Development and Application of a Salinity Risk Index for the Red River Valley of the North (MLRA 56)

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ABSTRACT

The Red River Valley of the North (MLRA 56) is a large, highly productive, dryland agricultural region in North Dakota, Minnesota, and Manitoba. Salinity has always been an issue facing producers in this area. However, due to changing cropping systems, an increase in acreage of less salt-tolerant crops, and two decades of higher precipitation; salinization has become an extremely important economic issue. Soil surveys have identified over one million acres of salt-affected soils. However, the surveys are dated and have only inventoried saline soils that have adequate crop response to be easily identified in the field. Considerable research has been done in MLRA 56 relating soil salinity to hydrology, topography, and soil classification. This research has shown a strong correlation between ground water discharge and salinity in the root zone. The Salinity Risk Index (SRI) is a resource inventory model used in Canada and Australia to assess the risk of soil salinity. The underlying principle for the initial phase of the SRI in MLRA 56 is to model soil hydrology and identify discharge sites using soil classification and data from the Soil Survey Geographic (SSURGO) database. Additional factors in the model include: current salinity status, drainage class, texture, presence of a contrasting layer, and slope. It is hoped the SRI can quickly and easily identify areas that are saline or have the potential for salinity. Areas identified as having potential for salinization can then be targeted by conservationists and land managers.

INTRODUCTION

The Red River Valley of the North, Major Land Resource Area (MLRA 56), is a highly productive agricultural region in North Dakota, Minnesota, and Manitoba. It encompasses over 15 million acres of dryland small grains, corn, soybeans, and sugar beets. Salinity has always been an issue facing agricultural producers in this area. However, due to changing cropping systems, increased acreage of less salt-tolerant crops, and almost two decades of higher precipitation; salinization has become an extremely important economic issue in the region. Soil surveys have identified over one million acres of salt-affected soils in MLRA 56. However, the surveys only inventoried saline soils that were visible in the field because of surface salts or crop response (Figs. 1 and 2). Additionally, salinity is commonly associated with microrelief, making it difficult to delineate at the scale of routine soil survey (Fig. 3).

Salinity in the region is highly variable, with significant changes both spatially (Fig. 4) and temporally. Traditional soil survey techniques have missed much of what Canadian researchers call "invisible" salinity – salinity at lower levels that reduce production by 10 to 25 percent (Steppuhn et al., 2005). Sophisticated multi-year remote sensing applications (Lobell et al., 2009) have attempted to identify the extent of salinity in the area by mitigating the influence of temporal and dynamic factors such as weather, disease, and management. To a degree these approaches have been successful, but the results are too broad to affect local producers. In-situ monitoring and evaluation using Electromagnetic (EM) technologies (Fig. 5) are too labor intensive and expensive for regional applications.

Figure 1. Area of salt crust on the soil surface.

Figure 2. An uneven stand of corn due to slight and moderate salinity.

Figure 3. Area of microrelief and associated soil survey in the northern Red River Valley. Red lines are soil survey map unit delineations.

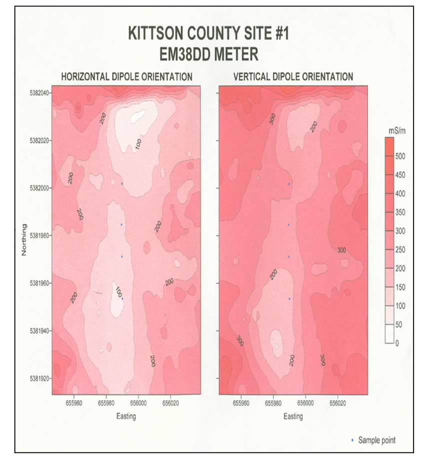

Figure 4. A high resolution salinity map developed with an EM-38; shows the high degree of spatial variability. Scale is 1:1580.

The Salinity Risk Index (SRI) is a resource inventory model utilized in Canada (Eilers et al., 1997, Wiebe et al., 2007) and Australia (Caccetta et al., 2010) to assess changes in soil salinity as a result of agricultural management practices. The model uses salinity (identified from the soil survey), topography, drainage, climate, and vegetation to predict the risk of increased salinization. Considerable research has been done in MLRA 56 relating soil salinity to hydrology (soil recharge/discharge), topography, and and land use (Benz et al., 1976, Sandoval et al., 1964, Knuteson et al., 1989.) This research has shown a strong correlation between discharge sites and salinity in the root zone. The underlying principle for the initial phase of the SRI project being developed for MLRA 56 is to model soil hydrology and identify groundwater discharge sites using soil classification and data from SSURGO. Unlike the work in Canada and Australia, which relied on small scale soil maps, use of SSURGO data provides greater resolution in results.

It is hoped the SRI can quickly and easily identify areas that are saline or have the potential for salinity. This would be analogous to areas identified as having a potential risk of wind erosion by the Wind Erosion Equation (WEQ) or water erosion by the Revised Universal Soil Loss Equation (RUSLE). The effectiveness of the model was evaluated by comparing results to existing quantitative data and qualitative data (areas qualifying for the Conservation Reserve Program [CRP] - salinity option).

Figure 5. EM-38 conductivity meter in sled for conducting field-scale salinity survey.

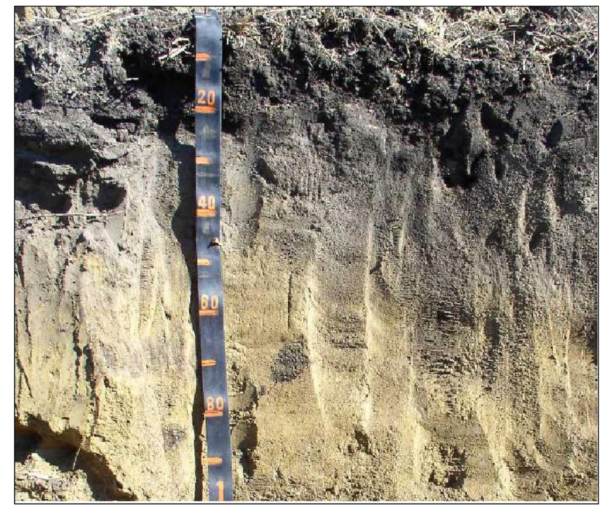

Figure 6. Profile of an Aeric Calciaquoll, a common soil in the Red River Valley. The accumulation of carbonates (gray-colored area) near the surface suggests this is a discharge soil. Scale is in centimeters.

METHODS

Salinity Risk Index for Soil Map Unit Components

To apply the SRI to SSURGO data, individual soil map unit components were first evaluated by querying appropriate soil property data from NASIS. Each variable was assigned a numerical risk rating; the greater the sum of these ratings, the greater the potential salinity risk of an individual component. The following variables contribute to the SRI value of an individual soil component:

Current salinity status - This variable is represented by the weighted average of the electrical conductivity of the saturation extract (ECe) in the root zone. It generates a high rating for soils that were mapped in the field as saline.

Hydrology - Soil Taxonomy (Soil Survey Staff, 2010) was used as a proxy for estimating hydrology. According to Knuteson et al. (1989) and Redmond and McClelland (1959) upward soil water flux and evapotranspiration are responsible for the accumulation of carbonates in the soil profile (Fig. 6) and are considered evidence that these are "discharge" sites. This research infers more soluble salts, responsible for salinization, will move in the soil profile in a similar fashion. The model searches for soil with taxonomic classifications in the Calciaquoll and Calciaquert great groups, in the great groups beginning with "Natr", or with surface calcium carbonate equivalent greater than zero and somewhat poor, poor, and very poor drainage classes.

Drainage class - Soil water transports salts into the rooting zone. Generally, the nearer the water table is to the soil surface the greater the potential for salinization.

Family particle size class - This variable considers the potential of capillary rise which may lead to a greater concentration of salts in the rooting zone.

Presence of a contrasting layer - This variable recognizes the potential for additional moisture, due to perching or disrupted flow, which may contribute to the transport of salts toward the root zone.

Salinity Risk Index and Classes for Soil Map Units

Initial map unit SRI values were determined by calculating the weighted average of all component SRI values in the unit. This approach is analogous to the development of a Storie Index for selected interpretations (O'Geen et al., 2008). It has the advantage of being easily applied to all map units. Once a map unit's SRI was calculated it was modified based on the following map unit variables:

Slope - Saline soils typically occur on level or nearly level landscapes. Higher slopes have a lesser propensity to become saline.

Complex mapunits - An adjustment is made for complex map units. This factor assumes additional potential for discharge exists based on the local hydrology.

To aid in the interpretation of the results, map unit SRI values were grouped into four classes using a peer review process to weigh the various factors. (Table 1).

Table 1. Salinity Risk Class (SRC) and associated map unit SRI range.

SRI Class	Map Unit SRI Range
Very low	0 to 20
Low	21 to 50
Moderate	51 to 70
High	> 70

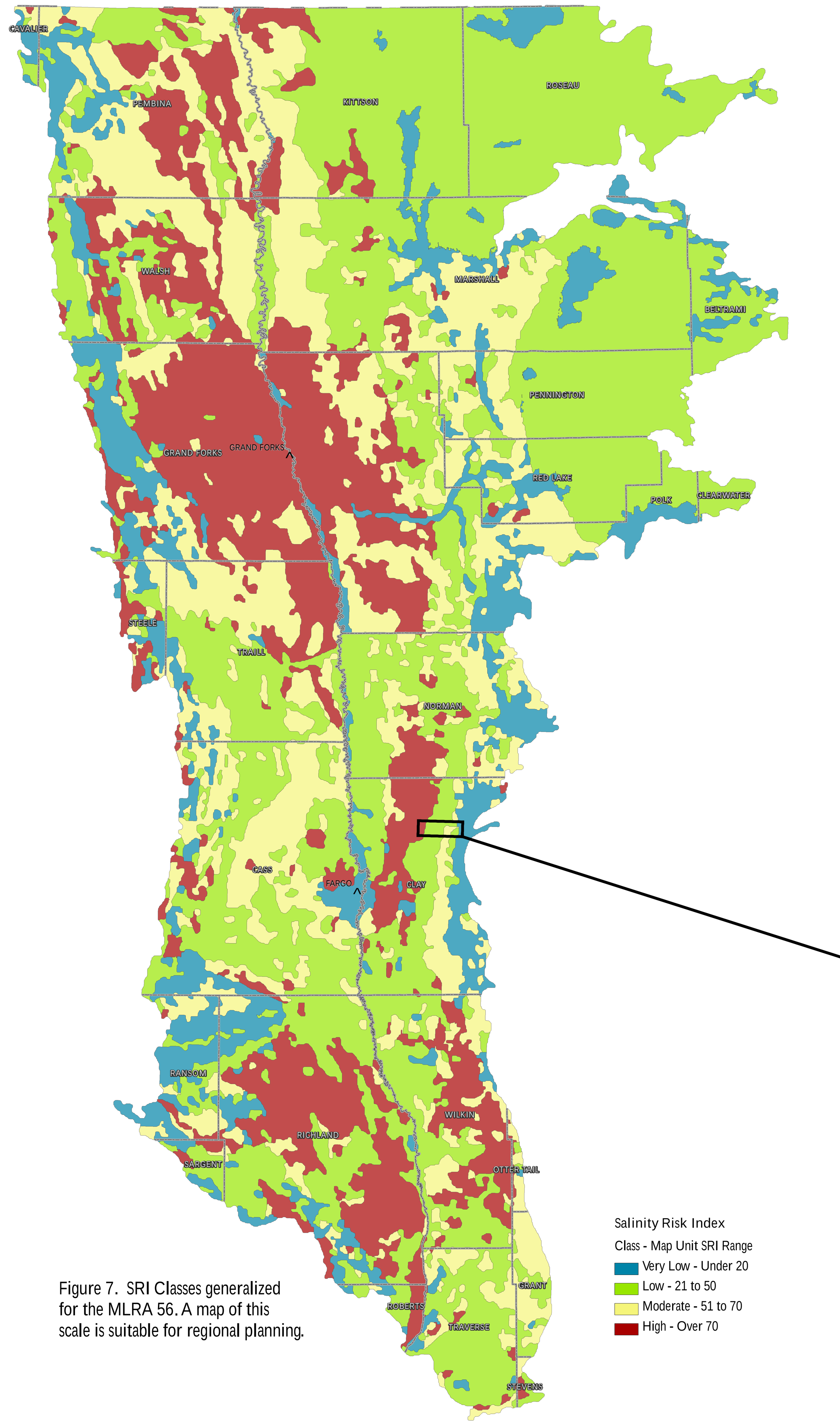

Figure 7. SRI Classes generalized for the MLRA 56. A map of this scale is suitable for regional planning.

RESULTS

SRI Classes based on SSURGO data can be displayed at various scales depending on the needs of the user. Figure 7 shows SRI Classes generalized for the entire Red River Valley and can be used for regional planning purposes. A detailed map can also be created (Fig. 8) for assisting in local conservation planning and management decisions.

VALIDATIONS

To test the usefulness of the SRI as a management tool, fields enrolled in the CRP salinity option (CP-18c) in Walsh County, North Dakota were compared to the field's SRI Classes (Table 2). CP-18c is a conservation program that allows landowners to set aside parcels of land impacted by salinity. To qualify for the program, the area is required to have an average ECe of 4 or more decisemens per meter (ds/m) in the rooting zone.

Table 2. A comparison of SRI classes and the number of parcels enrolled in CP-18c that occurs in each class.

SRI Class	Number of Parcels	% of total
Very Low	2	2
Low	22	20
Moderate	22	20
High	64	58
TOTAL	110	

This qualitative comparison indicates that 78 percent of the areas enrolled in the program fell into a moderate or high SRI Class. Areas of CP-18c in low or very low SRI Classes may have qualified because of small areas of higher salinity (such as ditch affected salinity) that were included in the field evaluation.

A more quantitative validation used laboratory results from several sampling projects from three counties in MLRA 56. The mean ECe for the upper 90 cm of the soil from 4 to 6 sites in the field was compared to the SRI class for the field. Data from 368 sample sites from 59 fields were summarized for this comparison (Tables 3 and 4).

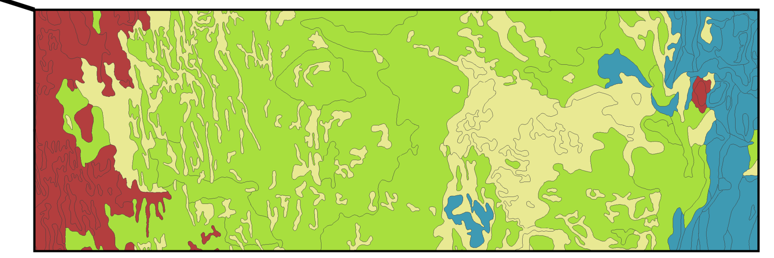

Figure 8. SRI Classes displayed on a detailed scale suitable for conservation planning. Notice the individual SSURGO soil map unit polygon boundaries visible at this scale.

Table 3. A comparison of SRI Classes and the number of parcels sampled that have a mean ECe value in the upper 90 cm of less than 4 ds/m. The Very Low SRI is not included since none of the parcels occurred in this class.

County	SRI Class		
	Number of Parcels		
	Low	Moderate	High
Kittson	1	14	2
Grand Forks	0	0	1
Walsh	1	7	3
TOTALS	2	21	6

Of the parcels with a measured ECe of less than 4 ds/m, 79% occur in the low or moderate Salinity Risk Class.

Table 4. A comparison of SRI Classes and the number of parcels sampled that have a mean ECe value in the upper 90 cm of > 4 ds/m. The very low SRI class is not included since none of the parcels occurred in this class.

County	SRI Class		
	Number of Parcels		
	Low	Moderate	High
Kittson	1	1	14
Grand Forks	0	0	3
Walsh	0	0	11
TOTALS	1	1	28

Of the parcels with an ECe greater than 4 ds/m, 94% occur in the high Salinity Risk Class.

FUTURE ENHANCEMENTS

The present model is a derivative of SSURGO. It can be enhanced by evaluating additional variables that affect soil hydrology. Landscape features, i.e. subtle topographic highs and lows not recognized in the soil survey map unit, may be incorporated utilizing high resolution digital elevation models derived from Light Detection and Ranging (LiDAR) (Fig. 9). Work similar to this was done in Canada by Florinsky, et al. (2000). Differences in the geology and groundwater across MLRA56 could be evaluated for possible influences on the extent or risk of salinization. Additionally, features in a neighborhood such as ditch effect, seep, or proximity to saline or sodic mapunits may affect the salinity risk of an area (Fig. 10.) Research by Skarie et al. (1986) confirms the important effect of the proximity to a ditch on the salinity level of the adjacent land in the MLRA56.

CONCLUSIONS

Soil properties derived from SSURGO data were used to generate an estimation of the potential risk of an area to salinize. Detailed digital soil maps allow the results to be displayed at detailed or regional scales. Based on this combination of tabular and spatial data, the SRI can quickly and easily identify areas at risk for soil salinization. Areas identified as having potential for salinization can then be targeted by conservationists and land managers. When compared to existing data, the SRI accurately predicted areas with root zone salinity about 80% of the time.

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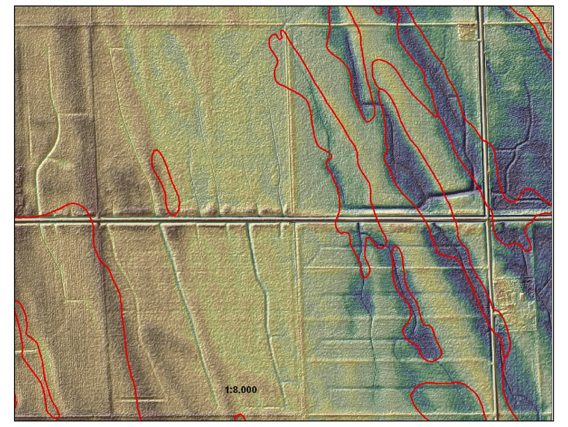

Figure 9. A LiDAR image showing microrelief of the area shown in Figure 3. Red lines are soil survey map unit delineations.

Figure 10. An example of ditch effect. Note the lack of a crop adjacent to the road ditch where the salinity has increased.