Management of Saline and Sodic Soils

Department of Agronomy MF-1022 Soil Management

Saline and sodic (alkali) soils can significantly reduce the value and productivity of affected land. Soil salinity and related problems generally occur in arid or semiarid climates where rainfall is insufficient to leach soluble salts from the soil or where surface or internal soil drainage is restricted. Salinity problems can also occur on irrigated land, particularly when irrigation water quality is marginal or worse.

It has been estimated that slightly more than one-fourth of irrigated farmland in the United States is affected by soil salinity. In humid regions salt problems are less likely because rainfall is sufficient to leach soluble salts from the soil, but even in higher rainfall areas, salinity problems occur. In some areas with high water tables, problems may occur with surface evaporation leaving salts to accumulate.

In Kansas, salt-affected soils and related problems occur statewide but often on small areas. Field-wide problems often are due to poor quality irrigation water and/or excessive manure applications. Drilling activity causing high-salt water to escape to the soil surface, spills, or natural causes may result in spotty problems. Some areas of the state where salt mining occurs, particularly south central Kansas, have soils naturally high in sodium and soluble salts.

Ions most commonly associated with soil salinity include the anions chloride (Cl^-), sulfate ($SO_4^=$), carbonate (HCO_3^-), and sometimes nitrate (NO_3^-) and the cations sodium (Na^+), calcium (Ca^{++}), magnesium (Mg^{++}), and sometimes potassium (K^+). Salts of these ions occur in highly variable concentrations and proportions. Salt-affected soils have been called white alkali, black alkali, gumbo, slick spots and other descriptive names. These names are associated with soil appearances caused by salt accumulation. The term alkali often refers to soils light in color and prone to surface crusting and implies that affected soils are high in exchangeable sodium. Salt-affected soils differ considerably in use suitability, productivity, ease of reclamation, and management.

Characterization of saline and sodic soils

Salt-affected soils are divided into three groups depending on the amounts and kinds of salts present. Classification depends on total soluble salts (measured by electrical conductivity, E.C.), soil pH, and exchangeable sodium percentage. Table 1 summarizes the categories: saline, sodic, and saline-sodic. Understanding the differences is critical because these factors determine how the soils should be managed and reclaimed.

Saline soils

All soils contain some water-soluble salts, but when these salts occur in amounts that are harmful to germination of seeds and plant growth, they are called saline. Saline soils are the easiest of the salt-affected soils to reclaim if good quality water is available and the site is well drained. Saline soils often are in normal physical condition with good structure and permeability. They are characterized by irregular plant growth and salty white crusts on the soil surface. These salts are mostly sulfates and/or chlorides of calcium and magnesium.

Electrical conductivity, the ability of a soil solution to carry electrical current, is used to measure soluble salt concentration and is reported in millimhos per centimeter (mmhos/cm). When a solution extracted from saturated soil is 4.0 mmhos/cm or greater, the soil is saline. The pH of these soils is generally less than 8.5, and sodium makes up less than 15 percent of the exchangeable cations.

Sodic soils

Sodic soils are low in total salts but high in exchangeable sodium. The combination of high levels of sodium and low total salts tends to disperse soil particles, making sodic soils of poor tilth. These soils are sticky when wet, nearly impermeable to water and have a slick look. As they dry, they become hard, cloddy and crusty.

Sodic soils have exchangeable sodium percentages of more than 15. This means that sodium

Table 1. Salt-Affected Soil Classification

Classification	Electrical Conductivity (mmhos/cm)	Soil pH	Exchangeable Sodium Percentage	Soil Physical Condition
Saline	> 4.0	< 8.5	< 15	Normal
Sodic (alkali)	< 4.0	> 8.5	> 15	Poor
Saline-sodic	> 4.0	< 8.5	> 15	Normal

> = greater than, < = less than

occupies more than 15 percent of the soil's cation exchange capacity (CEC). The pH is greater than 8.5, and the electrical conductivity is less than 4 mmhos/cm. Sodic soils are detrimental to growth of most plants. They can be reclaimed, but it may be slow and expensive due to the lack of a stable soil structure, which slows water drainage.

Saline-Sodic Soils

These soils contain large amounts of total soluble salts and greater than 15 percent exchangeable sodium. The pH is generally less than 8.5. Physical properties of these soils are good as long as an excess of soluble salts is present.

Identification of saline and sodic soil problems

An analysis of the soil for soluble salts and sodium accumulation will identify the specific problem and its severity. To see if a problem exists, take a composite sample of several cores, 6 to 8 inches deep, of the affected area, with a final sample volume of at least a pint of soil. In many cases, comparison soil samples from the affected area and surrounding normal appearance area will be beneficial. If a saltwater spill occurs and the water stands on the area for several weeks or a natural seep exists, depth increment samples to 3 feet should be taken to assess the depth of salinity. Profile information will help in planning a reclamation program. If you are unsure how to sample, consult the lab where you're submitting the samples or your county Extension agricultural agent.

Lab analysis methods vary, but most labs that run a specific salt-alkali test use about the same methods. The methods and interpretation presented here are used in the KSU Soil Testing Lab. Before applying these interpretations to other lab results, you should be certain similar methods were used.

Soluble salts are measured by taking a sample of soil, adding enough water (salt-free) to the soil sample to completely saturate it, and extracting water from the saturated soil after several hours of equilibration using a vacuum to obtain a saturation extract. The amount of soluble salts present is measured by determining the electrical conductivity (mmhos/cm). The electrical conductivity of a solution is proportional to its soluble salt content. The general interpretation of the results is found in Table 2.

A second important measure is the amount of exchangeable sodium, determined by extracting the soil with 1 M ammonium acetate and measuring the amount of sodium in the extract. The results of this extraction must be corrected for soluble sodium measured but not exchangeable. Once this correction is made, the results are expressed as percent exchangeable sodium. The general interpretation used by the KSU Soil Testing Lab is found in Table 3.

Detrimental effects of excess exchangeable sodium on plant growth occur because of poor soil physical condition. Some plants, however, begin to show some injury at levels as low as 5 percent exchangeable sodium. The commonly grown agronomic crops in Kansas are not among those sensitive to sodium. In the general discussion of a sodic soil, greater than 15 percent is the level of exchangeable sodium for poor physical condition to develop. Many factors enter into soil dispersion; depending on texture, type of clays, organic matter levels and many other factors, various soils may disperse over a range of 10 to 20 percent exchangeable sodium. To alert land owners of a potential problem, the KSU Soil Testing Lab interprets anything above 10 percent exchangeable sodium as excessive. Most well-drained, normal soils in Kansas will have less than 1 to 2 percent.

The occurrence of sodic or saline-sodic soil problems on a field basis nearly always can be traced to irrigation with marginal or poor quality water.

Table 2. Interpretation of Electrical Conductivity

Saturation Extract (mmhos/cm)	Salt Rank	Interpretation
0-2	Low	Very little chance of injury on all plants.
2-4	Moderate	Sensitive plants and seedlings of others may show injury.
4-8	High	Most non-salt tolerant plants will show injury; salt-sensitive plants will show severe injury.
8-16	Excessive	Salt-tolerant plants will grow; most others show severe injury.
16+	Very Excessive	Very few plants will tolerate and grow.

Table 3. Interpretation of Exchangeable Sodium Percentage

Exchangeable Sodium (%)	Alkali Rank	Interpretation
0-10	Low	No adverse effect on soil is likely.
10+	Excessive	Soil dispersion resulting in poor soil physical condition and plant growth is likely.

Irrigators should determine the potential salinity and sodium hazard of their water. Irrigation water quality tests are available through the KSU Soil Testing Lab. KSU Cooperative Extension Service Circular C-396, "Determining Water Quality for Irrigation," shows how to interpret the irrigation water test results of various soil textures for overall salinity and sodium hazard.

Salt effects on plant growth

Crops differ in the ability to tolerate salt accumulation in soils, but if levels are high enough, (> 16 mmhos/cm) only tolerant plants will survive. As salts accumulate in soil, the soil solution osmotic pressure increases. When this happens, the amount of water available for plant uptake decreases and plants exhibit poor growth and wilting even though the soil isn't dry (see Figure 1).

Crop selection can be a good management tool for moderately saline soils. Table 4 serves as a general guide of salt tolerance ratings for crops, realizing that management practices, irrigation water quality, environment, and crop variety also affect tolerance.

Just as crops differ in tolerance to high salt concentrations, they also differ in their ability to withstand high sodium concentrations. Crop growth and development problems on sodic soils can be nutritional (sodium accumulation by plants), associated with poor soil physical conditions, or both. Plants on sodic soils usually show a burning or drying of tissue at leaf edges, progressing inward between veins. General stunting is also common. Crops differ in their ability to tolerate sodic soil, but if sodium levels are high enough, all crops can be affected. Generally, soybeans are quite sensitive, corn and grain sorghum are intermediate and wheat and alfalfa are more tolerant. Crested and tall wheatgrass and a few sorghum-sudan hybrids are very tolerant, able to grow on soils with exchangeable sodium percentages above 50 percent.

Reclamation of soils

The first step toward reclamation of any salt-affected soil is an assessment of the soil including the soil profile. A salt-alkali soil test (available through KSU Soil Testing Lab) will establish whether the soil is saline, sodic, saline-sodic, or not affected by salts. An examination of the soil profile along with soil survey information will help determine soil permeability characteristics, which are important in leaching salts. In some cases, it may be necessary to facilitate drainage using tile drains or open ditches to allow successful reclamation. Prior to alteration of the affected area, check with the Soil Conservation Service to be sure the alteration (drainage, etc.) does not violate the swampbuster provision of the 1985 Farm Bill. Reclamation may be uneconomical because of poor soil permeability, lack of adequate drainage or lack of good quality irrigation water. Often, unless the source of the salt problem can be eliminated or reduced, reclamation will be impossible or, at best, only temporary.

Saline Soils

These soils are easy to reclaim for crop production if adequate amounts of low-salt irrigation water or rainfall are available, and internal drainage of

Figure 1. Salinity and available soil water

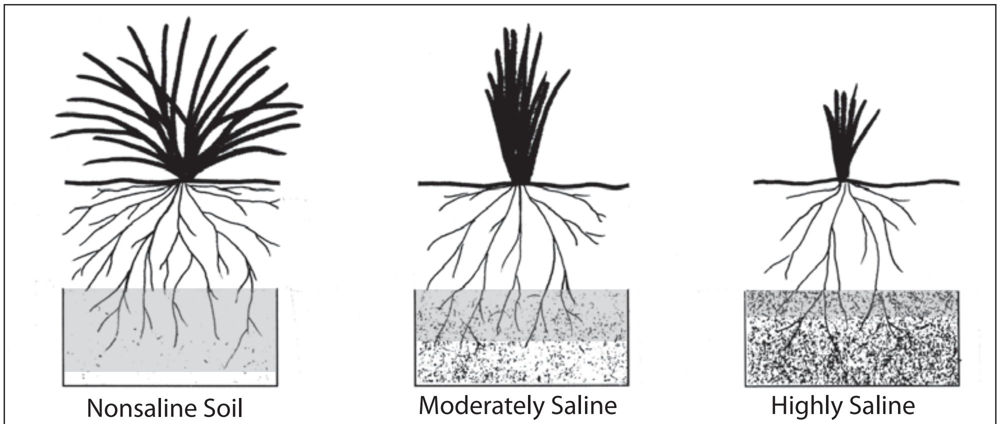

Table 4. Salt Tolerance Ratings for Various Field and Forage Crops

Sensitive (0-4 mmhos/cm)	Moderately Tolerant (4-6 mmhos/cm)	Tolerant (6-8 mmhos/cm)	Highly Tolerant (8-12 mmhos/cm)
Field Beans (Dry)	Corn	Wheat	Barley
Red Clover	Grain Sorghum	Oats	Rye
Ladino Clover	Soybean	Triticale	Bermudagrass
Alsike Clover	Bromegrass	Sunflower	Crested Wheatgrass
	Sudangrass	Alfalfa	
	Sorghum-Sundans	Tall Fescue	
		Sweet Clovers	

the soil is good. Saline soils cannot be reclaimed by chemical amendment, conditioner or fertilizer. Reclamation consists of applying enough good quality water to thoroughly leach excess salts from the soil. Water should be added in sequential applications, allowing time for the soil to drain after each application. The quantity of water necessary for reclamation varies with initial salt level, desired salt level, irrigation water quality, and how the water is applied. If sequential applications are used, 8 to 10 inches of leaching water may be necessary to remove 70 percent of total salts for each 12 inches of soil to be leached.

Sodic and Saline-Sodic Soils

Reclamation of sodic soils is different; excess sodium must first be replaced by another cation and then leached. Sodic soils are treated by replacing the sodium with calcium from a soluble source. Gypsum ($CaSO_4 \cdot 2H_2O$) is considered the cheapest, soluble calcium source for reclamation of sodic soils. On calcareous soils (soils with excess $CaCO_3$ present), elemental sulfur may be added to furnish calcium indirectly. Sulfur is oxidized to sulfuric acid which reacts with the calcium carbonate to form gypsum. Oxidation of elemental sulfur is slow, so this method may be of limited value.

Reclamation of a foot depth of sodic soil on one acre requires 1.7 tons of pure gypsum for each milliequivalent of exchangeable sodium present per 100 grams of soil. For example, if a soil has a CEC of 20 milliequivalents per 100 grams and 30 percent exchangeable sodium, there would be 6 milliequivalent of sodium per 100 grams of soil. Thus, 10.2 tons of gypsum (6 x 1.7) per acre would be required to reclaim this soil. The numbers needed for these calculations are provided by a salt-alkali soil test.

Once the gypsum is applied and incorporated, sufficient good quality water must be added to leach the displaced sodium beyond the root zone. Reclamation of sodic soils is slow because soil structure, once destroyed, is slow to improve. Growing a salt-tolerant crop in the early stages of reclamation and disking in crop residues adds organic matter which increases water infiltration and permeability, speeding up the reclamation process.

In reclamation of saline-sodic soils, the leaching of excess soluble salts must be accompanied (or preceded) by the replacement of exchangeable sodium by calcium. If the excess salts are leached and calcium does not replace the exchangeable sodium, the soil will become sodic.

Even non-irrigated sodic or saline-sodic soils show dramatic improvement with gypsum application. Gypsum (15 tons/acre) applied to a saline-sodic soil in Kansas increased wheat yields an average 10 bushels per acre over a 5-year period in an area with 28 inches average annual rainfall.

Summary

Salt-affected soils can severely reduce land value and productivity. Soil tests can determine if salt accumulation is a problem. Problems include high total salts (saline soils), excess exchangeable sodium (sodic soils), or both (saline-sodic soils). All of these soil conditions can severely affect crop growth. Crops react differently to salt-affected soils. Soil reclamation is possible but not always economically feasible.

Abbreviated step-by-step procedure for reclamation:

Step 1. Take a salt-alkali soil test to determine specific problem.
Step 2. Identify source/cause of problem.
Step 3. Eliminate source of salt contamination if possible and establish drainage if necessary.
Step 4. Add chemical amendment (gypsum) to sodic or saline/sodic soils.
Step 5. Incorporate residue to improve water intake.
Step 6. Apply irrigation water (if available).
Step 7. Allow time for leaching and consider planting tolerant crops.

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