Saline and Sodic Soils in Idaho

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Introduction

Saline and sodic soil and water are a concern in moisture-limited irrigated agriculture, because of the lower quality water and high evaporation rates. Salts, a combination of an acid and a base, are common in the soil and important to crop production. Table 1 shows some of the common salts found in soil and used in agriculture. These salts are important components to plants and their growth. A common misconception is that salts are all bad and only get worse at higher concentrations. Actually, salts are necessary and many salts are the plant available form of essential elements. This paper will describe the common methods of determining whether a soil has a salinity or sodicity problem. It will also address management practices to remediate these soils and prevents soils from getting worse.

What are saline, sodic and saline-sodic soils?

Saline soils have high levels of soluble salts in the root zone that affect the plants ability to compete with the soil for water. Salts create osmotic potential in the plant roots and in the soil. In a normal soil the osmotic potential is greater in the roots than in the surrounding soil, enabling water to move into the roots. As the salt concentration in the soil increase, either by adding additional salts or the soil drying, the osmotic potential of the soil increases. If the osmotic potential is greater than that of the roots then water will not move into the roots. One of the symptoms of saline soils are wilted and droughty plants in soil that appears to have adequate moisture. This diagnosis is easily confirmed with a soil test. Table 2 gives the accepted soil test measurements for saline (and sodic) soil. Salinity is determined my measuring the electrical conductivity (EC) of a saturated paste extract or 1:1 soil water mixture. The units of EC are dS/m. Most soil tests will report EC values using these units, however some soil test labs still report EC using mmhos/cm. The conversion is 1:1 so a value of 1.2 dS/m = 1.2 mmhos/cm. Saline soils will often have a white crust from salts that remain on the soil surface as water evaporates. Salts by definition are water soluble and hence will move up and down in the soil profile with irrigation and evaporation. Plants growing in saline soils will appear to be water stressed because of the plants inability to pull water from the soil (osmotic pressure).

In order to speed up the process of soil analysis, many soil test labs do not make a saturated paste but use a 1:1 soil slurry to measure EC. These values are lower than a saturated paste but are somewhat correlated. If you have a 1:1 EC value that gives cause for concern, it would be wise to ask the lab to run a saturated paste extract on the sample. Table 3 illustrates the relationship between 1:1 and saturated paste extract values. It is important to know which method is being used to measure EC.

Sodic soils have sodium ions in high concentrations on the soil exchange sites. Sodium has a very strong attraction to water and hence a large hydration radius. This means that the sodium ion, which is quite small, can be larger than many other cations like calcium and magnesium when it is hydrated. The hydrated sodium cation is attracted to the negatively charge soil particles and since it is so large and monovalent, it forces the soil particles apart. This action causes surface crusting and destroys the soil structure which results in poor water infiltration.

Visual symptoms of sodic soils are dark brown crusts on the soil surface due to the dispersion of the soil organic matter. Because of the low infiltration, there will often be ponding in lower field areas. By the time visual symptoms are apparent in both the saline and sodic soils, the problem is severe and remediation will be difficult. The best method by far is yearly soil samples to monitor the progression of the soil.

Saline-sodic soils have mixtures of both problems. Fortunately, saline-sodic soils have good soil structure so water can still move through the profile. The salt in the soil helps to keep the soil flocculated and maintain its structure. The major concern is the large percentage of sodium on the exchange sites. Rain or irrigation water that is low in salts can easily leach the salts and cause the soil to become sodic.

Visual symptoms of the saline-sodic soil will be very similar to the saline soils, drought stressed plants in soils with adequate moisture. The can be a problem if a soil sample is not collected and analyzed. If the assumption is made that soil is saline and remediation practices for a saline soil a implemented then the problem will get even worse. It is very important that a soil sample be collected before any remediation is implemented.

Water Quality

Soils may have very little accumulation of salts from parent material or management practices. Irrigation water, however, can be a large source of soluble salts, particularly ions that have direct effects on plants such as boron. Unknowingly, high concentrations of salt can be added to fields via the irrigations system. It is very important to take a water sample at the same time you soil sample, if a salt or sodic problem is suspected. The quality of water is determined by measuring the EC and the sodium adsorption ratio (SAR). The SAR is the proportion of Na to Ca and Mg in the water. Electrical conductivity values for water will be much lower than soil EC for the severity of problem. Table 4 gives ranges of EC values for water and the corresponding severity of problem. These values can also be converted to an actual quantity of salt added per acre foot of water. This is calculated by multiplying the EC of the water by 640 to get ppm and then ppm is multiplied by 2.72 to get lb salt per acre foot of water. Thus water with an EC of 1.15 dS/m will have 2000 lb of salt per acre foot of water. To determine how much of this salt sodium is, an SAR needs to be calculated. Water that is high in salt or has a high SAR will have to be mixed with other water to be usable in many cropping systems or more tolerant crops will have to be used.

Lagoon water samples are treated the same as an irrigation water samples. Lagoon water from the average dairy in Idaho is only about 2-5% dry matter, the balance being liquid. Many lagoon water samples can have an EC of 2.5-6.0 dS/m, which is about 4,350-10,500 lb of salts per acre foot of water. This illustrates that a large amount of salt is being added to the soil when lagoon water is applied. Yearly soil samples need to be collected to ascertain the change in EC and what management practices need to be implemented

What can I do about a saline soil? Sodic soil? Saline-sodic soil?

A saline soil is the most common form of soil and of the three types it is the easiest to remediate. In order to bring the soil into full production, the soluble salts in the root zone need to be removed. This can be done in one of three ways. First the salts can be leached below the root zone with adequate low salinity water. Second, the salts can be removed from the system through leaching and artificial drainage. Last, the problem can be adapted to, by controlling the concentration and location of the salts at critical growth periods and/or selecting tolerant crops.

Leaching the salts is accomplished by using water which has an EC lower than the level we are trying to get the soil to. The soil will never be less saline than the salinity of the water that is being added. The first step is to determine the EC of the soil. As a rule of thumb, the EC will be lowered by 50% for every 6 inches of water applied. This does not mean that we only need to apply six inches and consider it good. Six inches of water needs to pass through the rooting zone. For instance, if the EC of a soil is 3.2 dS/m in the top 2 feet, then it will take 6 inches of water moving deeper than 2 feet to lower the EC to 1.6 dS/m. It will take another 6 inches of water to lower the EC to 0.8 dS/m. Infiltration is not a problem in saline soils, the problem comes in having a place for the water to drain. That question is beyond the scope of this paper and will not be addressed.

Shallow soils or soils with an impermeable layer that have become saline do not have the depth to leach salts below the root zone. To remedy this, artificial drainages must be built in order to move the salts from the root zone. However this may be unfeasible for a number of reasons. First, it may be economically impossible to build this type of structure. Secondly, if there isn't drainage for the system in place, then there has to be a way of getting rid of the drainage water. This in and of itself is a large problem and removes drainages as a reasonable option. This method is not an option for many fields in Idaho.

The final way of dealing with a saline soil is to irrigate in excess at times when the plant is most sensitive to the high levels or use irrigation practices that move the salts away, e.g. water every other furrow for instance to move salts toward the dry furrow and out of the root zone of a germinating seedling. Growing tolerant plants may be the only solution in soils with poor drainage and poor water sources.

Saline soils cannot be reclaimed by adding fertilizers, chemicals or any other soil amendments. Many of these amendments such as fertilizers, are salts themselves. By adding these or by misdiagnosing a problem as a nutrient deficiency will only exacerbate the problem. Removal of the excess soluble salts from the root zone is the only way to remediate a saline soil.

Sodic soils are caused by soluble salts, however because the soil is dispersed, leaching is not an immediate option. The first step in reclaiming a sodic soil is replacing the Na ion on the exchange sites with a divalent cation such as Ca. Soil amendments such as gypsum are applied to the soil and tilled under. The gypsum requirement can be calculated as follows:

$$GR = (presentESP - desiredESP) \times CEC \times 0.021$$

Where GR is the gypsum requirement, ESP is the exchangeable sodium percentage, CEC is the cation exchange capacity and 0.021 is a conversion factor that assumes CEC is recorded in meq/100 g of soil. Once the gypsum is worked in a given time to react with the soil, then irrigation water is applied to leach out the soluble salts. If the field is irrigated too soon, then the soluble salts will be leached out leaving Na still on the exchange sites and the soil will be worse than before. The key to reclaiming sodic soils is getting an adequate source of Ca to replace the Na on the exchange sites.

A saline sodic soil, fortunately, still has good soil structure and water moves easily through the profile. Like the sodic soil, the Na on the exchange sites needs to be replaced by Ca, as in the sodic soil. Once there is adequate Ca, then the salts can be leached. If the soil is heavily watered without Ca being added then the soluble salts will be removed, leaving the Na on the exchange sites. The soil particles will disperse and the structure will be lost. It will be nearly impossible to get water into the profile. It is important that the Na be replaced first before the soil is leached. If a saline problem is suspected always get a soil sample. Never implements practice to reclaim a soil without getting a soil and water sample.

Management in Idaho

The influx of Dairies into Idaho has brought an increase in animal manures and waste that needs to be disposed of. These products have great nutrient value and can be a source of cost savings to crop producers if managed wisely. Excessive applications and inadequate irrigation to leach salts from the manure has caused crop growth problems in many fields. This problem has been exacerbated as crop producers have switched from furrow irrigation to sprinkler irrigation. By trying to improve irrigation the probability of having a salinity problem has increased. Proper management can alleviate many of the problems that may arise. Here are some management tips to control salinity problems in manured fields.

- Calculate the leaching fraction and irrigate accordingly
- Irrigate in the fall when the soil is dry and water will move readily through the system
- Collect soil and water samples to follow trends of EC and Na (Just a good practice anyway for nutrient management)
- Put less manure on fields with poor infiltration and drainage

Very few fields in Idaho have a significant salinity or sodicity problem. It's important that steps be taken now to prevent more fields from having these a problems. Saline and sodic soils do not have to become a problem in Idaho. With wise management and the coordination of irrigation and animal waste application, Idaho soils can be managed.

Table 1. Salts common in Idaho soils. The first column contains the cation, the second column is the anion and the final column is the common name.

Common forms of salt found in soil		
Cations (+)	Anion (-)	Common Name
Calcium	Sulfate	Gypsum
	Carbonate	Calçite (lime)
Sodium	Chloride	Halite (table salt)
	Sulfate	Glauber's Salt
	Bicarbonate	Baking soda
	Carbonate	Sal soda
Magnesium	Sulfate	Epsom salt

Table 2. Accepted soil test values for designating saline, sodic and saline-sodic soils.

Class	Electrical Conductivity (dS/M)*	Exchangeable Sodium Percentage (ESP)	Sodium Adsorption Ration (SAR)	pH	Soil Physical Condition
Normal	<4.0	<15	<13	<8.3	Normal
Saline	>4.0	<15	<13	<8.3	Normal
Saline-Sodic	>4.0	>15	>13	<8.3	Normal
Sodic	<4.0	>15	>13	>8.3	Poor

Table 3. Relationship of 1:1 soil slurry EC to saturated paste EC.

1:1 Extract	Saturated Paste	Classifications
mmhos/cm	mmhos/cm	
0.01-0.45	0.01-2.0	Salt sensitive plants can be grown
0.46-1.5	2.01-4.0	Sensitive plants will be affected
1.51-2.9	4.01-8.0	Medium tolerant plants will be affected
2.91-8.5	8.01-16.0	Most plants will be affected
>8.5	>16.0	Severe saline conditions

Table 4. EC of irrigation water, crop requirements to tolerance and amount of requisite leaching.

Water Class	EC	Comments
Low	0-0.4	Most crops, most soils, some leaching
Moderate	0.4-1.2	Moderate tolerance, more leaching
High	1.2-2.25	Tolerant crops, well drained
Very high	2.25-5.0	Very tolerant, excess water, drainage