MANAGING SALT AFFECTED SOILS

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The abundance of precipitation in the 1990's has increased the number and extent of salt affected soils in South Dakota. Many of these salt affected soils started in the middle 1990's as small isolated areas that had limited crop yield. As the wetness continued the salt areas grew larger and would support only foxtail barley or kochia vegetation. By the late 1990's many areas have accumulated enough salt on the surface to inhibit kochia survival and ensure barren ground. Before we can attempt to manage these salt affected areas we must first understand that there are different types of salts present in South Dakota soils.

CHARACTERIZATION OF SALINE AND SODIC SOILS

Salt affected soils can be categorized into three groups depending on the total soluble salts and the amount of sodium salts. Table 1 summarizes the different salt affected soils as: saline, sodic, and saline-sodic. Electrical Conductivity (EC), the ability of a soil solution to carry an electrical current, is used to measure soluble salts. The higher the EC value the higher the soluble salt content in the soil. Sodium Adsorption Ratio (SAR) is a measure of the amount of sodium present in comparison to calcium and magnesium. To calculate the SAR you must add the calcium and magnesium together and then divide by two. Next take the square root of the number. Finally, divide the sodium value by the square root number you just calculated. The calcium, magnesium, and sodium concentrations are in milliequivalents /liter. Soils with high sodium concentration typically are not a problem if the soil also has a very high concentration of calcium and magnesium. Soils high in sodium will be a problem if the calcium and magnesium concentrations are low. The pH is a measure of how acid (low pH) or alkaline (high pH) your soil is. Soils that have a high sodium concentration typically have a high pH. It is very important that we understand the difference in these soils as the management is dependent on the type of salt affected soil we are dealing with.

TABLE 1. SALT-AFFECTED SOIL CLASSIFICATION

Classification	Electrical Conductivity (mmhos/cm)	Sodium Adsorption Ratio (SAR)	pH
Saline	>4.0	<13	<8.5
Sodic	<4.0	>13	>8.5
Saline-Sodic	>4.0	>13	<8.5

SALINE SOILS

All soils contain some water-soluble salts, but when these salts occur near the surface and start to impede germination or plant growth they are referred to as saline soils (U S Lab Staff, 1954). The high salt content in the soil has an adverse affect on vegetative growth because of three main reasons. They are 1) salts can prevent soil water uptake into the plant because of the osmotic effect; 2) specific ion toxicity, which can disrupt the nutritional processes of the plant; and 3) salts can alter the soil structure and permeability (Brown et al., 1982). Plants vary in their tolerance to salts. South Dakota State University Extension Fact Sheet 903 shows the yield reduction of various crops and grasses due to salinity. Many plants are most sensitive to high salinity levels during germination or at the early seedling stage than as mature plants. The most tolerant crop is barley, while tall wheatgrass is one of the most tolerant grasses.

Electrical conductivity is the common method of measuring the salinity in the soil. The following table indicates the different salinity levels.

TABLE 2. INTERPRETATION OF ELECTRICAL CONDUCTIVITY.

EC (mmhos/cm)	Salt Rank	Interpretation
0 – 2	Low	Very little injury to plants.
2 – 4	Moderate	Sensitive plants may suffer
4 – 8	High	Non-salt tolerant plants will suffer
8 – 16	Excessive	Only salt-tolerant vegetation will grow
16 +	Very Excessive	Very few plants will grow

Most saline soils develop a white surface crust. There are typically two different types or formation of saline soils (saline seep or capillary seeps). All saline areas are a result of water movement. As water moves through the soil, soluble salts will be dissolved and increase in concentration in the water. When the water reaches an exposed surface the water evaporates and the salts are left behind to accumulate on the soil surface. It is common for South Dakota soils to have some salts present in the soil profile. That typically does not cause a concern, until the salts are elevated to close to the surface. South Dakota soils tend to have a large amount of salts present in the soil profile because of the lack of adequate rainfall to leach the salts down through the profile and because the soils in eastern South Dakota are fairly young (less than 10,000 years). The majority of these saline areas are located in cropland or poorly managed rangeland. In well managed rangeland, the native vegetation is so efficient at utilizing water that saline soils can not develop. The wetness that South Dakota experienced in the 1990's is nothing new. Studies have shown that South Dakota has had five periods of above average precipitation since the 1650's (Johnson et al., 2000). The four previous wet periods in South Dakota all occurred prior to settlement and thus under native vegetation. The excess precipitation in the 1990's provided the environment to increase the saline soils in cropped fields. There were many areas in fields that did not get cropped in the 1990's because of the wetness at planting time. Later in the year, when it was drier, these nonplanted areas were sprayed (compliments of 90 foot spray booms) resulting in no vegetation present to utilize this excess precipitation. A combination of a water table close to the surface and no vegetation was a perfect combination for capillary saline soil development. Summer fallow practices farther west were not utilizing enough moisture, resulting in water movement out of the root zone, prime conditions for saline seep development.

SALINE SEEPS

Factors in saline seep formation are the geology of the area, high precipitation, and farming practices that allow water to move out of the root zone into the subsoil (Figure 1). As the excess water continues to drain downward the water will dissolve and accumulate salts. At some point in the subsoil the water will reach a layer of very slowly permeability and accumulate above this layer, forming a perched water table. Over time the perched water will move laterally until the water reaches the soil surface. The water will evaporate, leaving the salts behind to accumulate and form the saline seep (Brown, et. al., 1983). Saline seeps are more common in western South Dakota because of the practice of summer fallow and the majority of the subsoil consists of bedded shale material, which has a very low permeability. The excess water from the summer fallow practice moves out of the rooting zone until it contacts the bedded shale material. In areas where the bedded shale is close to the surface, which often happens, the area will eventually become saline as the water evaporates. The saline seeps in eastern South Dakota are associated with those areas where the glaciated material has variable substratum. In these areas, it is common to have thin layers of sands above finer textured material or thin layers of slowly permeable clay in the subsoil.

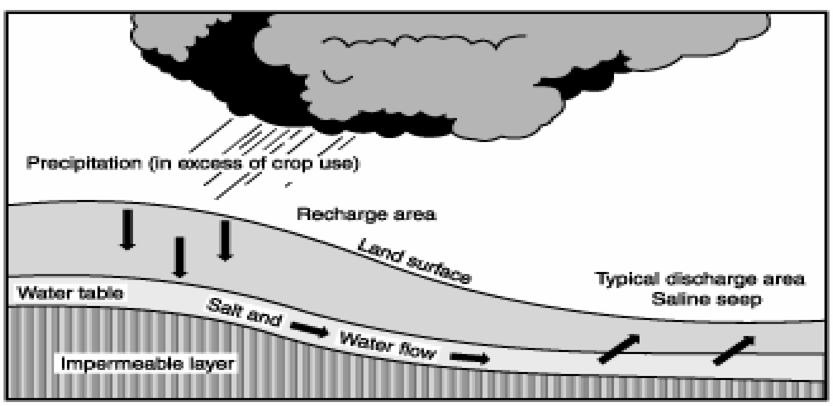

Figure 1. A generalized diagram of a saline seep.

CAPILLARY SEEPS

Capillary seeps are a result of a shallow water table. In capillary flow, water moves from where the soil is saturated, or nearly so, to drier soil independent of gravity. A high water table and a salinity problem can go hand in hand. When a water table gets close enough to the 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 4 to 5 feet while sandy soils, with the larger pore spaces, can only pull the water table about 2 feet (Figure 2) (Franzen et al., 1994). It is not that uncommon for the majority of South Dakota soils to pull the water table up 3 to 4 feet. The salts are left behind as the water evaporates from the soil surface. This is especially a problem in areas that do not have actively growing vegetation. Without vegetation there is no utilization of the excess water or any cover to prevent the water from being evaporated on the surface.

The majority of the saline soils that have developed during the 1990's in eastern South Dakota are located on the edge of wetlands, along road ditches, field ditches or drainageways. Figure 3 shows how the water high in soluble salts moves away from the water source. The soil evaporation rate is higher along the edge of the wetland and thus

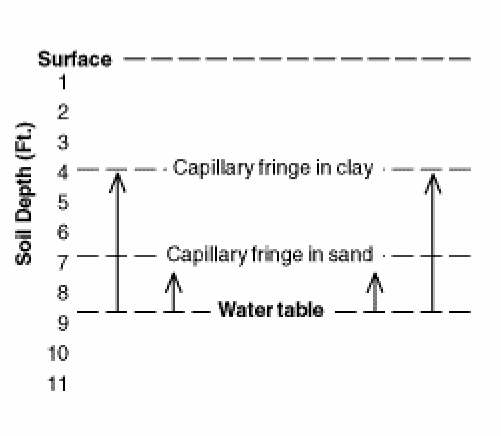

Figure 2. Capillary rise from a 9 foot water table depends on soil texture.

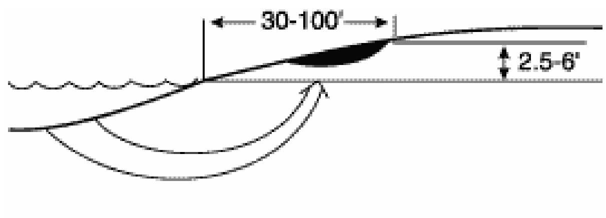

Figure 3. Saline soil development adjacent to pothole, road ditch, or field ditches.

as the water is moved toward the surface the salts are deposited along the edge of the wetland. The EC values of less than 1 mmhos/cm are common inside the wetland, while EC values greater than 10 mmhos/cm are not that uncommon on the wetland edge. In fact, the EC value is generally less than 1 mmhos/cm down to a depth of five feet inside the wetland. These saline areas will continue to occur until it reaches a landscape break. Wetlands that are surrounded by a steep landscape (> 6 % slope) typically will have only a narrow saline areas around the edge of the wetland. The largest saline areas in eastern South Dakota are found on flat land adjacent to wetlands, drainagways, etc. The saline area continues to grow out away from the original source and thus large acres can be consumed by the saline development. The narrow vs. extended saline areas are due to the rise above the wetland. If landscape is a steep short rise it deters the capillary water movement. If it is a low gentle rise, the capillary water movement will extend a greater distance from the wetland.

SALINE SOIL MANAGEMENT

Saline soils can not be reclaimed without first controlling the source of the soluble salts (i.e. water table). The only blessing of the dry conditions in 2002 was that the water tables have definitely been lowered and thus we can start to reclaim these saline areas. First and foremost there are no chemical amendments that will reclaim these saline areas. The application of gypsum and lime on saline soils is like peeing in the ocean, it may make you feel better, but it just adds more salt to the ocean. The salts that have been deposited in these saline areas are very soluble and move quite readily with water, as evident in how quick these saline areas formed. Now that the water table has dropped any snowmelt or rainfall will start to move the salts back down into the subsoil. This will require some time, as a large amount of salts have been deposited on the soil surface. Think about it, the evaporation rate in South Dakota is close to 40 inches per year. It will take time to move that much salt back into the subsoil. Tillage of saline areas will make the site look better (white to black) but typically will increase the surface salt concentration. A number of hot windy days and your black area is back to white. This is again caused by the evaporation of the water and leaving the soluble salts behind.

The following practices can aid in reclaiming saline soils: 1) intensify cropping rotation or plant salt tolerant crops; 2) drainage or tiling; 3) organic matter application; 4) perennial vegetation/CRP. Intensive cropping can reduce or eliminate water movement out of the root zone, which is eventually carried to the seep area. Eliminating fallow or growing crops that use more water, such as alfalfa are strongly recommended on the recharge area. The most salt tolerant crop available for these saline areas is barley followed by rye. Any drainage or tiling that can intersect the saline water flow to the surface can help with these saline areas. The major problems with drainage or tiling are the possibility of a wetland violation, cost of drainage/tiling, and trying to find an outlet area. Inadequate drainage can lead to a salinity problem not only around the rim of the wetland, but of the entire wetland itself. A shallow surface ditch out of a wetland will not lower the water table enough to prevent the formation of a saline soils around the edge of the wetland, but it will lower the water table enough in that the entire wetland can become salted out. Any type of organic matter application will increase the productivity of the saline area. The organic matter can help the soil tilth and also provide a barrier on the soil surface to prevent evaporation from the soil surface. Any method that eliminates evaporation reduces capillary rise of salt towards the saline area. Perennial vegetation or a deep-rooted crop (alfalfa) is the quickest and most effective method of reclaiming saline seeps. After vegetation is established in the upslope recharge area, it will intercept the saline water flow and prevent additional salt accumulation. The United States Department of Agriculture administers the Continues Conservation Reserve Program (CRP), which enables a producer to enroll these saline areas into the CRP program, for a yearly payment for 10 years. The contract requires establishment of permanent salt tolerant vegetation on the saline area and permanent vegetation on the adjacent recharge area. The CRP program will allow 10 acres of recharge area for every acre of saline area with a maximum contract of fifty acres. There is 50 percent cost share on seed cost, seedbed preparation, and seeding operation. Dormant seeding of these saline areas with western wheatgrass or tall wheatgrass has been successful. Research has shown that a one-inch spring rain can reduce salt concentration by 50 percent in the top inch or two of the soil. This gives the seed an opportunity to germinate prior to salts moving back to the surface (Franzen et al., 1994).

SODIC SOILS

Sodic soils are low in total salts (EC), but are high in exchangeable sodium (SAR). As mentioned in Table 1, a sodic soil should have a SAR value greater than 13. This number is not absolute because the type of clay and the soil organic matter content influence the value. As mentioned earlier, sodic soils are high in sodium concentration in relation to calcium and magnesium. The sodium will replace the calcium and magnesium on the clay particles, which causes the soil to become dispersed, and destroys the soil structure. When the soils become dispersed, clay particles will move down in the soil profile to form a layer of clay, enriched with sodium salts. All sodic soils will have a dense clayey layer within 18 inches of the surface and thus are commonly referred to as claypan soil, gumbo, or slickspots. These soils are very hard when dry, sticky when wet, and nearly impervious to roots, water, and air. Sodic soils typically have a very high pH (> than 8.5), but it is not that uncommon in eastern South Dakota for the sodic soils to have a pH down to 7.8. Because of these high pH values these sodic soils are typically referred to as black alkali soils. These soils are usually located on a level or nearly level landscape. Sodic soils normally are intermingled with non-sodic soils and often occur in very slight depressions on the landscape. Sodic soils are usually naturally occurring, and usually not caused by man's influence.

Using the Natural Resources Conservation Service (NRCS) soil survey publications can help to identify sodic soils. The NRCS has produced soil survey maps will indicate the presence or absence of sodic soils. There are very few sodic soils in the eastern third of South Dakota, with the majority of the sodic soils located in the James River Valley or the northwestern area of South Dakota (Figure 4). The NRCS recognizes three different types of sodic soils, based on the depth to the claypan, ranging from 0 to 6 inches, 6 to 12 inches or 12 to 18 inches. The sodic soils with the dense claypan layer within 6 inches are better suited to grass than crop production. These soils have a high SAR value near the surface and are virtually impervious. Farming this soil would be like farming the interstate highways. The sodic soil with the claypan layer at 6 to 12 inches typically does not have a high SAR value within in the top two feet, as the sodium is slowly starting to move through the profile. These soils can be farmed and will be productive under certain conditions. These certain conditions consisting of a normal to dry spring so the crop can be planted and timely rains throughout the growing season as the rooting depth is limited on this soil. One heavy rain will drown out the crop because of the slow permeability and any prolonged dry period will be detrimental on the limited rooted crop. Both types of sodic soils with claypan within 12 inches of the surface tend to crust relatively easy, because of the low organic matter content and the clay dispersion. The sodic soils with a fractured claypan layer at 12 to 18 inches is the most productive sodic soil, nearly as claypan layer at 12 to 18 inches is the most productive sodic soil, nearly as productive as non-sodic soils high in clay. The sodium has leached below the rooting depth and the once impervious claypan layer is partially fractured and thus roots, water, and air are able to pass through the profile. These soils only show decreased productivity during abnormally wet period (slow to dry) or abnormally dry periods.

SOUTH DAKOTA CLAY PAN SOILS

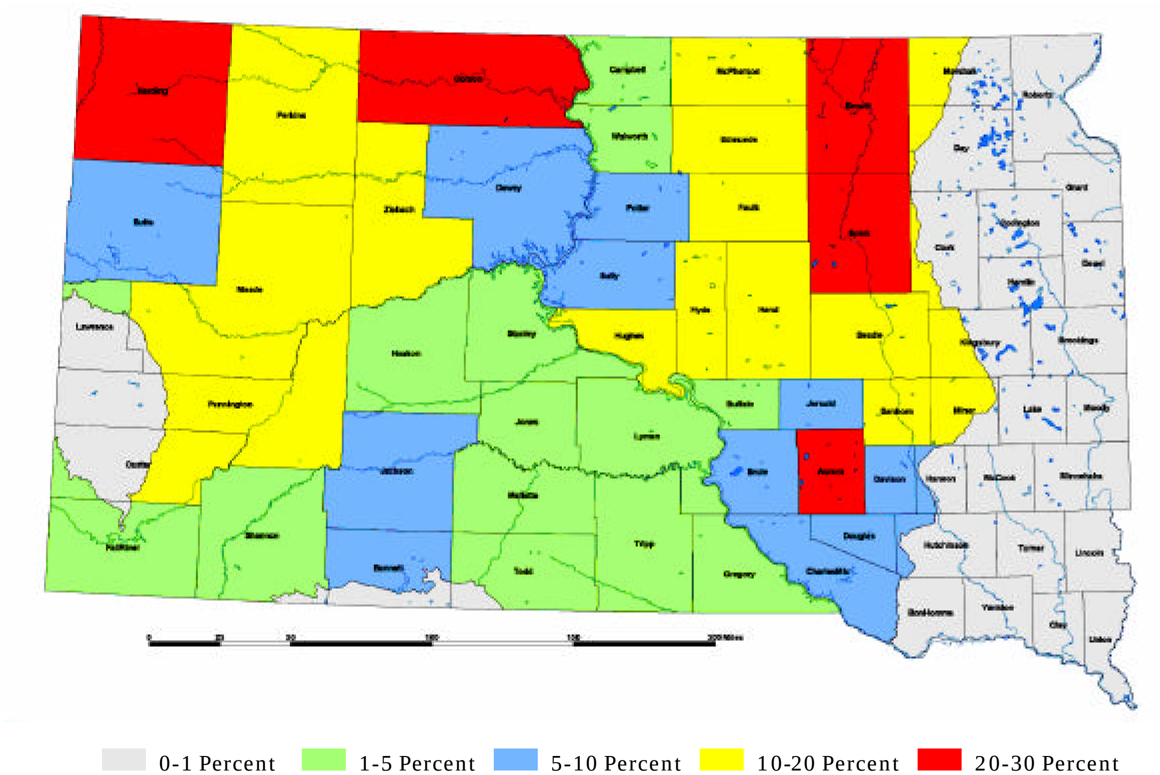

Figure 4. Percentage of sodic (claypan) soils for each county in South Dakota

Source: Counties, lakes and rivers–SD Dept. of Transportation; Claypan soils from soil surveys-NRCS-USDA; Projection Universe Traverse Mercator, Zone 14, NAD 83 Map produced by Brookings Field Support Office NRCS-USDA, January 2002

Vegetative growth is limited because of the shallow rooting depth in claypan soils and the high pH. Most roots are restricted to the topsoil above the claypan. This dense claypan also restricts water, nutrients, and air movement. The effect of sodic soils on crop growth is most noticeable in dry years. The high pH of the sodic soils reduces the availability of some plant nutrients, such as phosphorus, iron, and zinc.

RECLAIMING SODIC SOILS

Sodic soils are usually the most expensive type of soil to reclaim. Sodic soils can be reclaimed by adding chemical amendments, adding organic matter, or deep tillage (Seelig and Richardson, 1991). The purpose of applying chemical amendments is to supply calcium in the soil water for the replacement of the absorbed sodium on the clay particles. The major chemical amendments are gypsum ($CaSO_4$), lime ($CaCO_3$), elemental sulfur, and sulfuric acid. Gypsum is the most common amendment and also adds sulfur to the soil. Lime is only beneficial if the pH is below 7.5. The elemental sulfur or sulfuric acid will be beneficial for sodic soils that are calcareous (high in calcium carbonate). The sulfur will react with the calcium carbonate to form gypsum. The finer textured soils (clay soils) require more amendments and a longer time period to reclaim than coarse textured soils (sandy soils). Application of elemental sulfur is a slower process, as microbial activity is required to oxidize the sulfur. These chemical amendments are only beneficial on sodic soils and not saline soils. Applications of amendments may be largely ineffective unless the soil is periodically leached so the sodium can be moved deeper in the soil profile. Reclaiming sodic soils is slow because the poor soil structure is slow to improve.

Adding organic matter is always beneficial when working with sodic soils. Decomposing organic matter helps stabilize calcium as well as providing channels in the soil to conduct water, and to help reduce evaporative losses. The organic matter also helps to lower the soil pH, which decreases the exchangeable sodium near the surface. The organic matter stimulates microbial activity, which promotes aggregate stability of the soil particles.

To be effective deep tillage should reach below the sodic subsoil and mix several inches of the underlying material with the subsoil and topsoil. Many of the sodic soils contain natural gypsum below the claypan layer and thus deep tillage may bring the gypsum to the surface to react with the sodium. Depending on the soil, tillage to a depth of 15 to 36 inches may be needed. On-site investigation is needed to confirm the feasibility of deep tillage in a particular area. Any reclamation of sodic soils is a long-term endeavor. Complete reclamation may never be achieved.

IRRIGATION AND SALT PROBLEMS

All water from sources other that precipitation contains some salts. Application of irrigation water will increase the soil salinity. This is not a problem with good quality water (i.e. Missouri River) or if the soils are coarse textured. The biggest problem exists when poor water quality (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 become concentrated at the surface. Table 3 indicates the severity of poor water quality on heavier soils. This center pivot has not had any water applied since 1981. The irrigation water was so high in sodium that the quarter of land was virtually ruined.

TABLE 3. 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

Make sure you know the quality of the water you are applying, especially on heavier soils. Please refer to the following publication for additional information on water quality and irrigation: Irrigation: Your Water, Your Soils, and their Compatibility.

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