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An Introduction to Salt-Impacted Soils in South Dakota

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Overview

The intent of this publication is to serve as an introduction to salt-impacted soils for South Dakota landowners. It outlines the causes, classifications, ecological and economic effects, salt tolerance mechanisms, and remediation/restoration practices for affected soils.

Salt-impacted Soil: Cause and Classification

An estimated 3.4 million hectares of land in South Dakota have salt-impacted soil (Figure 1) (Seelig 2000; Millar 2003; Hopkins et al. 2012; Carlson et al. 2013; Soil Survey Staff). Salt-impacted soils are created by both natural and human actions. Naturally occurring salt-impacted soil results when salts accumulate in the soil through wind or rain deposition, from seawater intrusion, or soil parent material (Maas & Grattan 1999).

Figure 1. Salt-impacted soils in South Dakota.

In South Dakota, marine sediments in soil parent material have high salt concentrations. Salts move upward as soil moisture increases and accumulate at the surface after soil moisture evaporates (Rhoades & Halverson 1976; Seelig 2000; Carlson et al. 2016). Salts may also redistribute through wind to adjacent areas. Human actions that lead to salt impaction include fertilizer and other soil amendments (Rengasamy 2010), irrigation with saline water (Maas & Grattan 1999), roadway deicer application (Dudley et al. 2014), and oil and gas production (Merrill et al. 1990). Salt-impacted soil in South Dakota primarily occurs naturally, but human actions can also contribute.

Salt-impacted soils are categorized into three classes: saline, saline-sodic, or sodic. Saline soil has high amounts of salts (such as chlorides and sulfates of sodium, calcium, magnesium, and potassium), sodic soil has high amounts of sodium ions, and saline-sodic soil has high amounts of salts and sodium ions. Two soil tests can be conducted to determine these classes: sodium adsorption ratio (SAR) and electrical conductivity (EC). SAR measures the amount of sodium relative to the amount of calcium and magnesium. EC measures the concentration of salts in the soil (Brady & Weil 2000).

Consequences of Salt-Impacted Soil

Salt-impacted soil can decrease seed germination, plant growth, and survival by restricting water uptake and causing salt toxicity. Before plant growth, seeds first undergo imbibition and germination. Imbibition, or water uptake, is the first step in the seed germination process (Bewley & Black 1994). However, in salt-impacted soil, water uptake is restricted due to changes in osmotic potential and a lower amount of available water (Ryan et al. 1975). Consequently, seeds struggle to successfully take up water or germinate. In addition, salt-impaction can be great enough that it becomes toxic to seeds (Qadir et al. 2003; Greenberg et al. 2008). Any seeds that can still germinate, have problems with water uptake in salt-impacted soils. As salt concentrations increase, plant growth decreases (Munns & Tester 2008). Plants begin to accumulate salt within their leaves, leading to reduced growth and possible plant death (Munns & Tester 2008). Thus, even if seeds can germinate, it is difficult for many plants to grow and persist in salt-impacted soil.

Salt-impacted soil also has significant economic consequences. Excess salt decreases rangeland forage production and agricultural crop yield (Choukar-Allah 1996). Worldwide, annual land degradation caused by salt impaction results in a loss of $441 per hectare as of 2013, which is up from $264 per hectare in 1990 (Qadir et al. 2014; UNU-INWEH 2014). This equates to a projected annual loss in worldwide crop production of $27.3 billion (Qadir et al. 2014). Economic consequences of salt-impacted soil have been estimated in South Dakota. Specifically, in Beadle, Brown, and Spink counties, over 100,000 hectares of salt-impacted soil cause an estimated economic loss of $26.2 million per year (NRCS 2012).

Salt Tolerance Mechanisms

Plants possess mechanisms to tolerate adverse environmental conditions, such as salt-impacted soil. There are three mechanisms for salt tolerance: 1) tolerance of restricted water uptake, 2) exclusion of sodium ions and salts, and 3) tolerance of accumulated sodium ions and salts. The type of salt tolerance mechanism used depends on plant species, length of salt exposure, salt concentration, and local environment (Munns & Tester 2008).

As salt accumulates in soil, plants lose their ability to take up water. Most plants respond to restricted water uptake with slower growth. Some plants respond less severely and can still grow even with lower water uptake, because they can tolerate restricted water uptake.

Enough salts can accumulate in soil that they become toxic to plants. In response to salt toxicity, plants can either stop the accumulation (exclude) of sodium ions and salts or tolerate their accumulation. Some plant species have roots that stop sodium ions and salts from being absorbed into the plant and keep growing in salty soils.

Plant species with roots that do not stop the absorption of sodium ions and salts can respond by storing them in their cells. In contrast to plants that use the exclusion mechanism, which avoids the effects of salt toxicity, plants that store and accumulate sodium ions and salts experience delayed effects of salt toxicity.

Salt-tolerant Plants

We can categorize plant species based on their specific response to salts into three groups: halophytes, salt-tolerant non-halophytes, and salt-sensitive non-halophytes. Halophytes are plants that exhibit increased growth at low salt concentrations. In other words, halophytes are plants that grow better in salty soils than in non-salty soils. Salt-tolerant non-halophytes are plants that can grow in low salt concentrations (Barrett-Lennard 2002). Salt-sensitive non-halophytes do not grow even in low salt concentrations (Barrett-Lennard 2002). Salt-sensitive non-halophytes do not possess mechanisms for salt tolerance and therefore experience severely restricted water uptake and salt toxicity.

Common Remediation Practices

Commonly recommended practices of remediating salt-impacted soil were developed in different regions (primarily in the Southwestern U.S.). These practices, such as installing tile drainage, applying gypsum, and leaching salts with irrigation water, are ineffective at remediating salt-impacted soil in the Northern Great Plains (NGP), including South Dakota, and may even worsen the problem (Northcote & Skene 1972; McIntyre 1979). This is due to differences in rainfall, irrigation practices, and soil texture between the NGP and the Southwestern U.S. New practices, such as revegetation using native plants, are being researched in South Dakota, because common practices have proven ineffective in our state.

New Remediation Practices: Revegetation

Revegetation using native plants is a promising strategy in salt-impacted areas. By establishing native plants, ecosystems can begin to self-recover. The idea is that once salt-tolerant plants become established, their growth will jump-start the process to improve soil health and allow additional plants to become established. The roots of those first plants create spaces between soil particles as they grow. These spaces improve gas exchange and water movement which create conditions for more plants to become established (Elkins et al. 1977). Plant roots also help stabilize soil structure by releasing compounds that help aggregate soil particles (Bronick & Lal 2005). Stabilizing soil structure is important because it reduces erosion and helps regulate soil processes, nutrient cycling, productivity (Bronick & Lal 2005), root growth (Lal 1991), and water uptake (Rampazzo et al. 1998, Pardo et al. 2000). As plants decay and produce residue, the amount of soil organic matter increases, which improves soil health and allows even more plants to become established. Current research being conducted at SDSU seeks to identify native species that would be suitable to revegetate salt-impacted soils and jumpstart this self-recovery process.

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