SALINITY AND SODIC SOIL MANAGEMENT

(Act.)

CODE 610

Definition

Reducing or redistributing the harmful concentrations of salt in a soil (sometimes referred to as leaching).

Purpose

To permit desirable plants to grow.

Conditions Where Practice Applies

On land where the accumulation of salt at or near the surface limits the growth of desirable plants.

Planning Considerations

A. Adequate drainage both surface and subsurface must be installed if salt reduction is to be effective.

B. Obtain information on:
   1. Kind and quantity of salts present (percent salt or electrical conductivity in millimhos/cubic meter).
   2. Quality of irrigation water available.
   3. Presence or absence of calcium carbonate or gypsum.
   4. Availability and cost of soil amendments (gypsum, sulfur and calcium).
   5. Depth to water table.
   6. Drainage feasibility.
   7. Crops to be grown and their salt tolerances.

C. Do not expect immediate results from amendments.
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D. Soil tests provided by some soil testing laboratories can be used to identify salinity and sodic problems. Either SAR (sodium adsorption ratio) or ESP (exchangeable sodium percentage) can be used to identify a sodic soil. These tests, however, can be misleading. The ESP can be grossly inaccurate if CEC (cation exchange capacity) is obtained by summation of extractable cations as most labs do which regularly report CEC. SAR values may underestimate the sodic problem on soils with a very high salt content (EC$_s$ > 16 mmhos).

The degree of salinity is usually estimated by determining the electrical conductivity of a saturated soil extract (EC$_s$). The SAR should also be determined on this extract.

<table>
<thead>
<tr>
<th>Conductivity in mmhos.</th>
<th>Salinity</th>
<th>Sodic or Alkali Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>Non-saline soil</td>
<td>None</td>
</tr>
<tr>
<td>2-4</td>
<td>Yield reduction of salt sensitive crops</td>
<td>None</td>
</tr>
<tr>
<td>4-8</td>
<td>Moderately salt tolerant crops show yield loss</td>
<td>Dispersion possible</td>
</tr>
<tr>
<td>8-16</td>
<td>Only salt-tolerant crops will grow</td>
<td>Dispersion highly possible if salt content is low</td>
</tr>
<tr>
<td>&gt; 16</td>
<td>Few if any plants grow</td>
<td></td>
</tr>
</tbody>
</table>

**Soil Test Interpretation**

**Sampling**

Generally it is advisable to collect separate samples for saline-alkali soil tests, rather than to run them on regular fertility samples. Two samples should be made up of at least 5 cores from the problem spot to average out the wide variability common to saline or sodic soils. Request the saline-alkali soil test.

E. **Alkali Soils** -- To reclaim sodic (alkali) soils an amendment must be added that will provide large amounts of soluble calcium in the soil. It must furnish enough to replace the sodium on the clay fraction of the soil. If the soil is calcareous (contains excess lime), elemental sulfur or sulfuric acid can be applied which will dissolve part of the lime to form gypsum (calcium sulfate) which is much more soluble than the lime. Gypsum should be used if the soil is not calcareous. Gypsum can also be applied to calcareous soils, but is not always as effective as elemental sulfur. Either treatment may require several seasons for benefits to occur.

Once the sodium is replaced it must be leached below the root zone. Hard waters used for irrigation also have a beneficial effect on sodic soils.

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Specifications

A. Reclamation of saline soils 1/

1. Improve both surface and subsurface drainage to lower the permanent water table to at least 4 feet below the soil surface.

2. Leach soil with a minimum of 6 inches of water. Where irrigation water is available, establish levees to impound water for leaching purposes. Keep surface flooded until several feet of water have passed through the soil. The amount of water for leaching will depend on the degree of salinity. Six inches of water for every foot of root zone will leach out 50 percent of the salt. One foot will leach out 80 percent and two feet of water per foot of root zone soil will leach out 90 percent of the salt.

3. Reduce evaporation and improve soil percolation. Crop residues, hay, straw or other organic materials should be incorporated into the surface to reduce evaporation and keep the soil open for percolation of water.

4. First year after reclamation grow salt tolerant crops (See Table 2.)

B. Reclamation of sodic soils (alkali) or saline-sodic soils

1. Install drainage or improve both surface and subsurface drainage to lower the permanent water table to at least 4 feet below the soil surface.

2. Leach the soil to remove the sodium. Leaching must be done 2 to 3 months after amendments are applied. See reclamation of saline soils for leaching techniques (paragraphs A.1, A.2 and A.3).

3. Supply sufficient amendment to remove most of the adsorbed sodium from the top 6 to 12 inches of soil. Refer to Table 4 for amounts to apply per acre.


Gypsum, calcium chloride, sulfuric acid, iron and aluminum sulfates are broadcast directly to the soil surface. Material should be incorporated into the soil surface by plowing or disking.

5. Agronomic and management practices for soil improvement.

a. Grow crops that are most tolerant to exchangeable sodium percentage (ESP). (See Table 1.)
<table>
<thead>
<tr>
<th>Tolerance to ESP 1/ and range at which affected</th>
<th>Crop</th>
<th>Growth response under field conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely sensitive (ESP = 2-10)</td>
<td>Deciduous fruits</td>
<td>Sodium toxicity symptoms even at low ESP values.</td>
</tr>
<tr>
<td></td>
<td>Nuts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>citrus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Avocado</td>
<td></td>
</tr>
<tr>
<td>Sensitive (ESP = 10-20)</td>
<td>Beans</td>
<td>Stunted growth at low ESP values even though the physical conditions of the soil may be good</td>
</tr>
<tr>
<td>Moderately tolerant (ESP = 20-40)</td>
<td>Clover</td>
<td>Stunted growth due to both nutritional factors and adverse soil conditions</td>
</tr>
<tr>
<td></td>
<td>Oats</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tall Fescue</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rice</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dallisgrass</td>
<td></td>
</tr>
<tr>
<td>Tolerant (ESP = 40-60)</td>
<td>Wheat</td>
<td>Stunted growth usually due to adverse physical condition of soil</td>
</tr>
<tr>
<td></td>
<td>Cotton</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alfalfa</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Barley</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tomatoes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Beets</td>
<td></td>
</tr>
<tr>
<td>Most Tolerant (ESP = more than 60)</td>
<td>Crested wheatgrass</td>
<td>Stunted growth usually due to adverse physical condition of soil</td>
</tr>
<tr>
<td></td>
<td>Fairway wheatgrass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tall wheatgrass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rhodes grass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shoshone beardless wildrye</td>
<td></td>
</tr>
</tbody>
</table>

1/ ESP exchanges-sodium-percentage.

b. Maintain crop residue on the soil surface at all times. Use a conservation tillage system of crop production.

c. Plant sordan a sorghum-sudangrass hybrid. Sordan is used for livestock forage and helps dissolve lime or calcium carbonate in the soil which replaces the unwanted sodium attached to the clay particle.

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REFERENCES


USDA. 1954. Diagnosis and Improvement of Saline and Alkali Soils. Agriculture Handbook No. 60. Washington, DC.

NE-T.G. Notice 577
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### Table 2. General Salt Tolerance Ratings of Various Crops 1/ (Salinity)

<table>
<thead>
<tr>
<th>Sensitive 2/</th>
<th>Moderately tolerant</th>
<th>Tolerant</th>
<th>Very tolerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC x 10³</td>
<td>EC x 10³</td>
<td>EC x 10³</td>
<td>EC x 10³</td>
</tr>
<tr>
<td>2.0 - 4.0</td>
<td>4.0 - 6.0</td>
<td>6.0 - 8.0</td>
<td>8.0 - 12.0</td>
</tr>
</tbody>
</table>

#### FIELD CROPS

- **Field Beans**
- **Potatoes**
- **Soybeans**
- **Castorbean**
- **Wheat (grain)**
- **Barley (grain)**
- **Sesbania (seed)**
- **oats (grain)**
- **Sunflower**
- **Sugar Beet**
- **Corn (field)**
- **Rice (grain)**
- **Cotton**
- **Cotton**
- **Flax**
- **Sunflower**
- **Rape**
- **Guar**
- **Sorghum (grain)**

#### FORAGE CROPS

- **White Dutch Clover**
- **Reed Canarygrass**
- **Hardinggrass**
- **Rosana west wheatsrass**
- **Alskie Clover**
- **Oats (hay)**
- **Kleingrass**
- **Wheatgrass (tall)**
- **Red Clover**
- **Orchardgrass**
- **Buffelgrass**
- **Barley (hay)**
- **Ladino Clover**
- **Brome grasses**
- **Alfalfa**
- **Rye (hay)**
- **Crimson Clover**
- **Big Trefoil**
- **Birdsfoot Trefoil**
- **Panic-grass**
- **Burnet**
- **Grama Grasses**
- **Hubam Clover**
- **Alkali sacaton**
- **Meadow Foxtail**
- **Sour Clover**
- **Dallisgrass**
- **Rhodesgrass**
- **Corn (forage)**
- **Milk Vetch**
- **Tall Fesque**
- **Saltgrass**
- **Timothy**
- **White Sweet Clover**
- **Shoshone beardless wildrye**
- **Sudan-Sorghum Hybrids**
- **Yellow Sweet Clover**
- **Perennial Rye Grass**
- **Johnsonarass (hay)**
- **Sorghum (forage)**
- **Wheat (hay)**
- **Sorghum (forage)**
- **Cree ping Foxtail**
- **Sorghang sudangrass (sordan)**
General Salt Tolerance Ratings of Various Crops (Salinity)

<table>
<thead>
<tr>
<th>Sensitive 2/</th>
<th>Moderately tolerant 2/</th>
<th>Tolerant 2/</th>
<th>Very tolerant 2/</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC x 10^3</td>
<td>EC x 10^3</td>
<td>EC x 10^3</td>
<td>EC x 10^3</td>
</tr>
<tr>
<td>2.0 - 4.0</td>
<td>4.0 - 6.0</td>
<td>6.0 - 8.0</td>
<td>8.0 - 12.0</td>
</tr>
</tbody>
</table>

**VEGETABLE CROPS**

- Carrot
- English Pea
- Radish
- Celery
- Green Bean
- Lima Bean
- Kidney Bean
- Cucumber
- Rhubarb

- Lettuce
- Corn (sweet)
- Potato
- Squash
- Onion
- Sweet Potato
- Yam
- Bell Pepper
- Hot Pepper
- Blackeye Pea
- Muskmelon

- Tomato
- Beet
- Kale
- Spinach
- Broccoli
- Cabbage
- Cauliflower
- Watermelon

**FRUIT, NUT AND VINE CROPS**

- Grapefruit
- Orange
- Lemon
- Avocado
- Pear
- Apple
- Cherry
- Plum
- Walnut
- Blackberry
- Raspberry
- Strawberry
- Boysenberry

- Pecan
- Peach
- Apricot
- Grape
- Quince

- Pomegranate
- Date Palm
- Fig
- Olive
Table 2 Cont.
General Salt Tolerance Ratings of Various Crops 1/ (Salinity)

<table>
<thead>
<tr>
<th>Sensitive 2/</th>
<th>Moderately 2/</th>
<th>Tolerant 2/</th>
<th>Very tolerant 2/</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC x 10^3</td>
<td>EC x 10^3</td>
<td>EC x 10^3</td>
<td>EC x 10^3</td>
</tr>
<tr>
<td>2.0 - 4.0</td>
<td>4.0 - 6.0</td>
<td>6.0 - 8.0</td>
<td>8.0 - 12.0</td>
</tr>
</tbody>
</table>

**ORNAMENTAL SHRUBS**

- Viburnum
- Spreading Juniper
- Arbor Vitae
- Lantana
- Pyracantha
- Privet
- Japonica

Source of Table: Control of Soluble Salts in Farming and Gardening by D.E. Longenecker and P.J. Lyerly

1/ Data taken from many sources but primarily from publications of the U.S. Salinity Laboratory, Riverside, California (Ratings assume use of reasonably good production practices as suggested in section Salinity Control As Affected by Management.)

2/ Electrical conductivity (EC x 10^3) values listed at tops of columns are values of soil saturation extracts at which some reduction in growth and yields can be expected.

3/ Ratings may vary somewhat depending upon the particular rootstock used for propagation.
TABLE 3. The relative effectiveness of various chemical amendments in supplying calcium.

<table>
<thead>
<tr>
<th>Amendment</th>
<th>Chemical Composition</th>
<th>Physical Description</th>
<th>Solubility in water Equivalent to 100% gypsum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gypsum</td>
<td>CaSO₄·2H₂O</td>
<td>white mineral</td>
<td>2</td>
</tr>
<tr>
<td>Sulfur</td>
<td>S</td>
<td>yellow powder</td>
<td>0</td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>H₂SO₄</td>
<td>corrosive liquid</td>
<td>very high</td>
</tr>
<tr>
<td>Lime sulfur</td>
<td>9% Ca + 24% S</td>
<td>yellow-brown alkaline liquid</td>
<td>very high</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>CaCO₃</td>
<td>white mineral</td>
<td>.02 to 1.0*</td>
</tr>
<tr>
<td>Calcium chloride</td>
<td>CaCl₂·2H₂O</td>
<td>white salt</td>
<td>120</td>
</tr>
<tr>
<td>Calcium nitrate</td>
<td>Ca(NO₃)₂·2H₂O</td>
<td>white fertilizer</td>
<td>60</td>
</tr>
<tr>
<td>Iron sulfate</td>
<td>FeSO₄·7H₂O</td>
<td>corrosive granular material</td>
<td>30</td>
</tr>
<tr>
<td>Ferric sulfate</td>
<td>Fe₂(SO₄)₃·9H₂O</td>
<td>corrosive granular material</td>
<td>0.61</td>
</tr>
<tr>
<td>Aluminum sulfate</td>
<td>Al₂(SO₄)₃·18H₂O</td>
<td>corrosive granular material</td>
<td></td>
</tr>
</tbody>
</table>

* Solubility of CaCO₃ is pH-dependent. Solubility varies from 0.02 to 1.0 g/1 as the pH decreases from 10 to 6.
## TABLE 4.

<table>
<thead>
<tr>
<th>ESP</th>
<th>SAR</th>
<th>Exchangeable sodium (Meg. per 100 gm. of soil)</th>
<th>Gypsum 1/ CaSO₄·2H₂O</th>
<th>Gypsum 1/ CaSO₄·2H₂O</th>
<th>Sulfur</th>
<th>Sulfur</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tons/acre foot ²/</td>
<td>Tons/acre foot ³/</td>
<td>Tons/acre foot ²/</td>
<td>Tons/acre foot ³/</td>
</tr>
<tr>
<td>7 - 11</td>
<td>6 - 9</td>
<td>1</td>
<td>1.7</td>
<td>0.9</td>
<td>0.32</td>
<td>0.16</td>
</tr>
<tr>
<td>11 - 15</td>
<td>9 - 12</td>
<td>2</td>
<td>3.4</td>
<td>1.7</td>
<td>0.64</td>
<td>0.32</td>
</tr>
<tr>
<td>&gt; 15</td>
<td>&gt; 12</td>
<td>3</td>
<td>5.2</td>
<td>2.6</td>
<td>0.96</td>
<td>0.48</td>
</tr>
</tbody>
</table>

1/ The amounts of gypsum are given to the nearest 0.1 ton.
2/ 1 acre-foot of soil weighs approximately 4,000,000 pounds.
3/ 1 acre-6 inches of soil weighs approximately 2,000,000 pounds.

> = Greater than

Example: Soil test for a sodic or alkali soil 0-12 inches; had a sodium absorption ration (SAR) of 12. By referring to Table 4 which relates tons of gypsum and sulfur per acre-foot of soil to milliequivalents of sodium per 100 grams of soil, it is found that 3.4 tons gypsum or 0.64 tons of sulfur are required.

### Amendment:

<table>
<thead>
<tr>
<th>Amendment</th>
<th>Tons equivalent to 1 ton of sulfur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur</td>
<td>1.00</td>
</tr>
<tr>
<td>Lime-sulfur solution, 24 percent sulfur</td>
<td>4.17</td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>3.06</td>
</tr>
<tr>
<td>Gypsum (CaSO₄·2H₂O)</td>
<td>5.38</td>
</tr>
<tr>
<td>Iron sulfate (FeSO₄·7H₂O)</td>
<td>8.69</td>
</tr>
<tr>
<td>Aluminum sulfate (Al₂(SO₄)₃·18H₂O)</td>
<td>6.94</td>
</tr>
<tr>
<td>Limestone (CaCO₃)</td>
<td>3.13</td>
</tr>
<tr>
<td>Criteria</td>
<td>Normal</td>
</tr>
<tr>
<td>--------------</td>
<td>--------</td>
</tr>
<tr>
<td>EC, mmho/cm</td>
<td>&lt; 4</td>
</tr>
<tr>
<td>SAR</td>
<td>&lt; 11</td>
</tr>
<tr>
<td>pH</td>
<td>&lt; 8.4</td>
</tr>
</tbody>
</table>

< Less than  
> Greater than
GLOSSARY

EC - Electrical conductivity
A method of expressing salinity. The EC values are proportional to salt concentration in the soil solution and are usually expressed in units of millimhos per centimeter at 250°C.

ECa - Apparent electrical conductivity
A term used to express soil salinity as measured by the four-electrode resistivity or inductive electro-magnetic methods. The values are generally expressed millimhos per centimeter at 25°C.

Ece - Electrical conductivity of the saturation extract at 25°C in millimhos per centimeter.

ECs - The degree of salinity is usually estimated by determining the electrical conductivity of a saturated soil extract.

ESP - Exchangeable sodium percent

ESR - Exchangeable sodium ratio

Flexible cropping -
A nonsystematic rotation of fallow and growing adaptable crops in a sequence. Decisions to crop or fallow are based on available soil water and expected growing season precipitation at prospective date of planting a crop.

Saline soils -
Greater than 4 mmhos/cm. They are generally flacculated; that is, the soil particles are grouped together in clumps. (Table 5.)

Sodic soils -
Soil that have appreciable amounts of sodium adsorbed on their individual particles. (Table 5.)

REFERENCES:
Delmo Knudsen, Extension Soil Specialist
Agricultural Handbook No. 60
Water Quality For Agriculture No. 29
R.J. Prather, J.O. Goertzen, J.D. Rhoades, H. Frenkleet