Predictive Mapping of Saline Wetland Soils in the Canadian Prairie Pothole Region through Landscape Analysis

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Introduction

Wetlands can be major sources of salinity for cropland in the Prairie Pothole Region (PPR). Salinity accumulations in wetlands result from salt additions from groundwater and overland flow[1]. During periods of excess moisture, rising groundwater can increase soil salinity. Saline wetlands can also flood into adjacent fields, creating further salinity issues. The hydrological processes that cause wetland salinity accumulations may be modelled through digital landscape analyses. Successful predictions of freshwater vs. saline wetland distributions would allow land managers to determine potential risk for salinity issues under different climate and management scenarios.

Soils in saline PPR wetlands are often enriched with calcium carbonates[2]. These soils have been found to reduce phosphorus mobility from agricultural runoff[3,4]. This ecosystem service reduces nutrient loading of downstream waterbodies. Therefore, accurate freshwater vs. saline wetland predictions could enable more focused conservation efforts to preserve this ecosystem service while maximizing productive agricultural land.

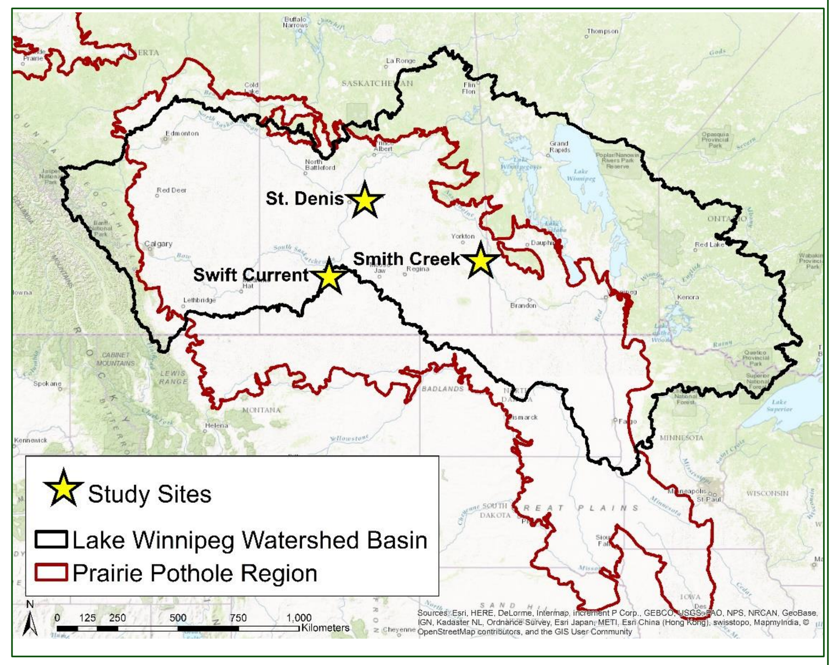

Fig. 1. Study site locations. Geographic extents of PPR and Lake Winnipeg Watershed Basin.

Objectives

Develop models to predict the spatial distributions of:

1. Saline wetlands in PPR landscapes
2. Saline soils within PPR wetlands

Site Selection

The study was conducted within three watershed basins across the PPR (Fig. 1):

- Swift Current, SK
- St. Denis, SK
- Smith Creek, SK

Sites were chosen based on:

- Available LiDAR digital elevation models (DEM) (Fig. 2)
- Having geophysical characteristics representative of the PPR
- Representing the three different soil climate zones of the PPR (brown, dark brown, and black, respectively).

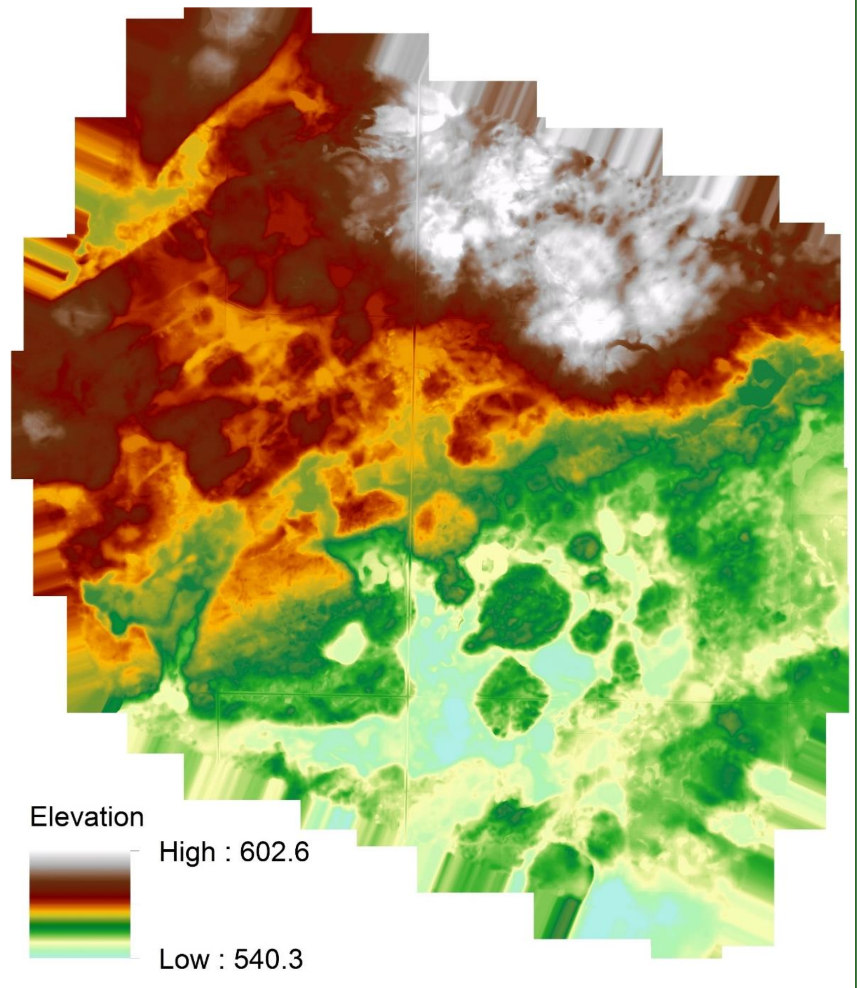

Fig. 2. 1 m resolution DEM for St. Denis watershed basin.

Saline Pond Distribution Predictions

PPR wetlands are hydrologically connected during wetter periods through shallow groundwater flow[5] and episodic fill and spill occurrences[6]. Through these processes, salts are redistributed to wetlands in lower landscape positions[1]. The hydrologic positions of each wetland were quantified through DEM analyses to make freshwater vs. saline predictions. Drainage networks were delineated to quantify the potential shallow groundwater and overland flow contributions a wetland may receive (Fig. 3 & 4). Wetlands with higher drainage orders receive greater contributions and hence are likely to have greater salinity accumulations.

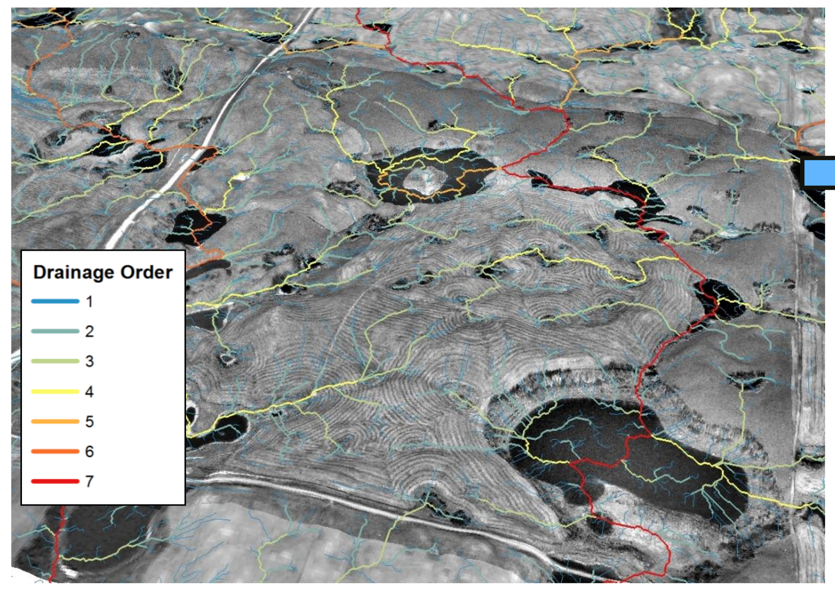

Fig. 3. Delineated drainage network for a portion of the St. Denis study site.

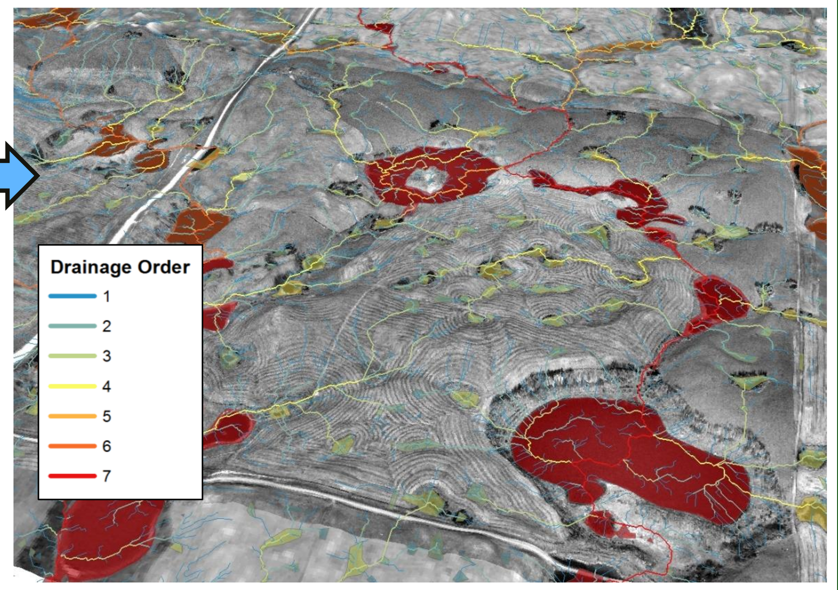

Fig. 4. Drainage orders ascribed to intersecting wetland polygons.

Binary fresh vs. saline predictions were made based on wetland drainage order (Fig. 5). Multiple prediction scenarios were generated by adjusting the two model parameters: (1) the expected level of hydrological connectivity in the landscape and (2) the drainage order of the freshwater vs. saline threshold. Fig. 6 shows three examples of the many potential prediction scenarios generated by the model.

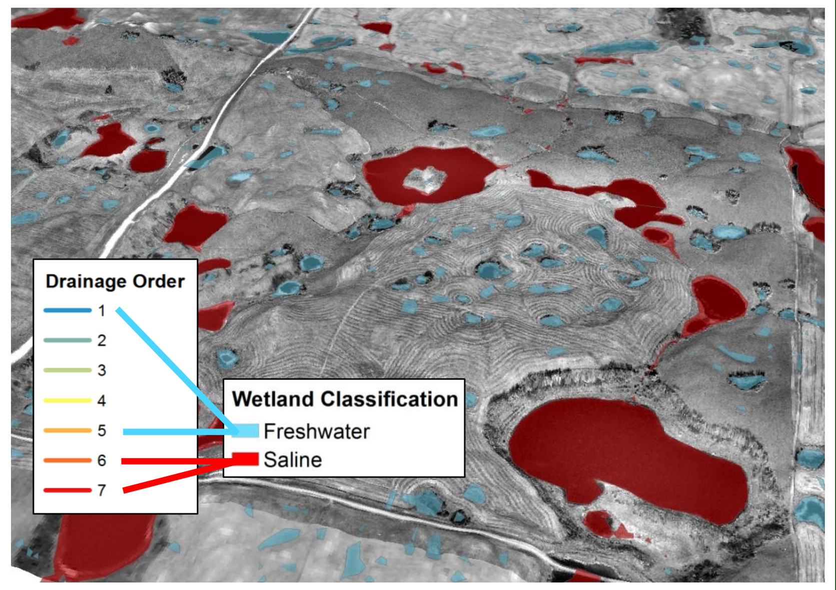

Fig. 5. Wetlands classified as freshwater or saline based on drainage orders.

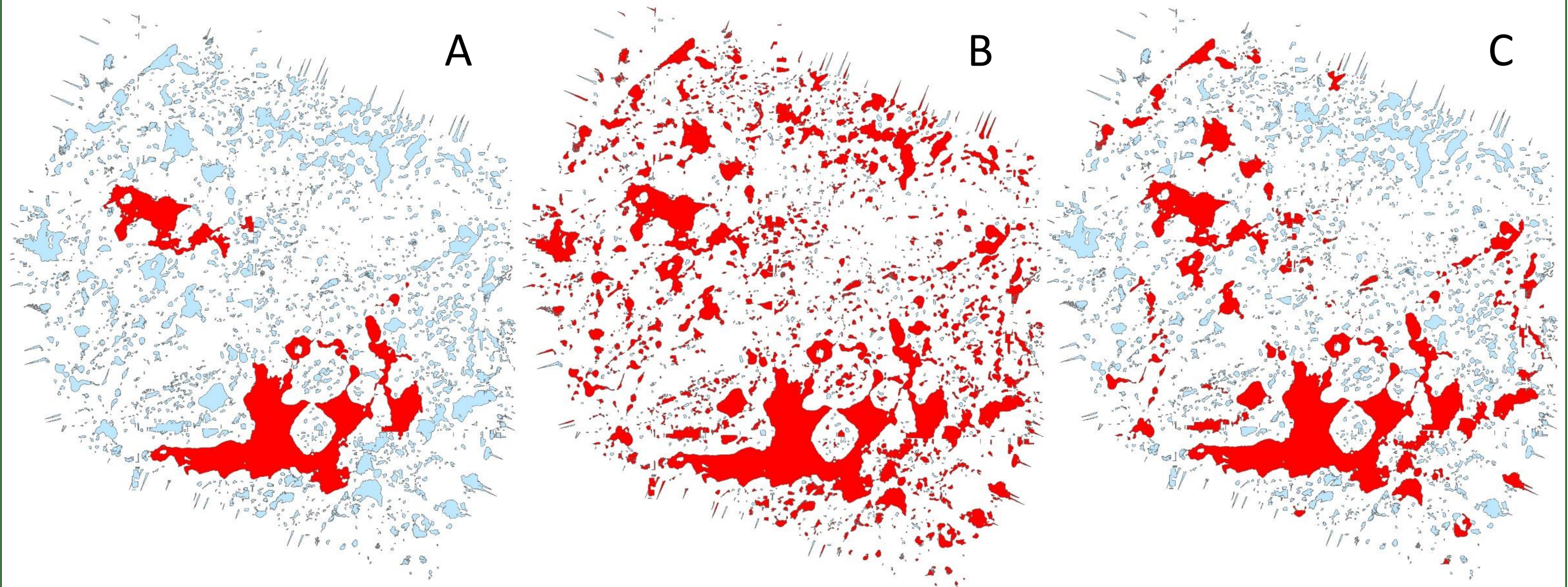

Fig. 6. Distributions of freshwater vs. saline wetlands in St. Denis watershed based on the three prediction scenarios listed in Table 2.

Obj. 1: Preliminary Results – Saline Pond Distributions

Wetland salinity was tested through electromagnetic survey (EM) and water sampling at over 200 wetlands across the study sites to test model prediction scenarios. Historic salinity data for St. Denis were also used. Wetlands were grouped into three categories based on their EM and water EC values (Table 1). Wetlands classified as Brackish were omitted for the preliminary model testing.

Table 1. Wetland category parameters.

Wetland Type	EM for 0 - 1.5 m (mS/m)	Water EC (µS)
Freshwater	< 60	< 1000
Brackish	60 - 70	1000 - 1500
Saline	> 70	> 1500

Table 2. Percentage of wetlands correctly classified by prediction scenarios A, B, and C at the three sites. n = actual number of wetlands per category.

Scenario	Model Parameters		Prediction Success Rates		
	Saline Drainage Order	Connectivity	Freshwater n = 135	Saline n = 86	Total n = 221
A	≥ 6	Minimum	**100 %**	25 %	68 %
B	≥ 3	Maximum	24 %	**96 %**	58 %
C	≥ 5	Moderate	93 %	61 %	**80 %**

The preliminary results indicate reasonable success of select model prediction scenarios in correctly classifying wetlands (Table 2) although in each prediction scenario, the model underestimates occurrence of saline wetlands. Prediction scenario A correctly classified the most freshwater wetlands, prediction scenario B correctly classified the most saline wetlands, and prediction scenario C correctly classified the most wetlands total.
The next step for this objective is to test the model with a separate validation sample set.

Obj. 2: Distribution of Saline Soils within PPR Wetlands

Discharge rings of saline soils form around wetlands. This is due to lateral and upward movement of water from within the wetland to the wetland fringes. We are currently attempting to model this distribution of saline soils through modern digital soil mapping approaches. Soil samples were taken at 46 wetlands across the study sites. Soil pit classifications and landscape characteristics were used as input in Classification Tree and Random Forest machine-learning models[7] to predict discharge soil distributions. Initial modeling attempts resulted in predictions with ~60% accuracy. We hope to improve prediction accuracy for this objective by incorporating new landscape variables and testing different model types.

References

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