TECHNICAL NOTE

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SALINE AND SODIC SOIL MANAGEMENT

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INTRODUCTION

Soil salinity, in South Dakota (SD), can be depicted with naturally occurring saline, saline/sodic or sodic soils. In addition to these soils, other areas of fields, pastures, or grazed range have artificially undergone salinization due to improper management. These artificially induced or accelerated capillary seeps and saline seeps increased in number and extent in the 1990's to the point where many of these areas went from the classic indicator vegetation of kochia and foxtail barley to no longer supporting vegetation.

The salts most commonly found in concentrations that affect crop growth are sodium sulfate (Na_2SO_4), calcium sulfate (gypsum, $CaSO_4$), magnesium sulfate (epsom salts, $MgSO_4$), sodium chloride (NaCl), calcium, and magnesium chloride. South Dakota's saline soils are usually a mixture of salts, with sulfates being the most dominant form.

Saline soils develop where the evaporation exceeds the growing season rainfall and local landscape features accumulate seasonal runoff to form a water table which at some point rises to less than six feet below the soil surface. This acceleration of surface salinity resulting from rising water table has occurred not only due to increased precipitation but the lack of vegetation in portions of the growing season. Annual cropping systems adopted, in SD, such as a corn-soybean rotation do not utilize the early or late season precipitation as did the native grassland communities resulting in conditions conducive for soil salinization. The Northern Great Plains of the United States and Canada have vast areas that meet these criteria and where saline soils are more common due to confounding factors of geology, climate, and current cropping systems.

NATURALLY OCCURRING SALINE/SODIC SOILS

Naturally occurring saline, sodic, and saline and sodic soils developed because of the soil forming factors and not from human intervention. These soils are moderately to strongly saline because of saline parent material, landscape position, or a saline water source.

Soil survey information can be used for offsite detection of saline and sodic soils. Table 2 below provides a breakdown of the characteristics that differentiate these soils. Examples of naturally occurring saline soils in South Dakota are: Playmor, Bearden saline, and Colvin saline. Examples of sodic soils are: Aberdeen, Nahon, Cresbard, Jerald, Ferney Dudley, Miranda, and Cavour. An example of a saline/sodic soil is Harriet.

Table 2 - Classification of salt-affected soils.

Classification	**Electrical Conductivity*	*Sodium Adsorption Ratio*
Naturally Occurring Saline Soils	>4 dS/m	<13
Sodic Soils	<4 dS/m	>13**
Saline/Sodic Soils	>4 dS/m	>13**

**EC – Electrical conductivity of a soil saturated paste extract used to measure salt concentrations. The results are reported in deciSiemens/meter (dS/m) or millimhos/cm (mmohs/cm). One dS/m is equivalent to one mmohs/cm. Salinity is measured in the surface layer (0-6inches).*
***Most sodic soils meet this requirement; however, some soils are also considered sodic with SAR values <13 and have a dense sodic subsoil.*

CAPILLARY SEEPS

Capillary seeps are formed as a result of a shallow water table. In capillary flow, water moves from where the soil is saturated, or nearly saturated, to drier areas of the soil profile independent of gravity. When a water table gets close enough to the soil surface, the soil can act as a sponge and pull water up through the soil to the surface (capillary action). Because of capillary action, soils high in clay can pull a water table up four to five feet while sandy soils, with the larger pore spaces, can only pull the water table about two feet. It is not that uncommon for the majority, of SD, soils to pull the water table up three to four feet. Surface soil salinity occurs when salts remain after water evaporates from the soil surface. This is especially a problem in areas that do not have actively growing vegetation where growing plants through transpiration and evaporation use free water in the soil profile and thus reduce surface evaporation. Without actively growing vegetation there is no utilization of the excess soil water or any cover to prevent the water from being evaporated on the surface, resulting in excessive salt accumulations on the soil surface.

The majority of the saline soils that have developed during the 1990's, in eastern SD, are located on the edge of wetlands, along road ditches, field ditches, or drainage ways. The largest saline areas, in eastern SD, are found on flat land adjacent to wetlands, drainage ways, etc. The saline area continues to expand out away from the original source and thus large acreages can be consumed by the saline development. The narrow vs. extended saline areas are due to the rise above the wetland. If the landscape is a steep short rise, it is not as conducive to capillary water movement. If the landscape has a low gentle rise, the capillary water movement will extend a greater distance from the wetland.

SALINE SEEPS

Identification of Saline Seeps

Remedial treatment of saline seeps includes the identification of discharge and recharge areas, as well as, the implementation of management practices to correct and improve the soil conditions of the seep area. Saline seeps are most common, in SD, west of the Missouri River, in soils developed in marine bedrock such as the Pierre shale. Areas most prone to saline seeps have sloping stratified geologic materials. Excess water from precipitation moves through the soil profile, dissolving salts as it moves through the soil. This area of the landscape is often referred to as the recharge area of the saline seep. Once the water reaches an impermeable layer of finer textured or impervious material this gravitational water will tend to move laterally. Where the contact between the two different materials approaches the soil surface along a hill slope, the laterally moving water and dissolved salts come to the surface and create a wet spot (discharge area) that eventually becomes saline as water evaporates.

Discharge Area

Detection of discharge areas may be accomplished by visual means or by electrical conductivity (EC) measurements. Visual symptoms may include: vigorous kochia or foxtail barley growth in small areas where soils would normally be too dry to support weed growth, salt crusting on the soil surface, prolonged soil surface wetness in small areas, poor seed germination or rank wheat or barley growth with accompanying localized lodging, stunted trees in a shelterbelt with leaf chlorosis, or a sloughed hillside in native vegetation adjacent to a cropped field.

Detection of a discharge area using soil (EC) can be used to identify and confirm the encroaching or developing saline seep. Soil (EC) at the discharge area may be high at the soil surface or may be low at the surface and increase considerably with soil depth.

Recharge Area

Several procedures for identifying the recharge area include: visual, soil probing, soil surveys, drilling soil resistivity, and electromagnetic techniques. Even if the previously mentioned equipment is not available, a visual approximation of the recharge area can be made. Perennials such as alfalfa seeded into an approximation of the recharge area can be used as an indicator to identify the recharge boundary. Vigorous growth of alfalfa in midsummer can be used to identify the boundaries of the recharge area. Facts to remember in a visual approximation of the recharge area are that the recharge area is always at a higher elevation than the discharge area and is usually within 2,000 feet of the discharge area, many are within 100 to 600 feet.

Management Practices to Improve Saline Seeps

Remedial treatment of saline seeps can be accomplished though proper soil moisture management; however, no permanent solution can be accomplished unless control measures are applied to the recharge area. Remediation can be accomplished through intensifying water use in the recharge area, proper snow management, and the establishment of salt tolerant species on the discharge area.

Recharge Area

On those cultivated lands where a perched water table has already developed and the depth to the bottom of the perched water table is greater than five feet, the establishment of deep-rooted perennial crops will be required to dry out the subsoil of the recharge area. Where the depth to the bottom of the perched water in the recharge area is less than five feet, the subsoil can often be dried out by eliminating fallow and by using a more intense continuous cropping system.

When a deep-rooted perennial crop is planted in the recharge area (such as alfalfa), it should remain established until the top of the water table in the discharge area has been lowered to four feet below the soil surface. At this time, the deep-rooted perennial crop in the recharge area can be replaced with continuous cropping using a more intense continuous cropping system. See Table 1 for crop selection characteristics.

Table 1 Crop Selection Characteristics*	
Considerations for Annual Cropping	***Considerations for Permanent Cover***
Salt Tolerant Crops	***Salt Tolerant Permanent Cover***
▪ Barley	▪ Alkaligrass, Nuttall
▪ Rye	▪ Alkali sacaton
▪ Safflower	▪ Tall wheatgrass
High Water Use Crops	***High Water Use Permanent Cover***
▪ Sweet clover	▪ Alfalfa
▪ Safflower	▪ Basin Wildrye
	▪ Intermediate Wheatgrass
Longer Growing Season Crops	***Longer Growing Season Permanent Cover***
▪ Corn	▪ Alfalfa
▪ Sunflowers	

Discharge Area

After the flow of water from the recharge area has been controlled, reclamation of the discharge area can proceed. Plant salt tolerant grain crops such as barley or moderately tolerant crops such as wheat, oats, sorghum, or safflower. In severe seep areas, plant salt tolerant grasses to initiate the reclamation process. (Refer to Range Technical Note 4 for pasture suitability group J, or the range site Saline Lowland for seeding requirements).

ADDITIONAL MANAGEMENT CONSIDERATIONS ON SALINE SEEPS

- When working with saline seeps, to the maximum extent practical, crops selected should utilize available soil water in the recharge areas.
- Determine the relationship of the ground surface topography and the water table contours in and adjacent to the problem area. One suggested method involves installing nine (three rows of three) auger hole observation wells for water table measurements. Additional wells may be needed to adequately define the recharge area. The construction of monitoring wells in the recharge, drainage ways, and the discharge areas may be beneficial in monitoring progress in the reclamation of the saline seep.
- Snow management is usually a necessary component in "soil moisture management." It increases the success of a more intense cropping system on the recharge area. Additional moisture from snow and more even distribution of the moisture are gained by leaving stubble stand over winter, no-till cropping systems, or by herbaceous barriers.
- On discharge areas, proper snow management can enhance the reclamation process. However, moving more precipitation through the soil profile in the discharge area will not be effective until hydrologic control of the recharge area has been achieved.
- In addition to the loss of cropland, saline seeps may also have additional adverse environmental effects. In South Dakota, discharge waters from saline seeps have been identified to have toxic contaminants that may affect human or animal health. At this point, these contaminants include excessive levels of nitrates, sulfates, and selenium.

IRRIGATION INDUCED SOIL SALINITY

All water sources contain salts with the exception of rainwater. Application of irrigation water will increase the soil salinity. This is not normally a concern with good quality water (i.e., Missouri River) or if the soils are coarse textured with a rapid permeability. The primary concern with irrigation induced salinity is when poor quality water (high in total salts or sodium salts) is applied to finer textured soils. These soils have slow permeability and thus the salts can not be leached out of the soil profile and eventually is concentrated at the soil surface. Poor quality irrigation water can have a destructive influence on SD soils and in the James River valley this poor quality may be high in sodium and not necessarily total salts. Table 2 indicates an example of the severity of poor water quality on heavier soils. The sampling results of this example center pivot displayed in Table 2 have not had any water applied since 1981. Prior to 1981, the water applied through this center pivot was high in sodium and due to the build up of sodium in the soil profile the center pivot was removed from the field and the crop rotation changed to attempt to manage for the resulting sodium damaged soil.

Table 2. Results of Irrigating with Poor Water Quality.

Sample	Depth (in)	EC	SAR
Outside the Center Pivot	0-2	0.4	1
	2-6	0.4	1
	6-12	0.3	1
Inside the Center Pivot	0-2	1.0	6
	2-6	1.2	8
	6-12	1.8	18

Soil Salinity Treatment Alternatives

Prior to planting, soil testing to determine the level of soil salinity is recommended as a basis for selecting adapted species. Developing crop rotations with salt tolerant crops or establishing perennial salt tolerant grasses is the first step in working with soil salinity in SD. Refer to Table 3 and 4 for the selection of crops or grass species suitable to the saline conditions of the site. In cases where annual crop production is not economically viable, the most practical and economically feasible treatment for soil salinity concerns, in SD, is establishing and maintaining permanent herbaceous vegetation. Other alternative such as soil amendments, soil drainage and leaching of salts in the soil profile are not practical alternatives throughout most of SD. Permanent herbaceous plantings shall be designed and installed in accordance with one of the following conservation practices: Range Planting (550), Pasture and Hayland Planting (512), Wildlife Upland Habitat Management (645), or Critical Area Planting (342) where erosion or other conditions are unusually adverse.

Table 3. Crop Salt Tolerance Ratings, Crops, and Annual Forages.

Crop	Threshold Salinity: 1:1 soil:water slurry, dS/m**	Threshold Salinity: Saturated paste method, dS/m	% Yield decrease: % per dS/m saturated paste	Ece at 70% yield: saturated paste dS/m	Relative tolerance*: S	MS	MT	T	Source
Alfalfa	1.4	2.0	7.3	6.1		X			Bernstein & Francois, 1973
Barley	3.4	8.0	5.0	14.0				X	Hassan et al., 1970a
Beans	1.1	1.0	19.0	2.6	X				Osawa, 1965
Canola (rapa)	4.0	9.7	14.0	11.8				X	Francois, 1994
Canola (napus)	4.4	11.0	13.0	13.3				X	Francois, 1994
Chickpea	-	-	-	-		X			Manchanda & Sharma, 1989
Corn	1.3	1.7	12.0	4.2		X			Hassan et al., 1970b
Crambe	1.4	2.0	6.5	6.6		X			Francois & Kleiman, 1990
Flax	1.3	1.7	12.0	4.2		X			Hayward & Spurr, 1944
Millet	-	-	-	-		X			Maas & Grattan, 1999
Oat	-	-	-	-			X		US Salinity Lab, 1954
Potato	1.3	1.5	14.0	3.7		X			Bernstein et al., 1951
Rye	4.5	11.4	10.8	14.2				X	Francois, 1989
Safflower	-	-	-	-			X		Francois & Bernstein, 1964
Sorghum	3.0	6.8	16.0	8.7			X		Francois et al., 1984
Sudangrass	1.7	2.8	4.3	9.8			X		Bower et al., 1970
Sugarbeet	3.1	7.0	5.9	12.0				X	Bower et al., 1954
Sunflower	2.4	4.8	5.0	10.8			X		Francois, 1996
Wheat	2.8	6.0	7.1	10.2			X		Asana & Kal, 1965
Wheat, semidwarf	3.6	8.6	3.0	18.6				X	Francois et al., 1986
Wheat, durum	2.7	5.9	3.8	13.8				X	Francois et al., 1986

*S = sensitive, MS = moderately sensitive, MT = moderately tolerant, T = tolerant **estimated value based on a medium soil

Table 4. Crop Salt Tolerance Ratings, Pasture, and Hay Grasses.

Crop	Threshold Salinity: 1:1 soil:water slurry, dS/m**	Threshold Salinity: Saturated paste method, dS/m	% Yield decrease: % per dS/m saturated paste	Ec_e at 70% yield: saturated paste dS/m	Relative tolerance*: S	MS	MT	T	Source
Alkaligrass nuttal	-	-	-	-				X	US Salinity Lab, 1954
Alkali sacton	-	-	-	-				X	US Salinity Lab, 1954
Brome, smooth	-	-	-	-			X		McElgunn & Lawrence, 1973
Fescue, tall	-	-	-	-			X		Bower et al., 1970
Grama, blue	-	-	-	-		X			US Salinity Lab, 1954
Ryegrass, perennial	2.6	5.6	7.6	6.5			X		Brown & Bernstein, 1953
Timothy	-	-	-	-		X			Saini, 1972
Wheatgrass, fairway crested	3.2	7.5	6.9	11.8				X	McElgunn & Lawrence, 1973
Wheatgrass, intermediate	-	-	-	-			X		Dewey, 1960
Wheatgrass, slender	-	-	-	-			X		McElgunn & Lawrence, 1973
Wheatgrass, tall	3.2	7.5	4.2	14.6				X	Bernstein & Ford, 1958
Wheatgrass, western	-	-	-	-			X		US Salinity Lab, 1954
Wild rye, beardless	1.7	2.7	6.0	7.7			X		Brown & Bernstein, 1953
Wild rye, Canadian	4.5	11.4	10.8	14.2			X		US Salinity Lab, 1954
Wild rye, Russian	-	-	-	-				X	McElgunn & Lawrence, 1973

*S = Sensitive, MS = Moderately sensitive, MT = Moderately tolerant, T = tolerant **estimated value based on a medium soil

The application of mulch is recommended immediately after planting saline areas if the soil is bare. Application of mulch should be according to the Mulching (484) standard, utilizing the additional criteria to conserve soil moisture. Reducing evaporation is the key to reducing salt accumulation at the soil surface, which in turn aids germination and seedling survival.

In some cases, salinity problems on flood-irrigated land can be managed by leaching. Apply leaching in accordance with Irrigation Water Management (449) standard, including additional criteria to manage salts in the crop root zone.

When planning crop production systems Table 5 can be used to assist producers in a determination of economic feasibility for saline soil management. An example of the use of this table might be a corn/soybean cropland field with a portion of the field having an EC of 8mmhos/cm. The yield potential has been reduced to 24 percent for corn and 50 percent for soybean of their respective maximum yield potentials. At this point, a producer should assess whether or not this potential yield is providing a return above their input costs. If this yield potential is below an economic return, then changes in rotation or land use are warranted.

Table 5. Relative crop yields at increasing levels of soil EC.

	Electrical conductivity, Ec_e dS/m, saturated paste method											
	2	4	6	8	10	12	14	16	18	20	22	24
Crop	Percent (%) of maximum yield potential											
Alfalfa	100	85	71	56	42	27	12	0	0	0	0	0
Barley	100	100	100	100	90	80	70	60	50	40	30	20
Canola (napus)	100	100	100	100	100	87	61	35	9	0	0	0
Corn	96	72	48	24	0	0	0	0	0	0	0	0
Beans	81	43	5	0	0	0	0	0	0	0	0	0
Flax	96	72	48	24	0	0	0	0	0	0	0	0
Sugarbeet	100	100	100	97	85	73	61	49	37	25	13	0
Sunflower	100	100	97	87	77	67	57	47	37	27	17	7
Wheat, durum	100	100	100	96	88	80	72	64	56	48	40	32
Wheat, semidwarf	100	100	100	92	84	76	68	60	52	44	36	28

REFERENCES

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