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**AT THE WESTERN SNOW CONFERENCE**

## MANAGING SNOW TO ABATE SALINITY

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### ABSTRACT

Food crops do not grow well in saline soils. Even relatively low concentrations of excess calcium, sodium and other salts dissolved in soil solutions reduce the grain yields of spring wheat, and other crops, by 5, 10, 20 percent or more. In arid or semiarid climates, ground water which approaches the soil surface typically leads to root-zone salinization. Subsurface drainage in these climates can usually lower the water table, but subsequent leaching of the offending salts out of the root zones often requires additional surface water to complement the natural precipitation. In many arid farming districts, irrigation provides this leaching water. Unfortunately, salinity affects some 30 million hectares of semiarid, North American farmland for which irrigation waters are not available. Fortunately, many of these dryland farms exist in locations blessed with snowfall and wind. In this study, single rows of perennial grass, sown as windbreaks on 15-meter centers across drained saline fields, capture blowing snow and supply meltwater for leaching the root zones just before spring seeding. The mean salinity of saturated soil paste extracts obtained from sets of soil samples taken every fall from such a site in southwestern Saskatchewan averaged 14.1 dS/m during 1985-90 before the drainage was installed, 13.0 dS/m for 1991-92 before the grass windbreaks became established, and 9.4 for 1993-96 with both drainage and snow management.

### INTRODUCTION

Vast expanses of the North American Great Plains rest on subsurface sediments which contribute solutes (mostly sulfates, carbonates, and chlorides) to the waters moving through them (Nielsen 1973; Miller et al. 1981). This chemical behavior typifies continental arid and semiarid climates found in mountain rain-shadows. When ground water approaches or intersects the land surface, evapotranspiration causes the solutes to concentrate and enrich the soil root zone. Soil salinization naturally results unless the process is countered by other natural processes or anthropological practices, such as irrigation, which dissolve and leach the excess salts out of the root zone (U.S. Salinity Laboratory Staff 1954).

Subsurface drainage systems offer one method for lowering water tables, removing dissolved salts, and reducing salinization by purging excess water from root zones (Rhoades 1974). When installed on irrigated lands, subsurface drainage usually lowers the water table and reduces salinity (Rapp 1968). However, on non-irrigated, semiarid lands, subsurface drains give mixed results. On these lands, drainage lowers the water table but does not initially reduce

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soil salinity (Buckland and Hendry 1992). After many years, drainage systems placed in non-irrigated, saline soils have lowered the electrical conductivity of soil solutions in the top 0.3 m of soil at some sites (Vander Pluym et al. 1985).

The U.S. Salinity Laboratory Staff (1954) set the standard for measuring soil salinity based on laboratory determinations. They defined the electrical conductivity of a water-saturated soil paste extract (soil-EC) as the most consistent measure. Their procedure starts with dried soil samples obtained from the field. Placed on filter paper in a funnel and saturated with de-ionized water, the soil sample is subjected to overnight vacuum producing the extract. Saturation percentages can vary among samples.

Black and Siddoway (1971) suggest that rows of tall wheatgrass, (*Thinopyrum ponticum* (Podp.) Barkworth & Dewey, offer an alternative to tree and shrub windbreaks commonly planted throughout the Great Plains and Canadian Prairies. Tall wheatgrass, a salt-tolerant perennial bunchgrass, typically develops seed culms averaging 1.2 m tall when placed in single or double rows to serve as wind-barriers spaced on 15.2-m centers across fields producing dryland crops. Research has shown that this grass shelterbelt system reduces ground windspeeds, controls soil erosion, deepens snowcovers, extends the geographic range of overwintering crops, conserves water, increases or stabilizes grain production, and minimizes the need for summerfallow (Aase and Siddoway 1974; Black and Aase 1986; Steppuhn and Nicholaichuk 1986). The soil water enrichments resulting from windbreaks are attributed to greater snow catch in the shelter than in the open field and to reductions in evapotranspiration of the wind-sheltered crop (Siddoway 1970).

The objective of the study described here is to enhance leaching of a saline soil in a cold, semiarid climate using a combined subsurface drainage system and tall wheatgrass windbreaks to augment natural precipitation and reduce evapotranspiration.

#### STUDY SITE

The site selected for this study is located 3 km southwest of Swift Current, Saskatchewan, (50.3° N, 107.8° W). The mean annual precipitation equals 359 mm, with up to one-third falling as snow. The growing season (May, June, July, August) precipitation and Class A pan evaporation average 210 and 883 mm, respectively, reflecting a semiarid climate for the site. Winter-to-summer air temperatures range within -40 to +40 °C.

Two parcels of severely salinized land, aligned north and south, characterize the site (Figure 1). The parcels, each about one ha in area, form part of a slightly undulating plain sloping 3% to the southeast; a slight rise in topography separates the two parcels.

The soil of the plain is mapped as a degraded, salinized Swinton silt loam (Ayres et al. 1985) and is classified a Saline Brown Chernozem (Salic Aridic Haploboroll in the U.S. nomenclature). The topsoil developed from a partially-eroded veneer of loess (25 cm or less thick) overlying glacial till. Cretaceous Bearpaw shale underlies the till at depths below land surface ranging from 3 m along the west boundary of the saline parcels to 1.5 m on the east side. The texture of the till and subsoil changes rather abruptly from a silty loam with sand lenses on the west side to a loamy clay on the east side. The transition occurs along a line trending north-south transecting both parcels of saline

soils. We have concluded that the higher water tables observed west of the transition, along with shallower depths to the shale eastward, have caused the root-zone salinity associated with both parcels.

#### STUDY METHODS

Soil and water sampling in the two parcels began in 1984 and continued during 1985 when most of the observation wells and piezometers were installed. A grid of ten sampling points west of the textural transition were established in each parcel (Figure 1). Every fall (October or November) from 1985 through 1996, a cylindrical core of soil, 50 mm in diameter, was removed from the upper 900 mm of the root zone within a 2 m radius of each sampling point. The core was sectioned into 150-mm depth increments, and the soil electrical conductivity of the saturated soil paste extract (soil-EC) was determined for each increment.

In August and September of 1990, plastic drain-tubing covered with a polyester filter was buried on grade within 1.5 and 1.8 m of the surface of the south parcel using a laser-controlled trencher; the north parcel was left untreated. The drain system consisted of north-south oriented, 100-mm, louvred tubing spaced on 15.2-m centers feeding an east-west, non-perforated, 150-mm collector conduit (Figure 1). Where possible, drain lines were placed approximately 5 m west of the soil sampling points.

In October, 1991, a dormant seeding of tall wheatgrass (variety: Orbit) was designed to form single rows located parallel and 3.8 m west of each drain line. Dry conditions during the following spring limited establishment of the wheatgrass. We seeded a second row about 150 mm adjacent the first in the spring of 1992. This resulted in effective windbreaks spaced 15.2 m apart across the south parcel averaging 0.7 m in height by November, 1992. A year later, the living windbreaks reached their normal height (1.2 m) and width (0.5 m).

We surveyed the accumulated snowcover on each parcel at about the time of peak accumulation each year beginning in January, 1993. Each survey included from 10 to 30 observations of snowcover depth and 3 to 5 measurements of the specific gravity from vertical snow cores taken between each windbreak. After each survey, the observations were used to calculate the mean snowcover water equivalent for each parcel according to the method described by Steppuhn (1976).

The mean soil-EC values from the south parcel obtained during the pretreatment period, 1985-1990, were regressed on those from the north parcel using a linear model (SAS Institute 1990). The regression statistics for each sampled depth layer and three combinations of the soil layers (0-450, 450-900 & 0-900 mm) provided comparisons for selecting the most reliable predictor. Predicted pretreatment soil-EC values for the south parcel from the selected regressions were analyzed covariantly resulting in a t-based least-significant-difference (LSD). Differences in measured post-treatment EC values for the parcels compared to the LSD allowed statistical inferences pertaining to the merits of the treatment.

#### RESULTS AND DISCUSSIONS

The annual precipitation during the six pretreatment years exceeded the long-term mean (359 mm) in two years out of six compared to three out of six post-treatment years. Growing season precipitation volumes averaged less before the

drainage system was installed than after installation.

Once established, the tall wheatgrass windbreaks caused more snow to accumulate on the wind-sheltered (south) parcel than on the open (north) parcel (Table 1). Over the five surveys (1993-97), the mean areal water equivalents averaged 74.2 mm on the south parcel and 26.2 mm on the north parcel. Snowcover over the sheltered parcel was usually not uniform, accumulating instead in the usual wind-foil pattern behind the windbreaks.

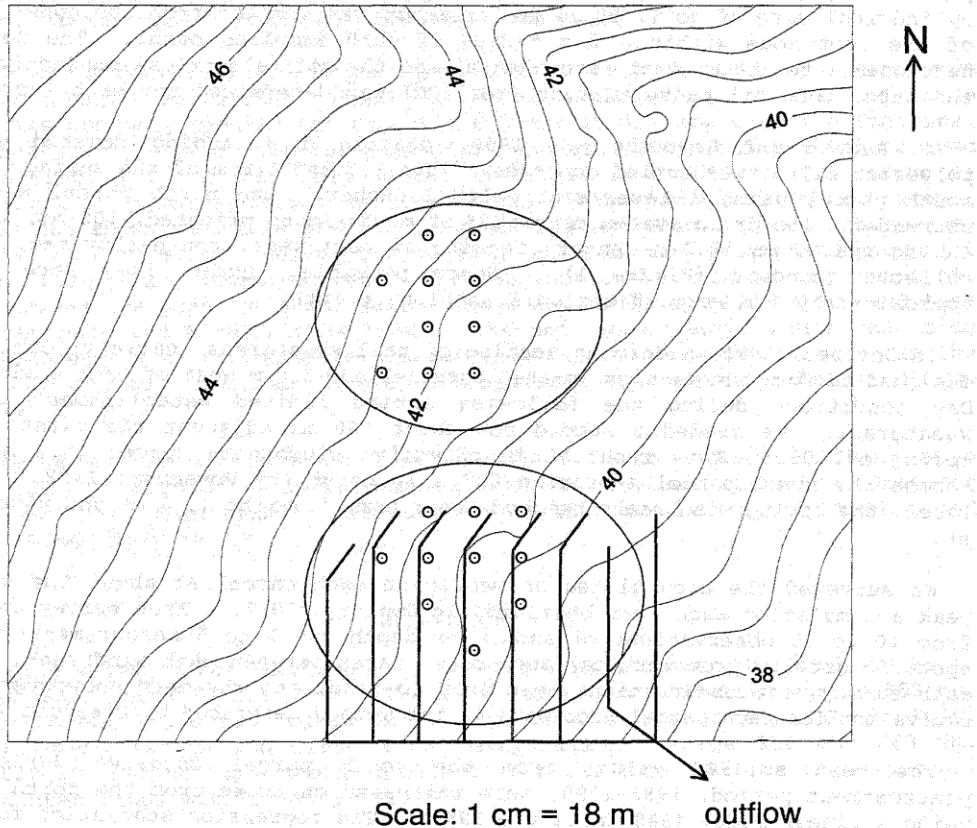


Figure 1. Subsurface drain lines and soil sampling points on the south parcel and sampling points on the north parcel at a saline site (50.3° N, 107.8° W) near Swift Current, Saskatchewan. Contour interval equals 0.5 m with arbitrary datum. (1 m = 3.28 ft.)

Table 1. Mean snowcover water equivalents from surveys across saline soil parcels located near Swift Current, Saskatchewan, measured at about the time of peak accumulation, 1993-1997.

Date	Parcel <sup>1</sup>		Date	Parcel <sup>1</sup>	
	North	South		North	South
	mm			mm	
22 Jan. 1993	26	31	11 Jan. 1996	23	95
15 Feb. 1994	29	78	13 Jan. 1997	42	136
28 Mar. 1995	11	31	Average	26.2	74.2

<sup>1</sup> North Parcel has neither subsurface drainage nor grass windbreaks; South Parcel has subsurface drainage and grass windbreaks.

The soil-EC covariance testing covering the six pre-drainage years (1985-1990) between the north and south parcels showed significant correlation in only the 0-150, 600-750 and 750-900 mm soil layers (Table 2). The salinity status of the soil layers within a soil profile is very dynamic. Therefore, we

Table 2. Parameters and statistics from linear regressions between the electrical conductivities of saturated soil-paste extracts (soil-EC) from the south parcel on those from the north averaged from ten soil cores sampled each fall during 1985-1990 (N = 6) and stratified by soil layers and depth units to 900 mm.

Depths mm	r <sup>2</sup>	Error dS/m	Prob.(slope>0)	Slope	Intercept dS/m
0-150	0.92	1.51	0.003*	0.977	1.572
150-300	0.63	1.62	0.060	0.733	5.510
300-450	0.61	1.12	0.066	1.132	0.500
450-600	0.55	1.18	0.091	1.102	0.049
600-750	0.71	0.89	0.036*	1.735	-6.102
750-900	0.77	0.81	0.021*	1.337	-1.333
0-450	0.95	0.54	0.001*	0.958	2.331
450-900	0.74	0.78	0.028*	1.469	-3.344
0-900	0.48	0.74	0.126	0.771	4.152

r<sup>2</sup> = Coefficient of determination

Error = Standard error of the regression

Prob.(slope>0) = Error probability that the slope of the regression does not equal zero

\* = The slope is significantly greater than zero at an error probability of 0.05 or less.

combined the results into mean soil-EC values for the 0-450, 450-900, and 0-900 mm depth units. The 0-900 mm unit did not correlate well ( $r^2 = 0.48$ ), but the splits into the 0-450 and 450-900 mm units did ( $r^2 = 0.95$  &  $0.74$ ). The covariant, linear, regression slope for the 0-450 mm unit approached unity ( $0.958$ ), and the intercept indicated that the south parcel was, on average, more saline (by  $2.3$  dS/m) than the north parcel during the pre-treatment years.

The least significant difference at a statistical error probability ( $p$ ) less than  $0.05$  for predicting the 0-450 mm, fall-measured soil-EC in the south parcel based on the north EC-measurements prior to drainage equalled  $\pm 0.66$  dS/m ( $\pm 0.83$  dS/m at  $p < 0.01$ ). This implies that, if all else is equal between the two parcels, results from imposing a subsurface drainage and concomitant grass windbreak system on the south parcel can be evaluated in comparison to that parcel's predicted behavior based on its pre-treatment covariance with the north parcel. Table 3 lists: the mean fall soil-EC values for the 0-450 mm depth unit by year; the measured north and south values; and, the predicted south value. The average post-treatment difference between the measured and predicted south soil-EC equalled  $6.12$  dS/m which exceeded the  $0.83$  dS/m precision (error  $p < 0.01$ ) seven fold. Changes in mean measured EC-values with time after drainage are visually evident in Figure 2 for the 0-450 mm depth unit.

Table 3. Soil salinity (soil-EC) averaged from measurements and those derived by regression (Predicted); ten soil cores per parcel, 0-450 mm deep, were obtained yearly in the fall during 1985-1990.

Year	North Parcel	South Parcel		
	Measured	Measured	Difference <sup>1</sup>	Predicted
		dS/m		
1985	12.07	13.18	+0.71	13.89
1986	8.84	10.68	+0.12	10.80
1987	15.32	16.74	+0.27	17.01
1988	12.21	14.69	-0.66	14.03
1989	11.40	13.40	-0.15	13.25
1990	13.73	15.78	-0.30	15.48
1991	15.71	12.02	+5.36 <sup>2</sup>	17.38
1992	15.75	14.04	+3.38 <sup>2</sup>	17.42
1993	13.77	9.74	+5.78 <sup>2</sup>	15.52
1994	13.91	9.93	+5.73 <sup>2</sup>	15.66
1995	15.33	8.66	+8.36 <sup>2</sup>	17.02
1996	15.53	9.09	+8.12 <sup>2</sup>	17.21

<sup>1</sup> Difference = South Predicted minus South Measured.

<sup>2</sup> Based on the 1985-1990 regression, the least significant difference equals:  $0.66$  dS/m at  $p < 0.05$  &  $0.86$  dS/m at  $p < 0.01$  ( $p$  = statistical error probability).

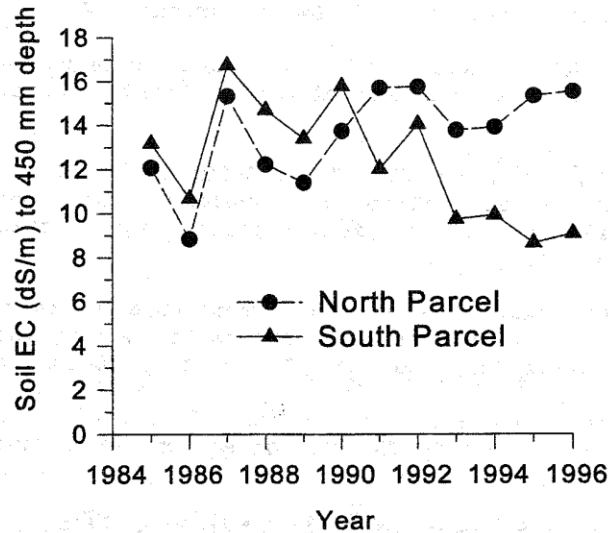


Figure 2. Average soil-EC to a depth of 450 mm for each year. The drain tubing in the south parcel was installed during 1990. Soil samples were extracted in October or November of each year.

These data lead to two inferences: (1) that snow management can increase the water available to leach salinized root zones, and (2) that a combination of subsurface drainage and grass windbreak technologies in semiarid, non-irrigated environments can result in a gradual reduction of salinity in the top 450 mm of soil. The windbreak system in our study is limited in size (1.1 ha). If our system, because of its size and upwind fetch, allowed extra measures of snow to accumulate in it, a larger windbreak system may not prove as beneficial. Also, if the volume or salt concentration of the water discharging from the drainage system is large, additional disposal techniques may be necessary.

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