SDSU Extension

iGrow Wheat

BEST MANAGEMENT PRACTICES

Chapter 19: Managing Saline and Sodic Soils for Wheat Production

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This chapter discusses wheat production hazards associated with salt-affected soils (Fig. 19.1) and presents guidelines for reducing salt impacts on wheat yield.

Rules of Thumb for Saline and Sodic Soils

- Saline soils have high concentrations of total salts (including sodium).
- Sodic soils have high concentrations of sodium.
- Production risks and management of saline/sodic problems vary by soil and landform.
- Salt tolerances vary between plant species; wheat yields begin to decline as saturated paste values approach and exceed 6 dS/m.
- Saline problems are best managed with drainage and deep-rooted crops strategically placed in recharge and discharge zones to allow salts to leach from the root zone.
- As the average annual precipitation increases (Iowa has significantly greater precipitation than does South Dakota), the salinity risk usually decreases.
- In a semiarid climate regime, above normal precipitation can raise localized water tables and create salinity problems.
- Methods vary among soil laboratories, giving different results. Some laboratories use a 1:1 water to soil ratio, while others use a saturated paste method.

Figure 19.1. Salt-affected soil.
(Photo courtesy of USDA-NRCS)

Saline soils have high concentrations of soluble cations ('+' charge) and anions ('-' charge) (Ca^{+2}, Mg^{+2}, Na^{+1}, K^{+1}, SO_4^{-2}, NO_3^{-1}, Cl^{-1}), while sodic soils have high sodium concentrations. Saline and sodic conditions impact long-term productivity and soil quality by reducing seed germination, crop growth, and water availability. Sodic soils typically have poor soil water infiltration, tilth, and in severe cases will not support any beneficial plant life. Prevalence of foxtail barley or kochia can indicate areas of salt accumulation and warrant soil testing to confirm saline and/or sodic conditions.

Saline and sodic soils require similar yet different management techniques. Improved drainage can benefit both but applications of a soluble calcium salt (gypsum, $CaSO_4$), is usually required to rapidly improve sodic soils. Salt problems can result from a variety of practices including changes in climate and/or management that impact local hydrologic cycles. In essence, productivity is improved by leaching salts away from the rooting zone.

Salt problems, natural or man-made

Soils with salt problems can result from the weathering of soil and geologic parent materials, management, irrigation, or a combination thereof. Regions in South Dakota with varying degrees of risk for salt problems are shown in Figure 19.2, but are not limited to risk areas shown on the map. At the field scale, the risk salt accumulation is higher in poorly drained areas compared to well-drained soils. The lack of subsoil drainage, periods of above normal precipitation, and/or over-irrigation cause water tables to rise. Salts dissolve in rising water, moving them into the root zone and can be transported to the soil surface. Salts accumulate at the surface as soil water evaporates leaving the salts behind. Reductions in seed germination, crop establishment and vigor, and increases in weeds are likely under these conditions. Saline and sodic conditions are known to be problematic throughout South Dakota.

Irrigation with high sodium or high salinity water is a high-risk practice that can render productive land useless. Over-irrigation can increase salts near the surface in lower areas by raising water tables. Always have irrigation water tested by a reputable laboratory if using a groundwater source. Regardless of the source, proper irrigation scheduling can help to reduce upward movement of salts (Werner 1993).

Impact on plants

Salt tolerance varies by crop and crop variety; one variety of wheat may be more tolerant than another. Wheat is classified as a moderately tolerant plant (Maas 1984) with a saturated paste EC threshold value of 6.0 dS/m (Fig. 19.3). Mass also indicates that wheat will have a 7.1% yield loss with each 1 dS/m increase above 6 dS/m. Yield losses may be due to reduced plant water availability, seed germination, or combination of both.

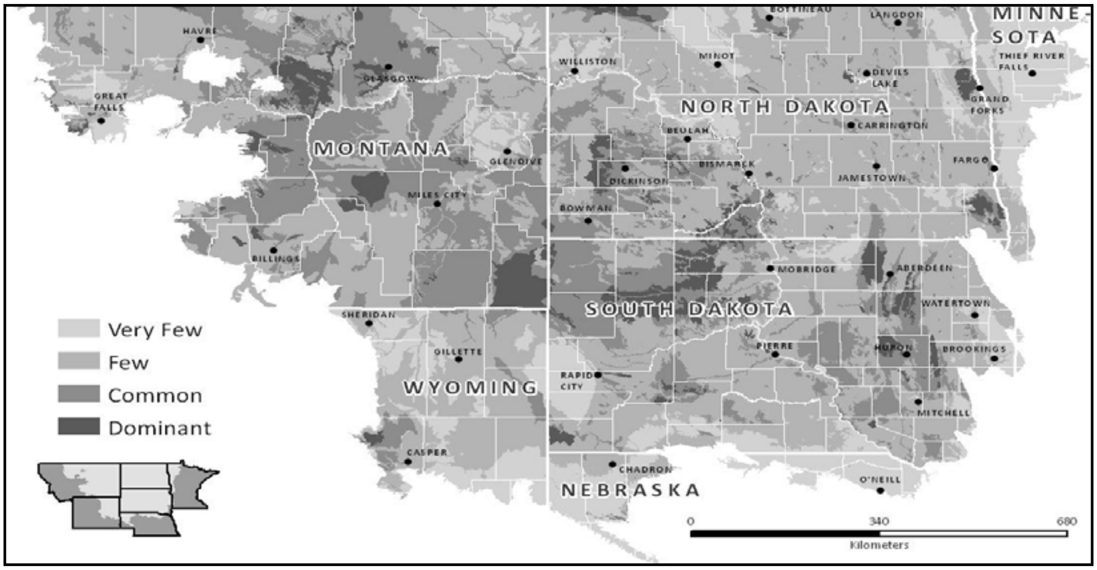

Figure 19.2. A map of the Northern Great Plains soils with a high risk potential for excessive soil salinity. Soils with EC> 4 dS/m constitute the high risk areas. (Source: http://www.soilsci.ndsu.nodak.edu/DeSutter/TomDeSutter.html)

Measurement and mapping soil salinity

Automated systems for field measurement of salinity have been developed and provide in-field measurement of "apparent EC" values. Examples of these systems include Geonics EM meters [http://www.geonics.com/html/em38.html] and Veris Soil EC [http://www.veristech.com/products/soilec.aspx].

The term "apparent EC" is used because results from these instruments are influenced by additional factors beyond salt concentration, including bulk density and soil water content. Apparent EC values are not readily equilibrated to laboratory measurements as it is difficult to define the factor responsible for the EC measurements. However, results from these systems can be used to develop a field map that can be used to define management zones. Areas that have a whitish material appearing on the soil surface should be treated as a separate zone that may require drainage to maximize yields.

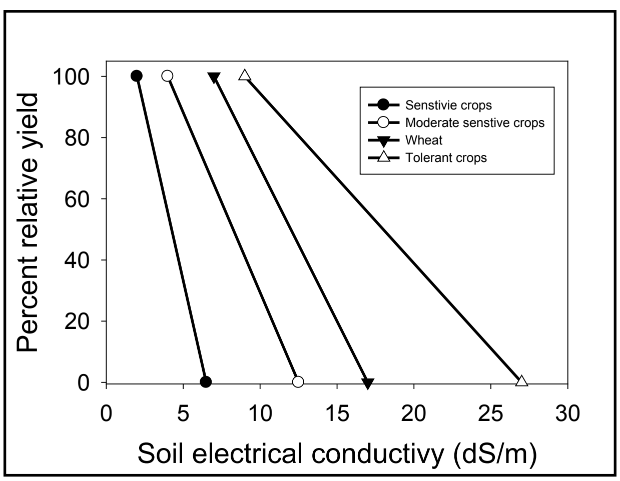

Figure 19.3. Relative crop yield potential as a function of soil salinity. (Source: D.E. Clay, SDSU)

Typically, laboratory analysis of salts is determined using the saturated paste extraction or a 1:1 soil:water solution. These two methods produce slightly different results (Table 19.1). Research conducted in South Dakota and North Dakota suggests that 1:1 EC dS/m values can be converted to saturated paste EC dS/m values by knowing the soil texture (Table 19.1, Franzen 2003). Because most recommendations are based on saturation paste values, it is important to convert 1:1 ratios to saturation paste values.

Table 19.1. The influences of soil texture (coarse, medium, and fine) on the relationship between EC (dS/m) using two approaches (1:1 vs saturation paste). (Modified from Franzen 2003)

EC 1:1	EC Saturated Paste		
	Course Texture Soil	Medium Texture Soil	Fine Texture Soil
0.5	1.4	0.7	0.5
1.0	3.0	2.2	2.0
1.5	4.5	3.7	3.5
2.0	6.0	5.3	5.0
2.5	7.5	6.8	6.5
3.0	9.0	8.3	7.9
3.5	10.5	9.8	9.4
4.0	12.0	11.3	10.9
4.5	13.5	12.8	12.4
5.0	15.0	14.3	13.9
5.5	16.5	15.8	15.3
6.0	18.0	17.3	16.5
6.5	19.5	18.8	18.3
7.0	21.0	20.3	19.8
7.5	22.5	21.8	21.3
8.0	24.0	23.3	22.7

Salinity management: drainage

High salinity is most often a symptom of a high water table. One option for lowering the water table is to install tile drainage (Chapter 20). A suitable outlet is critical for an effective tile drainage system, but there are many places in South Dakota where suitable outlets are not feasible. In addition, drainage laws require producers to work with local permitting authorities to avoid flooding and other issues.

In 1985, the South Dakota Legislature revised the statutory drainage law giving the authority to manage drainage to county governments. In addition, there is Federal authority administered by the Natural Resource Conservation Service (NRCS).

Pattern tile drains in very coarse-textured soils can be installed on 200 ft centers (using 2011 cost estimates) (~ 220 ft/acre at $1.50/ft =$330/acre), while tiling a clay soil may require 10 ft spacing (~4400 ft /acre ~$6600/acre). Consultation with drainage engineers is recommended when considering tile drainage.

Salinity management: cover and deep-rooted plants

In some situations, non-drainage solutions can be used. Perennial deep-rooted crops, such as alfalfa, can be used to lower water table and reduce the salinity problem. However, in saline soils alfalfa seeds may not germinate. It may be possible to overcome this problem by:

- Seeding alfalfa in strips several hundred feet wide just above the saline spot.
- Seeding a salt-tolerant crop such as Tall Wheat grass within a salinity pocket.
- Minimizing management practices that physically move salts to the soil surface.

Maintaining plant growth in these areas is critical and weed growth is better than no-growth.

Tillage in saline areas

In South Dakota, there is a significant opportunity for salt leaching from fall, winter and spring precipitation, assuming the water table is not close to the soil surface. Deep spring tillage can negate the leaching effect by bringing salt to the surface. For this reason, no-till or minimum till farming of salt spots is recommended. Deep ripping has not been found to be a consistently successful management tool to facilitate deep drainage and lower salt levels of saline areas.

Soil amendments for saline areas

A saline soil has a high concentration of total salt. Adding additional salts, such gypsum, will not mitigate the problem; however, gypsum can be effective in reclaiming sodium-affected areas. Drainage and/or increasing plant growth are effective tools to reduce total salinity problems.

Sodium problems

Sodium (Na) is a salt that requires special attention. High concentrations of sodium on the soil exchange complex can destroy the soil structure. Soils with high Na concentrations will be cloddy with poor infiltration and root growth rates. They may also have dome type structures in the subsoil (Fig. 19.4). Sodium-affected soils can become worse after significant in season or non-growing season precipitation. Leaching of salts from the top several inches of the soil solution may lower total salts, but will leave sodium on the exchange complex. The addition of a calcium-containing material such as gypsum can facilitate movement of sodium off the exchange complex and allow it to move downward with water.

The sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) are two calculations (resulting from a soil test) used to estimate soil sodium problems. Both of these calculations provide estimates of the relative amount of Na contained in the soil. If a Na problem is suspected, a soils specialist should be contacted for advice. Examples of these calculations are available in Clay et al. (2011).

Figure 19.4. Dome structure of sodium-affected soil. (Photo courtesy of USDA-NRCS)

The reclamation of sodium soil is slow because time is required to rebuild the structure. One relatively inexpensive approach to improve the soil structure is to apply low Na-containing manure or to apply crop residues to these areas. The organic matter in these materials can help stabilize and improve soil structure. It must be pointed out that not all manures have low Na concentrations. Manure from animals that have high concentrations of NaCl in their rations may contain high sodium concentrations. For example, 1) distillers grains from ethanol plants may be treated with NaCl; and 2) swine, poultry, and beef have diets that are often supplemented with NaCl. Many animals have diets supplemented with NaCl because the plant materials do not provide enough Cl or Na to meet the animals' nutritional requirement.

A second approach is to replace the Na on the soil exchange site with a calcium source such as gypsum ($CaSO_4 \cdot 2H_2O$) or lower the pH of the soil with elemental sulfur. As a rule of thumb, South Dakota soils should not exceed SAR values (~ESP) values of 8. For a typical South Dakota soil with a CEC of 25 and a SAR value of 12, a one-ton application of gypsum would be needed to lower the SAR value to 8, in the top 6 inches of soil. To lower the content of the top 6 inches of this same soil from a SAR of 12 to 4 will require about 2 ton/acre of gypsum.

Elemental sulfur is an additional option. Sulfur oxidizes to sulfuric acid which reacts to form gypsum if calcium carbonate is present. To displace the Na on the soil exchange site, good quality water must be added to leach the Na beyond the root zone.

Summary

In managing saline and sodic soils, care must be used to prevent further degradation. Some approaches to prevent further degradation are:

1. Collect soil and irrigation water samples to identify the scope and magnitude of the problem.
2. Plant salt-tolerant plants.
3. Eliminate sources of salt or balance salt additions with salt losses.
4. Apply gypsum to sodic soils, if needed.
5. Apply crop residues or animal manure low in Na to improve water infiltration.
6. Install tile drainage.

In soils with high water tables, salts can concentrate near the soil surface. In these areas, water and the salts dissolved in the water rise through capillary movement from the water table to the surface. As the water evaporates, it is replaced by more salt-containing water from the water table. Approaches for reducing capillary movement of water and salts to the surface include:

1. Install tile drainage.
2. Properly manage irrigation systems.
3. Adopt practices that maximize transpiration and minimize evaporation.
4. Plant full season deep-rooted crops or shelterbelts in these and in the recharge areas.
5. Eliminate fallow.

For sodic soils, extreme care must be used. High sodium has the added problem in that it can greatly reduce water infiltration. If a sodium problem is suspected, an agronomist should be contacted for assistance. Ultimately a soil sample should be collected and the sodium adsorption ratio (SAR) calculated (Clay et al. 2011).

If the SAR is greater than 8, a long-term plan that minimizes further degradation should be adopted. The plan may include providing tile drainage, adding low Na manure or gypsum, or lowering the pH (if the soil pH is high) with elemental S. If gypsum is present at deeper soil depths, tillage may help. If drainage and soil amendments are not possible, consider placing the field into pasture and planting it with salt-tolerant grasses.

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Additional information and references

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