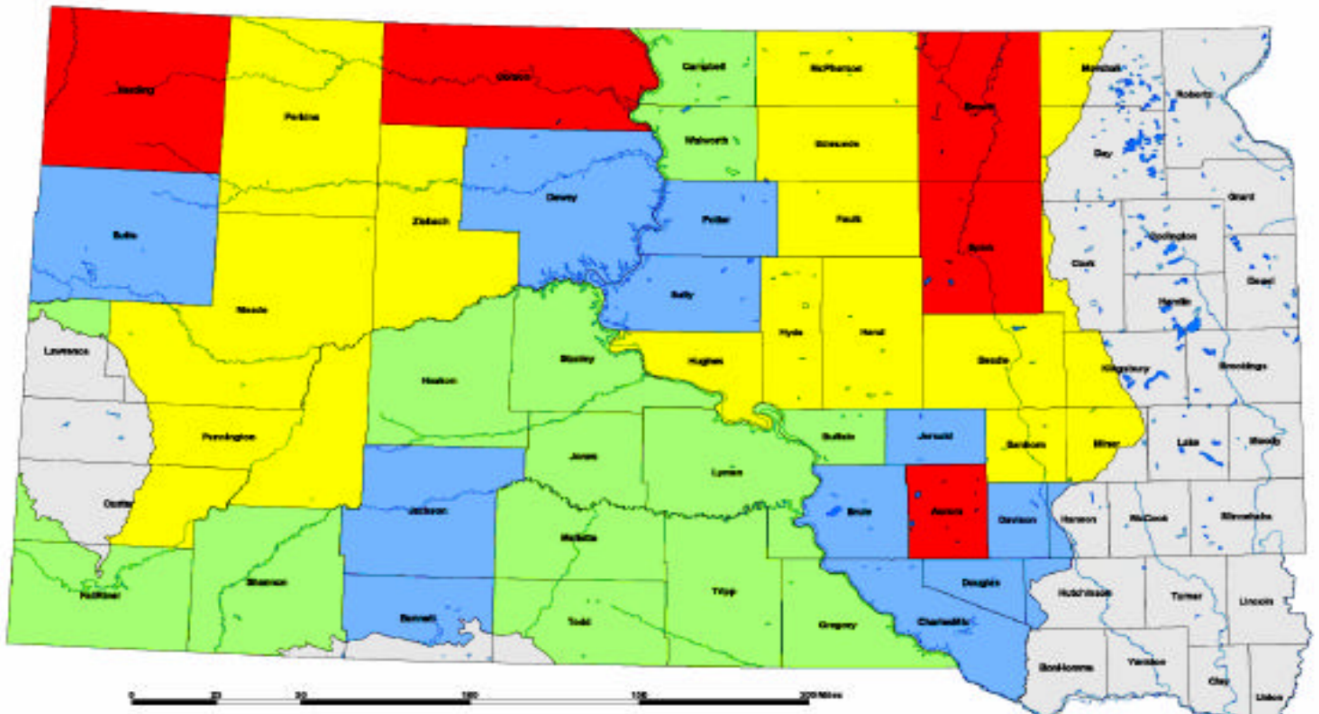
soils.usda.gov/classification/orders/images/mollisol.jpg

Extent of Salinity



A map of the Northern Great Plains soils with a high risk potential for excessive soil salinity. Soils with EC> 4 dS/m constitute the high risk areas. Source: http://www.soilsci.ndsu.nodak.edu/DeSutter/TomDeSutter.html

Extent of Sodicity



Map: Jim Millar

http://www.sdnotill.com/Newsletters/2003_Salt_Soils.pdf

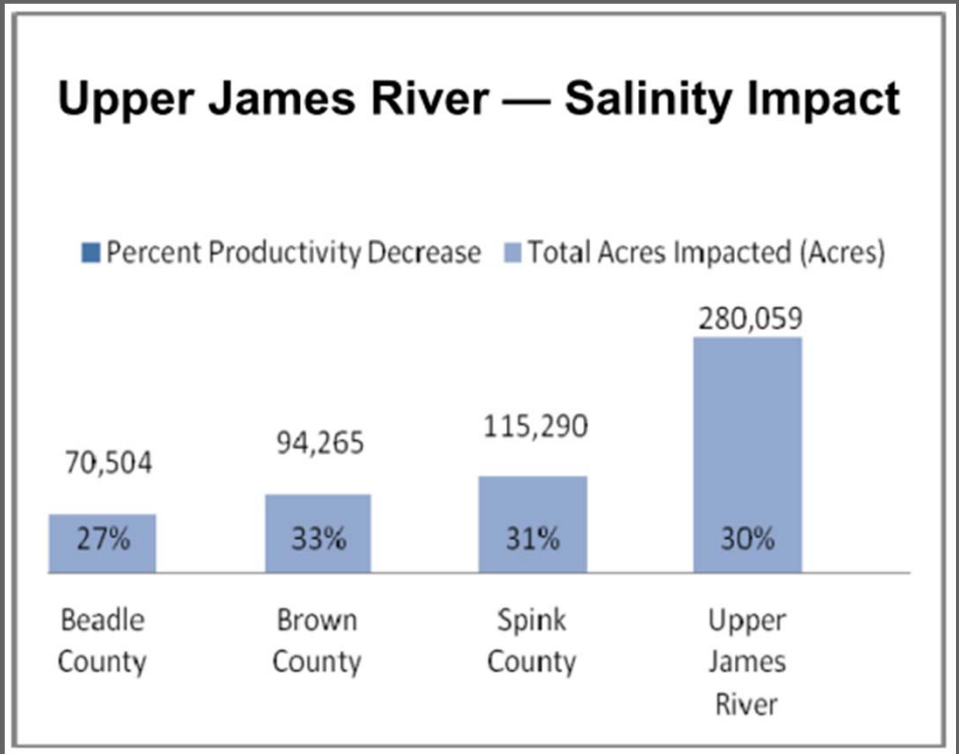
20-30 %

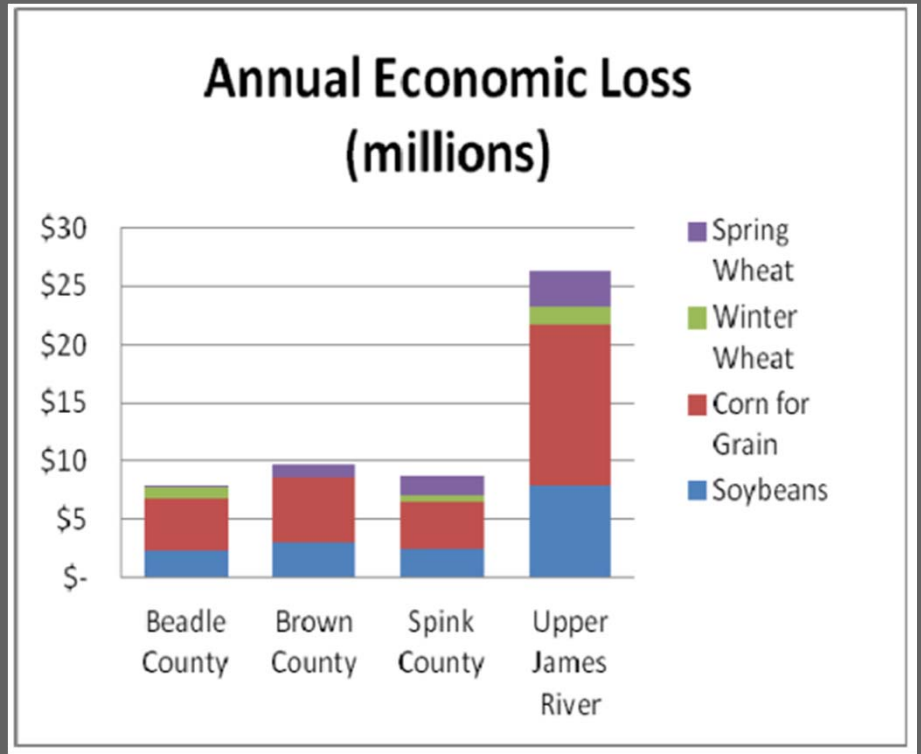
10-20 %

5-10%

1-5%

Economic Impact





Source - NRCS 2012

Summary

- Discussed how saline/sodic soils form
- Causes for increased areas of saline/sodic soils
- Basic properties of saline/sodic soils
- Basic soil properties measured to classify and identify saline/sodic soils

Funding Acknowledgements / Cooperators

- Natural Resources Conservation Service - United States Department of Agriculture (NRCS-USDA)
  - Conservation Innovation Grant (CIG Grant)
- SD Corn Utilization Council
- SD Soybean Research and Promotion Council
- South Dakota State University

- <u>Cooperators</u>
- Greg Tople, Pierpont, SD
- Roger Rix, Grant Rix, Andover, South Dakota
- Jim Millar, Kenny Sehlman, Jerry West, Redfield, SD
- David Gillen, White Lake, SD

Questions?