Nature and management of salt-affected land in Saskatchewan

saskatchewan.ca/agriculture

Saskatchewan

Contents

The nature of salt-affected soils 3

Types of salt-affected soils 3
Saline soils 3
Properties of saline soils 3
Effects of salt on plant growth 4
The properties and distribution of solonetzic salts 5

How soils become salinized — Sources of salts 5

The salinization process 6
1. Artesian discharge 6
2. Evaporitic rings around sloughs 7
3. Side hills seeps 8

Management of salt-affected soils 8

Management of saline soils 8
Managing the recharge area 8
Managing the discharge area 9
Crop selection 9
Forage crops for saline soils 12
Manure and other mulches 13
Fertilizers 13
Tillage and weed control 13
Chemical amendments 14
Drainage and leaching 14
Management of solonetzic soils 15

Investigating and measuring salinity investigating soil salinity 15

Measurement of soil salinity in the laboratory 16
Saturated paste method 16
The 1:1 Soil:Water method 16
Measurement of soil salinity in the field 16
Chemical reactions and criteria for salt-affected soils 18
Cation exchange reactions 18
Criteria for defining salt-affected soils 19

Summary 20

The nature of salt-affected soils

Types of salt-affected soils

Many terms have been used to describe the different types of salt-affected soils. For example, to most farmers the word "alkali" means the "white spot where nothing grows". Strictly speaking, most of these white areas are saline rather than "alkali". Saline soils have a high concentration of soluble salts. True alkali soils are low in soluble salts but have a high sodium content and high pH (over 8.5). There are virtually no true alkali soils in Saskatchewan.

Solonetzic soils ("burnout soils") have a high sodium hard pan layer and often have a saline subsoil that restrict root growth. Therefore, they are a form of salt-affected soil. However, their properties and management are substantially different from those appropriate for saline soils. For more information on management of Solonetzic soils, refer to Solonetzic soils management publications. The primary purpose of this publication is to focus on the properties and management of saline soils.

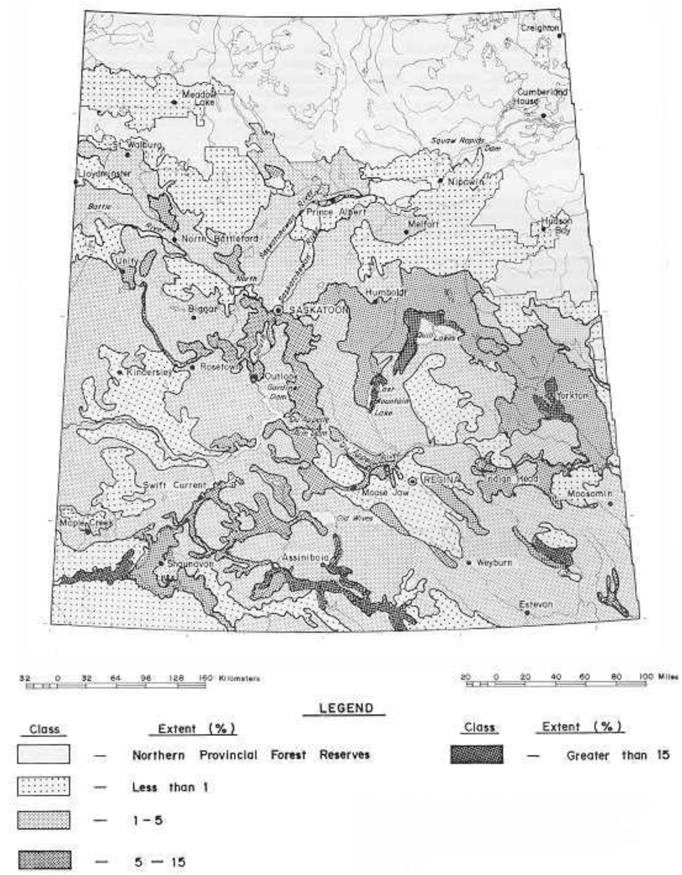

Figure 1. Areas of saline land in Saskatchewan. Map compiled by W. Eilers, G. Padbury and B. McCann, based on rural land assessment data supplied by SAMA.

Saline soils

Estimates of the total amount of saline land in Saskatchewan vary widely but all agree that at least several million acres are affected to some degree. For example, salinity deductions made by the Saskatchewan Assessment Authority (SAMA) suggest that an area equivalent to 600,000 acres of zero production due to salinity occurs within the currently cultivated area (G.A. Padbury, 1986, personal communication, Figure 1). More information can be found on the Saskatchewan Soil Information System (SKSIS) website.

Properties of saline soils

Saline soils have a high concentration of salts that dissolve in water. The soluble salts include: sodium sulphate (Glauber's salts), magnesium sulphate (Epsom salts) and calcium sulphate (gypsum). In a few small areas chloride salts are present, but in the majority of cases sulphate salts are dominant. The solubility of various salts is provided in Table 1.

Figure i. Salt crusts on the surface of the soil.

While calcium sulphate (gypsum) and calcium carbonate (lime) are present in most saline subsoils, their low solubility means that they do not harm plant growth as much as the other salts. Gypsum is frequently present in soils as clearly identifiable white or buff-coloured crystals. Lime is more difficult to identify visually but its presence is easily verified by effervescence (fizzing) upon application of dilute acid.

Detection of soil salinity is often easy. On saline soil, crops grow poorly or not at all. Particularly after a long dry period, the salts may precipitate on the soil surface as a white crust (Figure i). Where white crusts are not present it is sometimes possible to see streaks of salts by digging in the soil (Figure ii).

Table 1. Solubility of salts in pure water at 20 C

Salt	Chemical formula	Solubility (grams/litre)
Sodium sulphate	Na_2SO_4	160
Magnesium sulphate	$MgSO_4$	300
Calcium sulphate	$CaSO_4$	2
Sodium chloride	NaCl	264
Magnesium chloride	$MgCl_2$	353
Calcium chloride	$CaCl_2$	427
Calcium carbonate	$CaCO_3$	0.01

It is not always possible to see the salts. Laboratory soil analyses, field measurements and vegetation can be used to confirm their presence. The salt content of soil can be estimated by measuring its electrical conductivity (EC), which is usually expressed in deciSiemens per metre (dS/m) or millimhos/cm (mmho/cm). Laboratory analyses give the most accurate and detailed information but are slow and costly and provide information on only a small portion of the landscape.

Figure ii. Salt crystals and streaks in the soil.

Routine soil tests for fertilizer recommendations usually include an EC measurement. When moderate levels of salinity appear at lower sample depths, special management practices, such as those discussed in the "[Management of salt-affected soils]" section, may be required. However, the EC measured during soil tests for fertilizer recommendations are often different from those for which crop tolerances are given. For an explanation of the differences between methods of measuring EC, see "Investigating and measuring salinity investigating soil salinity". Direct field measurement of salinity is now possible using noncontracting conductivity metres such as the EM31 and EM38.

Generally, plants that are affected by soil salinity have a bluish-green appearance. In cultivated land, Russian thistle, Kochia, foxtail barley and goosefoot species indicate areas of high salt concentration. In uncultivated saline areas, plants such as samphire (Salicornia rubra), desert salt grass (Distichlis stricta), and greasewood (Sarcobatus vermiculatus) are frequently dominant species.

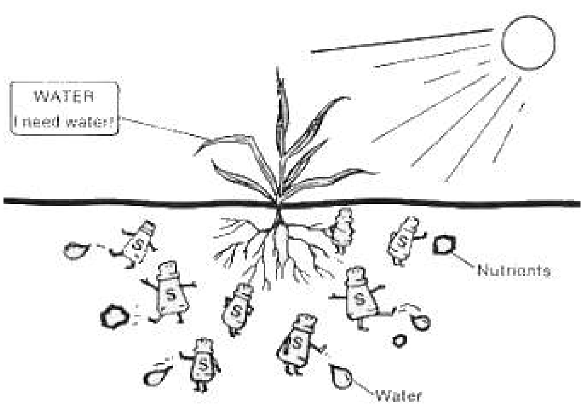

Figure 2. The presence of salts in the soil makes it difficult for crops to take up water and nutrients.

Effects of salt on plant growth

The primary effect of salts in soils is to deprive plants of water. Plants need both the water and the nutrients dissolved in it for proper growth. The sap in plant roots contains salt which attracts water into the plant via osmotic pressure. Dissolved salts in the soil increase the osmotic pressure of the soil solution. This decreases the rate at which water from the soil will enter the roots. If the soil solution becomes too concentrated the plants will slowly starve, though the supply of water and dissolved nutrients in the soil may be more adequate. Simply put, the salts prevent the water and nutrients from entering the plant (Figure 2).

Some plants may be adversely affected by high concentrations of certain elements, such as boron. In Saskatchewan, however, this does not appear to be a major cause for concern; we are dealing primarily with a problem involving a high concentration of total salts.

The properties and distribution of solonetzic salts

Solonetzic soils are of three types: Solonetz, Solodized-Solonetz, and Solod. We will consider the characteristics of the most easily recognized Solonetzic soil: the Solodized-Solonetz. As shown in Figure iii, this soil consists of three main layers (sometimes called "horizons") each of which is different in composition.

A horizon - Surface layer consists of two distinct levels, the Ah and the Ae. The Ah layer is high in organic matter; the Ae is highly leached, coarse-textured, and can be acid.

Bnt horizon - Upper subsoil level contains high amounts of clay and exchangeable sodium and is tough, dense, and impermeable, interfering with the penetration of both water and plant roots. It has a distinct round-top columnar structure.

Csa, Cca horizon - Usually has a high concentration of soluble salts (including gypsum) and lime. Thus it can be seen that Solodized-Solonetz soils exhibit the properties of acid soils in the A layer; sodic soils in the B layer; and saline soils in the C layer.

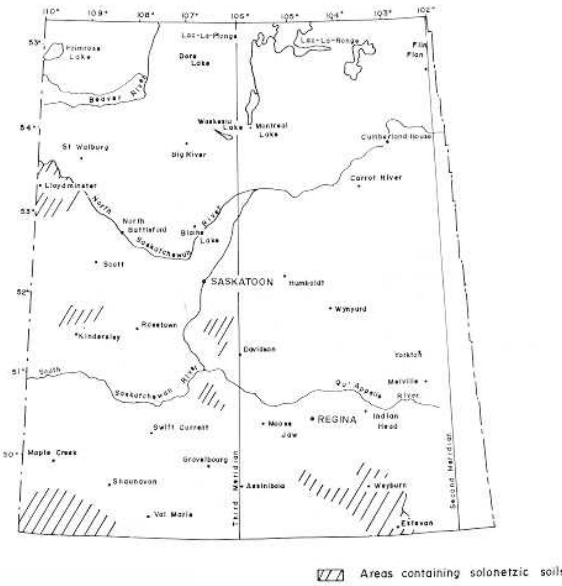

Figure 3. Major areas in Saskatchewan where solonetzic soils occur.

Solonetzic soils do not often occupy a large continuous area; they are more likely to appear as a number of distinct patches within a given field. In such fields wind and water erosion may completely remove the A horizon, leaving small scattered depressions in which crops do very poorly. Such is the origin of the term "burn-out", which refers to these small depressions and the "burned" crop within them.

The distribution of major areas of solonetzic soils in Saskatchewan is shown in Figure 3.

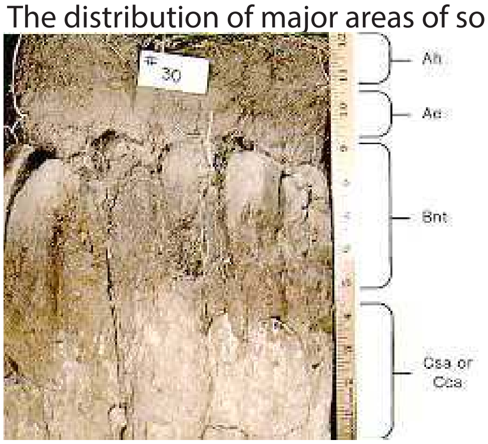

Figure iii. Solodized Solonetz soil profile.

How soils become salinized — Sources of salts

Weathering of rocks and minerals: Over a period of time salts contained in rocks and minerals are gradually released into the soil by chemical and physical weathering. It is important to realize, however, that weathering, alone, seldom produces a soil salinity problem.

Evaporation of ancient seas: In ancient times large areas of the province lay submerged under an immense sea. Gradually the sea disappeared, leaving marine shales with high concentrations of sodium salts. The movement of glaciers mixed the underlaying marine shale with surface deposits. In some areas, where glacial deposits are relatively shallow, the total supply of salts is large and the risk of salinity and other salt-related problems is very great.

Irrigation water: All irrigation water contains some salt. Over an extended period of irrigation, salts will accumulate in the soil and a salinity problem may develop. Water from the Saskatchewan River system being used in major irrigation projects is of high quality and there is little risk of salt buildup. However, farmers considering the development of small irrigation systems utilizing sources of water such as ponds, sloughs or ground water may face salinity problems. Any water source for irrigation should be analyzed to make certain that it will not result in a buildup of salts.

Most of the salinity associated with irrigation is not due to the addition of salts in irrigation water. Rather it is due to the redistribution of existing salts in the soil. Canal seepage or excess irrigation may raise the water table increasing the risk of salinity.

Saline areas are often excessively wet due to a high water table.

The salinization process

Salinity is more of a water problem than soil problem.

As described previously, weathering of rocks and minerals, alone, seldom produces a soil salinity problem. Because the salts are soluble, water moves and accumulates them in some parts of the landscape. To understand how these salt accumulations occur we must understand the movement of underground water. Salts can invade any type of soil, productive or unproductive, and when this invasion occurs, otherwise highly productive soils can be converted to unproductive soils.

A prerequisite for soil salinization is a free water table close enough to the soil surface to allow capillary (wick) action to lift the water from the free water table to the soil surface (Figure 4). Generally, if the water table is within two metres (six ft.) of the soil surface, capillary movement will carry water to the surface. However, the critical depth varies with soil texture. It is important to note that a high water table alone is not sufficient to cause soil salinization. It is not uncommon to find sloughs and depressions in Saskatchewan with water tables very near to the soil surface but because of the constant input of fresh runoff water the net movement of water in these sloughs is downward and hence they are not salinized. A high water table plus evaporation exceeding infiltration are both required for the salinization process. In other words, the salinization process is solar-powered. In a semi-arid climate, warm temperature, low humidity and wind evaporate water at the soil surface and cause salt accumulation.

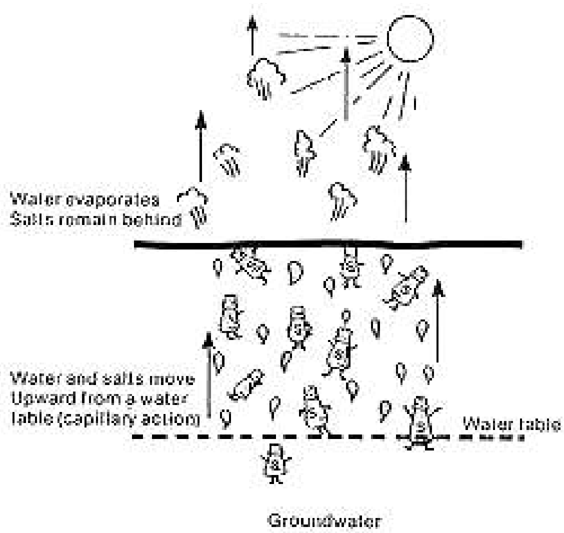

Figure 4. Salts build up on the surface where a shallow water table exists and where evaporation exceeds infiltration.

Simply put, salt accumulation occurs whenever the quantity of water leaving the soil surface by evaporation exceeds the quantity of water that enters the soil through rainfall, runoff accumulation, or irrigation. If this very simple principle is kept in mind it should be relatively easy to understand the situations that are observed in the field.

The high water table required for salinization to proceed can be a result of several ground water movement patterns. Water enters the ground water system in the recharge area where infiltration exceeds evaporation for at least part of the year. Groundwater flows in water bearing layers called aquifers to lower positions in the landscape. Salinity develops in the discharge area where the water is near the soil surface (within two metres) and where evaporation exceeds infiltration. What follows is the discussion of the major underground conditions resulting in high water tables and salinization in Saskatchewan.

1. Artesian discharge

Artesian discharge occurs where the pressure in the aquifer is sufficient to force water to near the surface of the soil. Research in Saskatchewan has shown that artesian discharge from aquifers of both glacial and bedrock origin is the major factor responsible for high water tables and soil salinization. The term "bedrock" refers to deposits that were present prior to glaciation and does not mean solid rock. Thus, when we speak of bedrock aquifers, we mean sand layers within bedrock formations.

A salt crusts forms when saline water evaporates, leaving the salt behind.

The mechanism of soil salinization by artesian discharge is shown by a generalized diagram in Figure 5. The water entry to the aquifer is in the upland area, for example, in the hummocky moraine of the Missouri Coteau. In these hilly areas the recharge to the aquifer is concentrated primarily in sloughs or depressions and during periods of high precipitation or runoff. These recharge areas may be at a great distance away form the saline area. Any factors such as excess summerfallow or cultivation which increases runoff into the sloughs will have the long term impact of increasing the water in aquifer and hence increasing salinization. However, saline areas have also been encountered where the adjacent upland is in native pasture.

If, as illustrated in Figure 5, the sand or gravel deposit of the aquifer "pinches out", then a pressurized situation results such that upward flow of water from the aquifer to the soil surface takes place. In such areas the water in farm wells comes close to the soil surface or may actually flow. There is a strong relationship between areas of flowing wells and areas of salinity problems.

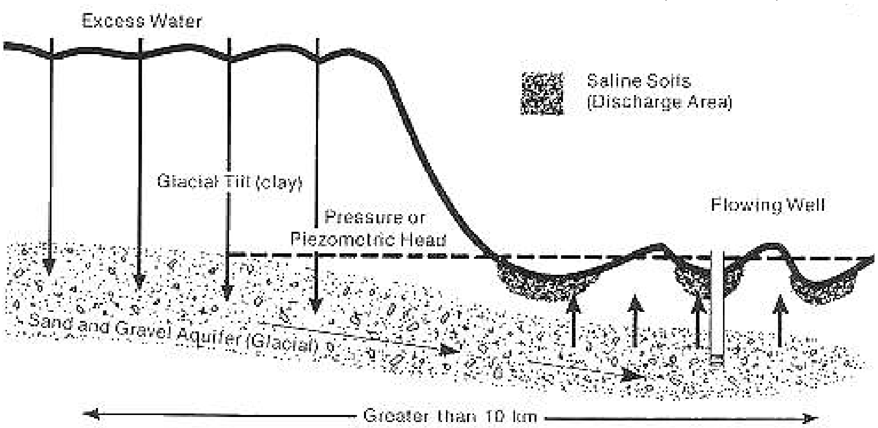

Figure 5. Regional artesian discharge mechanism of salinization.

In such areas the water table will be maintained close to the soil surface by the slow but constant upward movement from the aquifer. Land at or below the elevation to which water rises in wells will be at high risk for soil salinization. The actual amount of salinization will depend upon the pressure of the water in the aquifer, the salt content of the water and the extent to which the overlaying layers control upward movement.

Salinization by artesian discharge has been going on over the many centuries since the last glaciers receded from the settled areas of Saskatchewan.

2. Evaporitic rings around sloughs

In much of the thickly glaciated areas of Saskatchewan the landscape is characterized by a series of undrained depressions called potholes or sloughs. In these areas external drainage from the immediate site is limited and most of the drainage is from the hillside to the depression. When these sloughs occur in upland areas with no impediment to downward drainage, they form the focus for ground water recharge. In recharge areas ground water mounds form but the net movement of water is downward both in the slough and in the area adjacent to the slough. However, when these sloughs occur in lower lying areas in which deep drainage is limited by an impermeable barrier or ground water pressure, the groundwater mounds can cause salinization. The

Flowing wells are common in areas where soil salinity is caused by artesian discharge.

Saskatchewan

combination of a high water table and evaporation results in an evaporitic ring of saline soil around the edge of the depression as shown in Figure 6. Other depressions including dugouts and ditches may also form salinity in this manner.

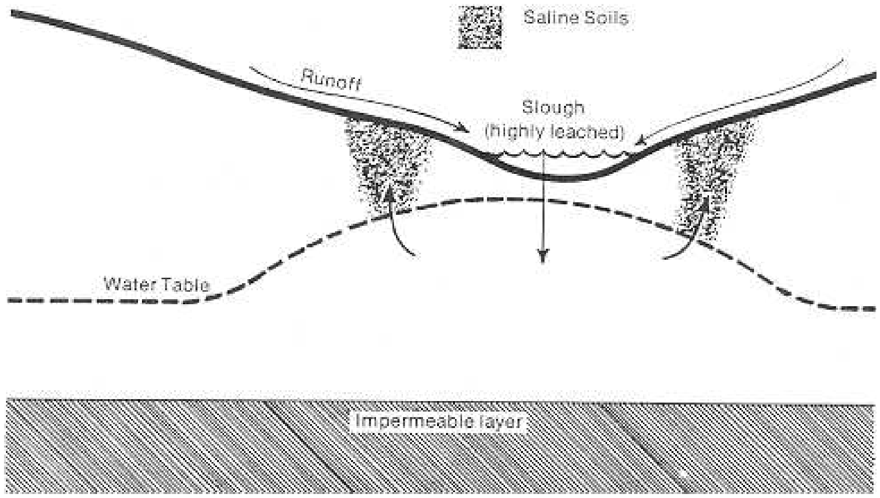

Figure 6. Evaporitic ring mechanism of salinization.

3. Side hills seeps

Where glacial deposits are very shallow and rest upon impermeable bedrock shale, salinization can be caused by lateral water movement along the impermeable shale surface (Figure 7). In this mechanism of soil salinization the recharge area and the discharge area are near each other and may be in the same field. With this type of salinization the changes in hydrologic cycle that have been brought about by cultivation of prairie lands has been a major factor in causing and increasing the severity of salinity. For similar reasons, changing cropping practices may allow a farmer to control saline seeps. However, recent salinity investigations indicate that side hill seeps are not as common in Saskatchewan as has been reported in other areas in the Northern Great Plains of North America.

The causes of soil salinity in a particular field are generally not as simple as describe above. A combination of these mechanisms is usually involved.

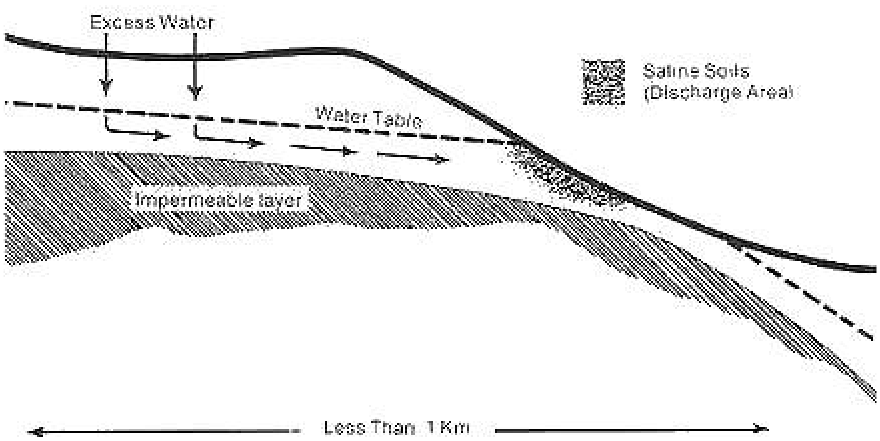

Figure 7. Local side hill seep mechanism of salinization.

Management of salt-affected soils

Management of saline soils

In recent years there has been growing concern over the increasing problem of cropping saline areas. Although Saskatchewan had soils affected by salinity long before agricultural settlement, man's activities have aggravated the problem increasing the incidence, extent and severity of soil salinity. The increasing problem is due to changes to surface drainage and cropping techniques that are not as water efficient as the native Prairie grasslands.

There are no easy or magical cures for soil salinity. Salinity must be regarded as a production limitation in the same way as stoniness and steep slopes. Unique management practices may always be required. For example, many saline soils may never be suitable for summerfallow crop production.

Water management is the key to controlling salinity. The degree to which water movement can be managed determines the feasibility of controlling the salinity problem. Therefore it is at least as important to manage recharge as it is to cope with discharge of ground water.

Managing the recharge area

Any excess moisture that recharges the ground water can eventually cause salinity in a discharge area. Preventing the accumulation and deep percolation of excess water in the recharge area is important for controlling the salinization process at its point of origin. In some mechanisms such as in the artesian system the recharge area may be very extensive and far away from the salinity problem. It may not be practical to control recharge in these cases. For that reason, prior to attempting recharge management, an investigation should be conducted to determine the salinity system and to accurately identify the area and the amount of recharge that may be occurring locally.

Excess water in recharge areas is often the result of natural and manmade ponding, excess accumulations of snow, the growing of annual instead of perennial crops and excessive summerfallowing. Recharge of ground water is most likely during months or years when rainfall or snowmelt runoff is high and where soils are coarse-textured.

Control of ground water recharge can be obtained through removal of the excess water by improving drainage or cropping practices that use up more of the moisture. Wherever possible, recharge water should be used locally. Recharge water is usually non-saline and should be treated as a valuable resource.

Surface drainage using an open trench or buried pipe will remove the water before it has a chance to infiltrate and recharge the ground water table. In some cases sloughs or ponds may be consolidated to provide a water source for irrigation or other uses. Subsurface drainage may also be effective if a suitable outlet is available. Care should be exercised when altering natural drainage. Some drainage practices may aggravate local salinity problems and permission should also be obtained from the Water Security Agency.

Continuous cropping or growing perennial forages uses up more recharge water than summerfallow cropping. See Figure 8. Regardless of crop rotation length, adequate fertilization will encourage better use of soil moisture. Where recropping is attempted, snow trapping may be used to increase soil moisture and to distribute snowmelt water uniformly. Snow should be managed in a way that barriers will not accumulate excessive amounts of snow in one location.

Deep-rooted forages grow very well where there is a high water table in the recharge area. Alfalfa is the deepest rooted and highest moisture use forage, so it is the preferred species for recharge control. For more information on forage crop management please contact the Saskatchewan Ministry of Agriculture's Agriculture Knowledge Centre, toll free 1-866-457-2377.

Managing the discharge area

Managing the discharge area is difficult because there are excesses of both water and salts. The objective of discharge area management is to establish crop growth while attempting to move the salt downward. In most dryland situations it is unlikely that the salts can be removed entirely. However, lowering the salt concentration in the top 30 cm will often improve production dramatically. Even so, particularly reclaimed saline areas will always require special management practices.

Crop selection

Crop selection is the main management practice that a farmer can use to combat a soil salinity problem in the discharge area. Leaving the soil bare promotes evaporation and salt accumulation at the surface. Therefore fallowing or growing non-tolerant crops aggravates salinity problems.

The tolerance of various annual, forage and vegetable crops is shown in Table 2. Barley, sunflower and safflower are the most

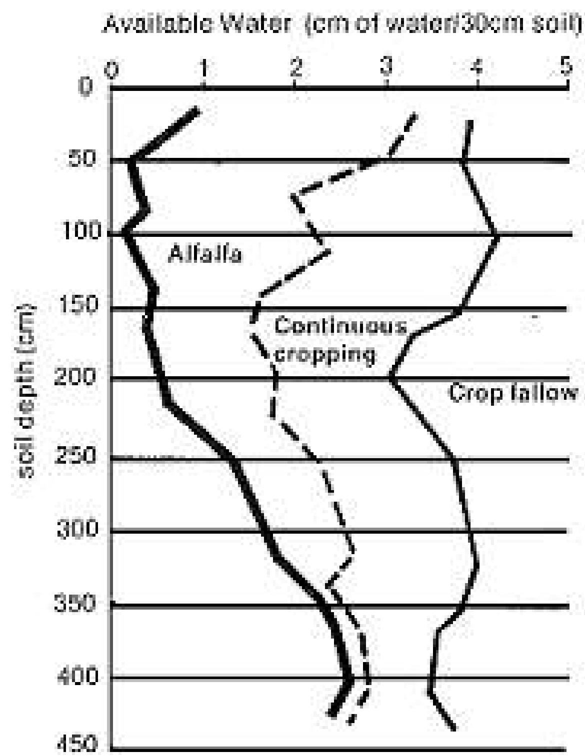

Figure 8. Available soil water under various crop systems, fall 1978 (Brown, USDA, Montana).

tolerant of the annual crops grown in Saskatchewan. In most saline management cropping situations, barley becomes the mainstay of the cropping program. While continuous cropping to one annual plant species is not a general agronomic recommendation, it may have a role in management of moderately saline soils. Close attention to disease problems will be required and if disease becomes significant, changes in the cropping pattern will be required.

Table 2. The relative tolerance of crops to salinity*1

Degree of Salinity Tolerated (Electrical Conductivity)*2	Annual Field Crops	Forage Crops	Vegetable Crops
Non to Slightly Saline (0-4)	Soybeans Field Beans Fababeans Peas Corn	Red Clover Alsike Timothy	Peas Beans Onions Celery Radishes Cucumber Carrots Corn (sweet)
Moderately Saline (4-8)	Canola Flax Mustard Wheat Fall Rye*3 Oats Two-Row Barley*3 Safflower Sunflower Six-Row Barley*3 Sugar Beets	Reed Canary Meadow Fescue Intermediate Wheat Crested Wheatgrass Bromegrass Alfalfa Sweet Clover*3	Tomatoes Lettuce Cabbage Potatoes Peppers Spinach Asparagus Garden Beets
Severely to Very Severely to Saline (8-16)	Barley may produce some crop but this land best suited to tolerant forages.	Altai Wild Ryegrass Russian Wild Ryegrass Slender Wheatgrass Tall Wheatgrass Beardless Wild Ryegrass Levonns alkaligrass Alkali sacaton Salt Meadow Grass	

Crops within each group are listed in order of increasing salt tolerance.

***1 Differences of one or two places in the rank may not be significant.**

***2 Rating for salt content in dS/m conductivity in saturated paste. For more information about conductivity, see the "Investigating and measuring salinity investigating soil salinity" section.**

***3 These crops are not tolerant of flooding, which is common in some saline soils.**

If economic yields of annual crops cannot be maintained on saline land, then perennial forage production is the only management practice that can be recommended.

Forage crop mixtures for varying levels of soil salinity and degrees of spring flooding is provided in Table 3. As a general rule, mixtures of grasses and legumes are seeded so that at least some plant species will establish in even the most saline area and the more valuable species will grow on less saline portions of the field.

The major reason for failure of forage crops to establish is seeding into seedbeds that are too loose and seeding depths that are too great. Forage crops, in general, are small seeded crops that require careful seedbed preparation and shallow seeding for successful establishment. Consult forage crop pubilcations for details on varieties and seeding practices.

Table 3. Forage crops for saline soils and flooded ares, 15 to 18 cm (6 to 7 in.) row spacings*1

Salinity rating*2	Crop or mixture	Seeding rate for hay or pasture lb./ac. or kg/ha
	Soils with little or no flooding (up to two weeks)	
Slight to moderate (2-6 dS/m)	Bromegrass+Russian wild ryegrass+alfalfa	4+4+4
	Bromegrass+slender wheatgrass+alfalfa	4+4+4
	Russian wild ryegrass+alfalfa	6+3
	Altai wild ryegrass+alfalfa	10+3
	Crested wheatgrass+alfalfa	7+3
	Altai wild ryegrass	11
	Slender wheatgrass+sweet clover (short-term stands and not over 1 week of flooding)	8+6
Severe (6-10 dS/m)	Bromegrass+Russian wild ryegrasss+slender wheatgrass	4+4+4
	Altai wild ryegrass+alfalfa	10+3
	Altai wild ryegrass	11
	Tall wheatgrass (moist districts of seepage areas)	12
Very severe (10-15 dS/m)	Russian wild ryegrass+slender wheatgrass	4+4
	Altai wild ryegrass+alfalfa	10+3
	Altai wild ryegrass	10
	Tall wheatgrass (moist districts of seepage areas)	12
	Spring flooded (two to five weeks)	
Little or none (up to 2 dS/m)	Reed canarygrass + bromegrass	4+6
	Reed canarygrass+timothy	4+4
	Timothy+bromegrass	4+6
	Altai wild ryegrass+alfalfa	10+3
	Altai wild ryegrass	11
Slight to Moderate (2-6 dS/m)	Reed canarygrass + bromegrass	4+6
	Reed canarygrass+bromegrass +slender wheatgrass	4+6+6
	Altai wild ryegrass+alfalfa	10+3
	Altai wild ryegrass	11
Severe to Very Severe (6-15 dS/m)	Altai wild ryegrass+alfalfa	10+3
	Slender wheatgrass	8
	Altai wild ryegrass	11
	Tall wheatgrass	12

***1 For more information, see Forage Crop Production Guide or contact the Agriculture Knowledge Centre toll free at 1-866-457-2377.**

***2 Rating for salt content in DS/m conductivity in saturated paste. For more information about conductivity see the "Investigating and measuring salinity investigating soil salinity" seciton.**

Forage crops for saline soils

1. The standard grasses: Crested wheatgrass and Bromegrass show relatively equal tolerance to salts.

   These standard grasses do not establish nearly as well under salinity stress as do the salt tolerant types. Outside the saline area they establish more easily and are more competitive with weeds.

   Consequently, the standard grasses should be a part of any seeding mixture for saline land, because of the wide range of salinity levels usually present.

2. The legumes: Sweet clover and Alfalfa have salt tolerances somewhere between standard grasses and salt-tolerant grasses.

   Alfalfa and sweet clover are the backbone of salinity reclamation. Both fix their own nitrogen when properly inoculated and are capable of prolific growth under good moisture conditions. Sweet clover establishes easily and grows vigorously in saline conditions. It is a proven green manure crop for soil improvement. The one drawback is its short life (biennial).

   Alfalfa is a long-lived perennial legume. Alfalfa has a deep tap root system and once established provides excellent production for many years. Alfalfa should be a part of any forage crop mix for salt-affected land.

3. Common salt-tolerant grasses: Altai wild ryegrass, Tall wheatgrass, Russian wild ryegrass and Slender wheatgrass show relatively equal salt tolerance, but have different roles in saline soil management.

   Slender wheatgrass exhibits greatest ease of establishment followed by Russian wild ryegrass, Tall wheatgrass and Altai wild ryegrass. Slender wheatgrass is short-lived and best suited to short-term rotations. Under dry conditions slender wheatgrass is more salt tolerant than Tall wheatgrass. Altai wild ryegrass is a grass with very limited creeping ability and is most useful in pasture situations. It has a high degree of tolerance to soil salinity and has the deepest rooting system of any grass species, but is slow to establish.

   Russian wild ryegrass is similar to Altai wild ryegrass in salt tolerance and is a bunch grass most useful in pasture situations. However, Russian wild ryegrass is not as deep-rooted as Altai. Russian wild ryegrass often establishes very slowly and patience will be required when establishing this crop.

   Tall wheatgrass is the most salt-tolerant and will produce the largest yield of forage hay. It is also the most tolerant to flooding and extremely wet conditions, and as such, is most useful in seriously salt-affected areas. While Tall wheatgrass is the most salt-tolerant, it is not the most palatable or nutritious livestock feed and will require mixing with other forage species in any feeding program.

   These grasses, although highly salt tolerant are slow to establish and do not compete with weeds during establishment. Weed encroachment in the seedling stage, whether under saline or normal soil conditions, is undoubtedly the biggest handicap to satisfactory forage establishment. Under saline conditions typical problem weeds include wild barley ("foxtail"), kochia, the goosefoots, and pigweeds. For more information on weed control, see the Guide to Crop Protection or contact the Agriculture Knowledge Centre.

   Because of their high salt tolerance, the accepted salt tolerant grasses should be a part of the seeding mixture for saline land.

4. The "exotic" grasses: Shoshone beardless wild ryegrass, Levonns alkaligrass, Salt Meadow Grass and Alkali sacaton exhibit remarkable tolerance to very high salinity levels. Limited testing suggests decreasing tolerance in the order listed. These grasses appear to thrive at conductivity levels of 20 dS/m or more. The very small seeded Salt Meadow Grass and Levonns alkali-grass, however, are very difficult to establish and require extra firmness of seedbed and very shallow seeding. The larger seeded Shoshone beardless wild ryegrass, being close to Russian wild ryegrass in seed size, appears to establish similarly to Russian

wild ryegrass under normal soil conditions and has a creeping habit enabling it to fill into bare areas. Seed of these exotic grasses may not be widely available and may be expensive.

5. Kochia (or "summer Cypress") has long been considered a weed. Recently, agronomists have noted its ability to colonize bare saline patches where no other plants will grow. Kochia will reseed itself naturally if allowed to, but the soil must be worked at least once each year or else the Kochia stand will 'self-suffocate'. Kochia may be used as a feed, but it can be toxic under some circumstances, especially when fed in excessive amounts. For more information contact the Agriculture Knowledge Centre.

   The precise place of Kochia in salinity management is not yet known, but research is continuing.


Altai wild ryegrass growing on saline soil.

Manure and other mulches

Application of high rates of manure, 40 to 60 tonnes/hectare, have improved crop establishment and crop yields on saline soils. Manure increases the organic matter content and water-holding capacity of the soil. In this way more water is available to plants even though salts are present. Manure also adds nutrients and improves the structure or tilth of the soil.

Neither fertilizers nor manure actually get rid of the salts. Better crop growth can result from fertilizer or manure and more moisture will be used. Manure will also assist in water movement through the soil to leach the salts down.

For short periods of time, when the manure mulch is present on the soil surface, it reduces evaporation and concentration of salts at the surface of the soil. Other forms of mulch such as straw probably perform the same function. When a mulch is present and significant precipitation occurs, some leaching of salts out of the surface layer may even be possible.

Fertilizers

On moderately saline soils the use of phosphate fertilizers with the seed of cereal grains has given excellent yield increases. Nitrogen fertilizers do not usually provide much yield response in the most seriously salt-affected area but if salinity is scattered within a field the nitrogen fertilizer should be applied according to soil test recommendations for the non-saline areas. Interpretation of nitrogen soil tests is often complicated by the presence of salts, so areas which are obviously saline should not be sampled. Special attention should be paid to the location of available nitrogen in the soil profile under saline soil conditions. If the subsoil is saline it will usually contain a high concentration of nitrate-nitrogen which may not be useful to plants.

Perennial grass crops will respond strongly to high application rates of fertilizer in years of average or above-average rainfall.

It should be emphasized that fertilizer use is one additional aid in crop production on some moderately saline soils. However, fertilizer use will not solve the problem of salinity itself in these soils and does not result in any "neutralization" of the salts.

Tillage and weed control

Since salt concentrations in subsoil are frequently higher than they are at the immediate soil surface, shallow tillage is generally recommended for saline soils. Deep tillage may, in many cases, bring more salts to the surface and make the problem worse.

Tillage practices should maintain all possible residues at the soil surface.

Shallow seeding is just as critical on saline soils as it is on normal soils. Timeliness of seeding is particularly important for small seeded crops such as flax, alfalfa, sweet clover and canola. These crops should be seeded early to have them germinate when surface salt concentrations may be temporarily lowered.

A number of weeds mentioned earlier are very tolerant of salts. Chemical weed control along with tillage is essential to get crops, particularly forages, properly established.

Chemical amendments

There are no chemical amendments that will "neutralize" the salts present in the soil. The salts that are causing the problem are neutral salts (neither acid nor base).

In areas of the world where true alkali soils exist, the application of elemental sulphur or gypsum can have beneficial effects. Elemental sulphur applications assist in reducing the pH where an extremely high pH is the problem. The gypsum applications supply calcium to replace the sodium and improve the soil structure. However, as we have no true alkali soils in Saskatchewan these applications would be of no benefit. In most areas of saline soils, gypsum (calcium sulphate) is one of the major salt constituents and the application of additional gypsum would simply be supplying more of the same material that is already present in abundance.

Drainage and leaching

One way to reclaim saline soils and restore their productivity is to install drainage (such as tile drains) and then provide a source of leaching water. In irrigation areas drainage for salinity control may be feasible because there is usually enough water to leach the excess salts out of the soil. However, in dryland areas drainage is seldom an economically viable proposition. Desalinization of dryland soils takes place very slowly upon installation of drainage without extra water to leach the salts out of the soils.

Most installations of underground perforated plastic pipe for drainage and reclamation of soils in Saskatchewan have not been successful. These failures have been due largely to the fact that the soils in which they were installed were extremely fine-textured and slow draining and no provision was made for the application of leaching water.

The installation of perforated plastic drain pipes is not recommended as a reclamation practice for saline soils unless a specific site investigation suggests that the practice will work and a permit has been obtained.

In some dryland areas it may be possible to improve surface drainage in recharge areas where small sloughs or other water bodies are contributing to the problem. For example, in areas where local saline seeps have been identified, it may be possible to determine a source of surface water (such as an upland slough) which is contributing to the problem and to drain that particular water body.

Drainage is a very controversial issue because one might always be concerned with where the water is going. There is little point in solving a problem on one field if it is simply contributing to the further development of a problem on an adjacent field. For this and other reasons, it is presently illegal to undertake drainage of any kind without a permit.

A new possibility for drainage and leaching exists in those areas where salinity is caused by artesian discharge from shallow glacial aquifers containing only moderately saline water dominated by calcium and magnesium salts. It may be possible to utilize this water for irrigation and at the same time lower the pressure of the water in the aquifer and provide the necessary conditions for leaching the salts downward. However, this technology needs to be proven.

Management of solonetzic soils

The main areas of Solonetzic soils in Saskatchewan are shown in Figure 3. It is not the purpose of this publication to present detailed information on Solonetzic soils. For further information on Solonetzic soils, please refer to Solonetzic soils management publications.

The major management tool available for managing solonetzic soils is timeliness of tillage operations. Tillage operations and seeding must be done when the soil is at the correct moisture content. If the soil is worked when it is too wet, the structure breaks down completely. If tillage is left too late, the soil bakes and it becomes almost impossible to get proper penetration of tillage implements.

Deep plowing is expensive but breaks up the hardpan and brings up calcium to help reclaim true Soloetzic soils. Deep plowing is not recommended for saline soils.

Deep plowing or deep ripping to a depth of 45 to 75 cm (18 to 30 in.) is a reclamation practice for Soloetzic soils, which has proven beneficial in Alberta and North Dakota and, more recently, in the Weyburn area of Saskatchewan. However, deep plowing at insufficient depth or where the subsoil is very saline or stoney can do more harm than good.

Before proceeding with any deep plowing projects the farmer should seek professional advice and refer to Solonetzic soils publications to be certain that his problem is in fact one of Solonetzic soils and that the plowing operation has some chance of success.

Deep plowing is not a management or reclamation practice for saline soils.

Investigating and measuring salinity investigating soil salinity

The causes of soil salinity vary from site to site and so do the appropriate controls. Because salinity control is often costly and risky, an investigation should be carried out if possible.

This durum wheat field in the Weyburn area responded very well to deep plowing, even in a wet year.

Detailed salinity investigations consist of:

- Collecting and interpreting:
  - Existing water well information;
  - Aerial photographs; and
  - Soil survey maps;
- Field inspections to observe the extent and severity of salinity;
- Drilling to:
  - Determine geologic material;
  - Identify water bearing layers; and
  - Install water table observation wells and piezometers (see Figure 9); and
- Monitoring to determine:
  - Water table elevations; and
  - Response to recommended controls.

In most cases, a detailed salinity investigation requires hydrological expertise and expensive equipment. For more information, contact the Agriculture Knowledge Centre or PFRA offices.

Farmers play an essential role in investigating salinity because of their long term experience in the local area.

If the salinity is recent or it is changing in size, there may be some hope for reclamation if the recharge mechanism is clearly identified and manageable. If salinity is known to have been present for many years, it is unlikely to be reclaimable for normal crop production. The occurrence of flowing wells or regional water tables within two metres (six ft.) of the soil surface may indicate a ground water recharge system that is too large for a single farmer to control.

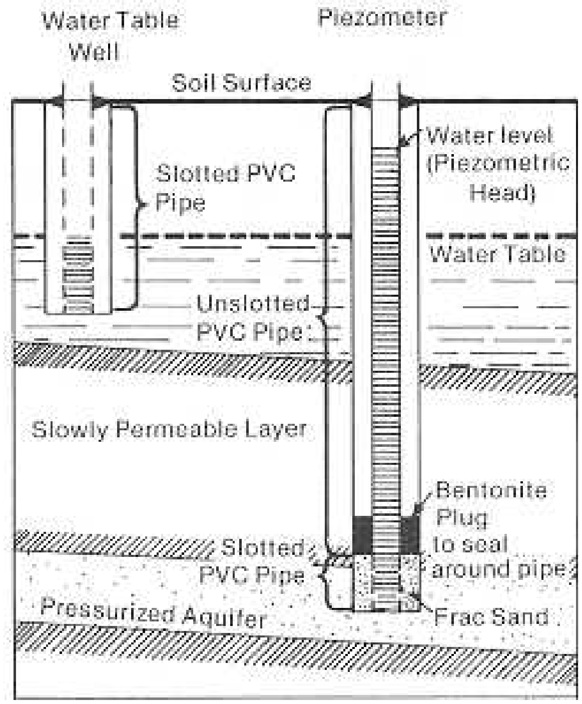

Figure 9. Water table well and piezometer construction. Note: Many small diameter farm wells are, indeed, piezometers because they intercept water from a specific water-bearing layer.

Measurement of soil salinity in the laboratory

Saturated paste method

In this method water is added to a given weight of soil until the soil is saturated and just reaches the flow point. This condition is referred to as a saturated paste. The **saturated paste** is allowed to sit for approximately two hours to reach equilibrium. At that time the water present in the paste is extracted with the aid of a suction apparatus. This extract is referred to as the **saturation extract**. The **electrical conductivity** of this extract is then measured. The higher the salt concentration in a specific soil the higher will be the conductivity of the saturation extract. The conductivity is expressed in deciSiemens per metre (dS/m) or millimhos per centimetre (mmho/cm).

Conductivity values determined on a saturation extract have been the standard method of measuring soil salinity by research workers throughout the world for many years. Thus, almost all available research data on crop tolerance is related to the saturation extract values.

Unfortunately, the determination of salt content of the saturation extract method is too costly and time consuming to allow this method to be used routinely.

Detailed salinity investigations consist of many steps including drilling to identify the origin of the excess ground water.

The 1:1 Soil:Water method

Use the 1:1 Soil to Water quick test during routine soil analysis for fertilizer recommendations. In this method a given weight of water is added to the same weight of soil to provide a suspension. This suspension is allowed to equilibrate for a short period of time (approximately one half hour). At this time a conductivity probe is inserted in the suspension and conductivity reading is made directly. Thus, laborious paste preparation and vacuum extraction is not required.

The actual conductivity value obtained by the 1:1 suspension method is not as easily interpreted as that for the saturated paste. However, recent research work has determined the relationship between the values obtained by the different methods. This relationship varies for soils of different texture as outlined in Table 4.

Measurement of soil salinity in the field

The development of non-contacting terrain conductivity metres in the past decade has been a major advancement in the capability to assess saline soil conditions in the field. The most common units in use today are the Geonics EM31 and EM38. The EM31 unit can assess conductivity to depths of approximately six metres with the instrument in the vertical orientation and approximately three metres with the instrument in the horizontal orientation. EM31 units are used extensively for a variety of purposes besides salinity monitoring, including tracing pollutants in underground water systems. The EM31 unit is rather large, requires approximately five or 10 minutes to set up and break down at the beginning and end of a job and quickly becomes a physical burden in extensive field investigations. For this reason the EM31 in now used only in situations where there is a specific desire for the greater depth capability of this instrument.

Table 4. The relationship of electrical conductivity (EC, dS/m) of the 1:1 suspension to that obtained by the saturated paste method.

Salinity rating for top 60 cm (2 ft.)					
Texture	**Non-saline**	**Slightly saline**	**Moderately saline**	**Severly saline**	**Very severely saline**
EC, 1:1 suspension (dS/m)					
Sand, Loamy					
Sand	0-0.7	0.8-1.5	1.6-3.0	3.1-6.1	6.2+
Sandy Loam	0-0.8	0.9-1.6	1.7-3.3	3.4-6.6	6.7+
Loam	0-0.9	1.0-1.8	1.9-3.6	3.7-7.2	7.3+
Clay Loam	0-1.0	1.1-2.0	2.1-4.0	4.1-8.0	8.1+
Clay, Organic	0-1.1	1.2-2.2	2.3-4.4	4.5-8.8	8.9+
Saturation Extract, EC	0-2	2-4	4-8	8-16	16+

EC Ratios of Saturated Extract to 1:1 Suspension for Various Soil Textures

Texture	EC, saturated extract/1:1 suspension
Sand, Loamy Sand	2.6
Sandy Loam	2.4
Loam	2.2
Clay Loam	2.0
Clay, Organic	1.8

The most popular instrument now in use is the EM38. The EM38 unit senses the average or bulk conductivity of approximately the surface 1 or 1.2 metres with the instrument in the vertical position and approximately 0.5 metres with the instrument in the horizontal position. Thus, the readings it provides are of direct application to the root zone of crops, making the EM38 unit a useful sensor of soil salinity in the field. The EM38 is extremely light and portable and, with the addition of a carrying strap, can be used to monitor changes in the bulk conductivity of the surface metre as one traverses the field. In practice, an operator traverses the field notes the deflection of the needle, and at appropriate points in the traverse, pauses to place the unit in the horizontal position.

The EM38 conductivity metre is used to assess salinity in the field.

The EM38 unit is of most value to people who know and understand soil, especially soil texture and soil moisture. Both soil texture and soil moisture and the interaction of the two factors affect the readings obtained. All other factors being equal, coarse-textured (light) soils will read much less than fine-textured (heavy) soils and dry soils will read much less than wet soils. For example, in non-saline soils, a reading of five to 10 may be obtained in a dry gravel pit, a reading of 15 to 30 in a dry pasture in a sandy soil, and a reading of 70 to 80 in a Regina heavy clay summerfallow field in which the water is at field capacity throughout the rooting zone. Thus, especially for readings less than 100, it is necessary to use a soil probe or auger to verify the reason for the reading obtained with the EM38.

Apart from the moisture and texture factors noted above, the major factor influencing readings is the salt content, and a high salt content overrides all other factors. Readings much above 100 in either the horizontal or vertical position can only be obtained by elevated salt concentrations, and the higher the reading, the higher the salt concentration. For example at the edge of salt lakes such as Muskiki Lake east of Saskatoon, readings of 700 to 900 are obtained.

The major points to remember when using the EM38 to assess salinity are to suspend the unit just above the ground surface when traversing the field so that changes can be noted and be prepared to use a soil probe or auger to verify the message being received.

EM units can also be useful in soil assessment of any kind in non-saline environments. Particularly in recharge areas, EM readings are useful in locating and mapping coarse-textured soils which may be allowing greater entry of water into the system, possibly causing greater salinization at some lower elevation.

When recording the EM readings, it has become customary to record the readings in the vertical orientation first, followed by a slash and the reading in the horizontal orientation. Thus, an EM reading of 150/100 would mean a reading of 150 in the vertical position and a reading of 100 in the horizontal position.

Chemical reactions and criteria for salt-affected soils

Cation exchange reactions

Clay particles in soils carry a negative charge. Because of this they attract cations (positively charged ions) to their surface as illustrated in the diagram below (Figure 10).

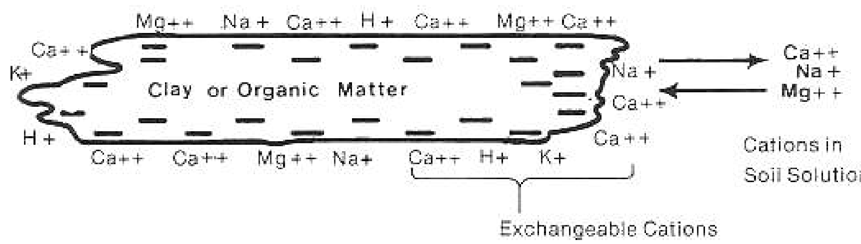

Figure 10. The negatively charged clay and organic matter particles attract cations from soil to exchange sites.

Exchange reactions take place between the cations on the clay surface and the cations in the soil solution. The ability of a soil to retain the exchange cations is referred to as cation exchange capacity (CEC). **The cation exchange capacity** of a soil is expressed in centimoles of positive charge per kilogram of soil (cmol(+)/kg) or milliequivalents per 100 grams of soil (me/100 g).

Organic matter particles also carry negative charges. The entire complex of clay and organic matter and mixed clay-organic matter material in soils is referred to as the **exchange complex**.

The reaction that takes place between the exchange complex and the soil solution is similar to that which takes place in a water softener as illustrated in the diagram (Figure 11). The softener is "charged" with sodium ions (Na +) which attach themselves to the negatively charged exchange resin. Calcium ions (Ca++) in the hard water enter the water softener where they displace some of the sodium ions. The calcium ions remain "stuck" to the exchange resin in the softener and the displaced sodium ions go with the water that leaves the softener.

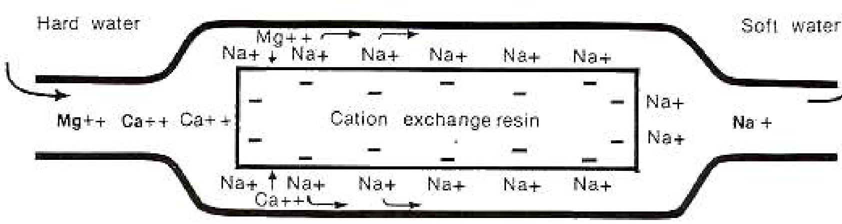

Figure 11. The principle of cation exchange in soils is similar to the exchange of magnesium and calcium for sodium in a water softener.

To measure the cation exchange capacity of a soil the exchange complex is saturated with a particular cation, which is then replaced with a second cation. The total amount of the first cation that was driven off by the second cation is then measured. This procedure is laborious, time consuming and expensive. Therefore, it is not economically feasible to use this method for large numbers of samples.

Fortunately, for Saskatchewan soils it is possible to make an estimation of the cation exchange capacity of a soil if the clay and organic matter contents of that soil are known.

The equation relating cation exchange capacity to the clay and organic matter content of soils is:

$$\text{CEC (cmol(+)/kg or me/100 g)} = 0.5 \text{ X } (\%\text{ clay}) + 2.0 \text{ X } (\%\text{ organic matter})$$

Criteria for defining salt-affected soils

Soils with a dominance of calcium on the exchange complex will be well granulated and in good physical condition. They will be well aerated and will allow water to enter.

Soils with sodium on the exchange complex have very poor structure. They "puddle" when wet, not allowing water to enter readily. They also bake and crust badly when dry.

The above phenomena have lead to the often quoted expression:

"Soft water makes hard land. Hard water makes soft land."

From the above discussion it can be seen that the amount of sodium present on the exchange complex is a critical criterion that will affect the physical condition of the soil.

In this publication, salt-affected soils are defined as:

- **Saline soils** — soils that have a high concentration of salts but have a low concentration of exchangeable sodium;
- **Sodic soils** — soils that have a low concentration of salts, but have a high concentration of exchangeable sodium. Alkali soils are sodic soils which also have a high pH; and
- **Saline-Sodic soils** — soils that have both a high concentration of salts and a high concentration of exchangeable sodium.

The specific criteria used to define different soil types of saline soils are given in Table 5.

Table 5. Chemical criteria for different types of salt-affected soils.

Type	Conductivity (dS/m)	Exchangeable sodium percentage (ESP)	Sodium absorption ratio (SAR)
Saline	greater than 4	less than 15	less than 13
Saline-Sodic	greater than 4	less than 15	greater than 13
Sodic	less than 4	greater than 15	greater than 13

The exchangeable sodium percentage (ESP) is one of the major criteria utilized to separate salt-affected soils into three categories. The exchangeable sodium percentage is defined as:

$$\text{ES} = \frac{\text{Exchangeable Na}}{\text{Cation exchange capacity}} \text{ X } 100$$

Note: Concentrations in cmol(+)/kg or me/100 g

To determine ESP, total exchange capacity and exchangeable sodium measurements must be performed. Since these procedures are difficult and laborious, an estimate of exchangeable sodium is frequently obtained from the saturation extract.

By measuring the cations present in the saturation extract it is possible to determine the s**odium absorption**

$$\text{SAR} = \frac{Na^{+}}{\sqrt{(Ca^{++} + Mg^{++})/2}}$$

ratio (SAR). Sodium absorption ratio is defined as:

Note: Concentration in millimoes (+) or milliequivalents per litre of extract. In many references works on soil salinity the SAR is quoted and hence we have to have some knowledge of the interpretation of SAR values. It conveniently turns out that SAR and ESP values are approximately numerically equivalent up to values of about 25. The specific equation relating these two is:

$$ESP = \frac{(1.47 \text{ X } SAR) - 1.26}{(0.0147 \text{ X } SAR) + 0.99}$$

Summary

Saline and Solonetzic soils are major salt related soil problems in Saskatchewan that require different management practices.

Solonetzic or "burnout" soils usually have a high-sodium hardpan layer and a saline subsoil, resulting in poor crop establishment and root growth. Timely cultivation and deep plowing or deep ripping help to alleviate problems with Solonetzic soils.

Saline soils have a high concentration of soluble salts which reduces the ability of plants to take up water and nutrients. The salts accumulate in certain areas due to ground water movement and evaporation. Until recently, the side hill seep model was frequently used to explain soil salinization in Saskatchewan. In this model, water in excess of crop use moves underground from an up slope position to a local and adjacent lower slope position. However, recent salinity investigations suggest that artesian discharge from larger scale, regional ground water aquifers is causing salinity in many areas of Saskatchewan. In pothole landscapes, evaporitic rings of saline soil form around depressions due to ground water mounds underneath the sloughs.

Salinity can be controlled in some situations once the specific causes are understood. In the recharge area, improved drainage and water-efficient crop management practices will reduce the amount of water that enters the ground water system. In the discharge area, where salinity appears, it is important to establish plant growth.

There are no easy or magical cures for soil salinity. Salinity must be regeared as both a water and soil problem that requires a long-term management strategy. Although few soils may me completely restored to a normal state, the impact and spread of salinity can be reduced with appropriate management practices.

For more information, contact the Agriculture Knowledge Centre toll-free at 1-866-457-2377 or aginfo@gov.sk.ca.