NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

SALINITY AND SODIC SOIL MANAGEMENT

(Ac.)

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.

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 (ECs). The SAR should also be determined on this extract.

Soil Test Interpretation

Salinity		Sodic or Alkali			
				Problems	
Conductivity in mmhos.	Interpretation	ESP	SAR	Sandy	Non-Sandy
0-2	Non-saline soil	0-7	0-6	None	None
2-4	Yield reduction of salt sensitive crops	7-11	6-9	None	Some permeability problem
4-8	Moderately salt tolerant crops show yield loss	11-15	9-12	Dispersion possible	
8-16	Only salt-tolerant crops will grow	> 15	> 12	Dispersion highly possible if salt content is low	
> 16	Few if any plants grow				

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.

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.

4. Application of soil amendments.

   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.

1/ Soils that contain excessive soluble salts EC greater than 4 mmho/cm.

5. Agronomic and management practices for soil improvement.

   a. Grow crops that are most tolerant to exchangeable sodium percentage (ESP). (See Table 1.)

TABLE 1.

Tolerance of various crops to exchangeable sodium percentage

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

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.

REFERENCES

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USDA, Soil Conservation Service. 1993. National Engineering Handbook (NEH), Part 623, Chapter 2- Irrigation Water Requirements. Washington, D.C.

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

Table 2.
General Salt Tolerance Ratings of Various Crops 1/ (Salinity)

Sensitive 2/	Moderately tolerant	Tolerant	Very tolerant
EC x 10^3 2.0 - 4.0	EC x 10^3 4.0 - 6.0	EC x 10^3 6.0 - 8.0	EC x 10^3 8.0 - 12.0
		FIELD CROPS	
Field Beans	Soybeans	Wheat (grain)	Barley (grain)
Potatoes	Castorbean	oats (grain)	Rye (grain)
	Sesbania (seed)	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
Alsike Clover	Oats (hay)	Kleingrass	Wheatgrass (tall)
Red Clover	Orchardgrass	Buffelgrass	Barley (hay)
Ladino Clover	Bromegrasses	Alfalfa	Rye (hay)
Crimson Clover	Big Trefoil	Birdsfoot Trefoil	Panic-grass
Burnet	Grama Grasses	Hubam Clover	Alkali sacaton
Meadow Foxtail	Sour Clover	Dallisgrass	Rhodesgrass
	Milk Vetch	Tall Fesque	Saltgrass
	Timothy	White Sweet Clover	Shoshone beardless wildrye
	Sudan-Sorghum Hybrids	Yellow Sweet Clover	
	Sorghum (forage)	Perennial Rye Grass	
	Corn (forage)	Wheat (hay)	
	Creeping Foxtail	Johnsonarass (hay)	
		Sorghan sudangrass (sordan)	

Table 2. Cont.

General Salt Tolerance Ratings of Various Crops 1/ (Salinity)

Sensitive 2/	Moderately 2/ tolerant	Tolerant 2/	Very tolerant 2/
EC x 10^3 2.0 - 4.0	EC x 10^3 4.0 - 6.0	EC x 10^3 6.0 - 8.0	EC x 10^3 8.0 - 12.0
	VEGETABLE CROPS		
Carrot	Lettuce	Tomato	Asparagus
English Pea	Corn (sweet)	Beet	
Radish	Potato	Kale	
Celery	Squash	Spinach	
Green Bean	Onion	Broccoli	
Lima Bean	Sweet Potato	Cabbage	
Kidney Bean	Yam	Cauliflower	
Cucumber	Bell Pepper	Watermelon	
Rhubarb	Hot Pepper		
	Blackeye Pea		
	Muskmelon		
	FRUIT, NUT AND VINE CROPS 3/		
Grapefruit	Pecan	Pomegranate	Date Palm
Orange	Peach	Fig	
Lemon	Apricot	Olive	
Avocado	Grape		
Pear	Quince		
Apple			
Cherry			
Plum			
Walnut			
Blackberry			
Raspberry			
Strawberry			
Boysenberry			

Table 2 Cont.
General Salt Tolerance Ratings of Various Crops 1/ (Salinity)

Sensitive 2/	Moderately 2/ tolerant	Tolerant 2/	Very tolerant 2/
EC x 10^3 2.0 - 4.0	EC x 10^3 4.0 - 6.0	EC x 10^3 6.0 - 8.0	EC x 10^3 8.0 - 12.0
	ORNAMENTAL SHRUBS		
Viburnum	Spreading Juniper Arbor Vitae Lantana Pyracantha Privet Japonica	Oleander Bottlebrush	Purple Sage

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 productior 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.

Amendment	Chemical Composition	Physical Description	Solubility in water g/l	Amount Equivalent to 100% gypsum
Gypsum	$CaSO_4 \cdot 2H_2O$	white mineral	2	1.00
Sulfur	S	yellow powder	0	0.19
Sulfuric Acid	H_2SO_4	corrosive liquid	very high	0.61
Lime sulfur	9% Ca + 24% S	yellow-brown alkaline liquid	very high	0.78
Calcium carbonate	$CaCO_3$	white mineral	.02 to 1.0*	0.58
Calcium chloride	$CaCl_2 \cdot 2H_2O$	white salt	120	0.86
Calcium nitrate	$Ca(NO_3)_2 \cdot 2H_2O$	white fertilizer	60	1.06
Iron sulfate	$FeSO_4 \cdot 7H_2O$	corrosive granular material	30	1.62
Ferric sulfate	$Fe_2(SO_4)_3 \cdot 9H2O$	corrosive granular material		0.61
Aluminum sulfate	$Al_2(SO_4)_3 \cdot 18H2O$	corrosive granular material		

* Solubility of $CaCO_3$ is pH-dependent. Solubility varies from 0.02 to 1.0 g/1 as the pH decreases from 10 to 6.

TABLE 4.
Amount of gypsum and sulfur required to replace indicated amounts of exchangeable sodium

ESP	SAR	Exchangeable sodium (Meg. per 100 gm. of soil)	Gypsum 1/ $CaSO_4 \cdot 2H_2O$	Gypsum 1/ $CaSO_4 \cdot 2H_2O$	Sulfur S	Sulfur S
			Tons/acre foot 2/	Tons/acre foot 3/	Tons/acre foot 2/	Tons/acre foot 3/
7 - 11	6 - 9	1	1.7	0.9	0.32	0.16
11 - 15	9 - 12	2	3.4	1.7	0.64	0.32
> 15	> 12	3	5.2	2.6	0.96	0.48

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-6inches 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:	Tons equivalent to 1 ton of sulfur
Sulfur	1.00
Lime-sulfur solution, 24 percent sulfur	4.17
Sulfuric acid	3.06
Gypsum ($CaSO_4 \cdot 2H_2O$)	5.38
Iron sulfate ($FeSO_4 \cdot 7H_2O$)	8.69
Aluminum sulfate ($Al_2(SO_4)_3 \cdot 18H_2O$)	6.94
Limestone ($CaCO_3$)	3.13

TABLE 5.
Criteria and Standards for Classifying Salt-Affected Soils

	Soil condition (standards with reference to saturation extracts)			
Criteria	Normal	Saline	Sodic	Saline-sodic
EC, mmho/cm	< 4	> 4	< 4	> 4
SAR	< 11	< 13	> 13	> 13
pH	< 8.4	< 8.4	> 8.4	< 8.4

< 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 250C.

EC_a - 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.

EC_s - 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:

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