# Water flow characteristics and salt transport of a shrink-swell soil from a wetting and drying cycle.


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## Abstract

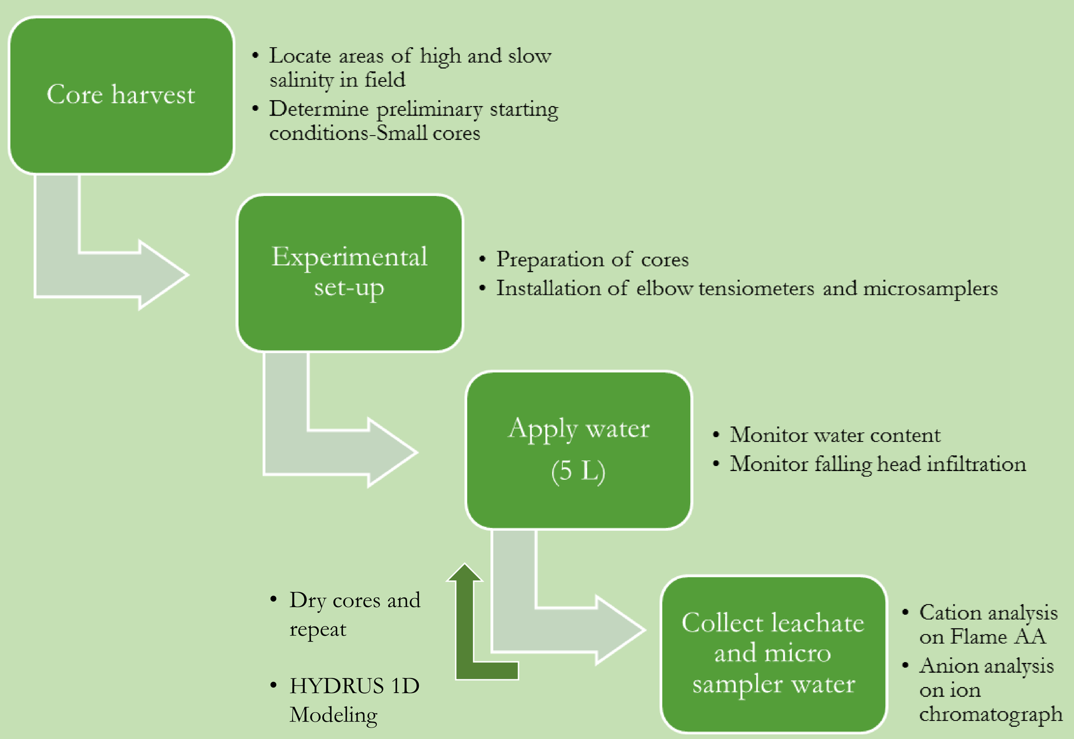

Soils native to the Red River Valley are high in smectitic shrink-swell clay. The shrink-swell process of these soils causes varied hydrological characteristics that are not well understood. As a result, water flow and solute transport are difficult to model and predict. This study was conducted to monitor water flow and salt transport through a Fargo silty clay soil. Six large (20 cm-dia. by 121 cm-length), undisturbed soil monoliths were harvested from a field near Mooreton, ND. Three of these cores were considered saline and three were considered non-saline. A laboratory experiment was designed to accelerate field conditions of wet/dry cycles native to North Dakota. Five liters of water were applied to the dry soil and leachate was collected for analysis to represent salt removal. Elbow tensiometers were installed at four different depths (12 cm, 39 cm, 67 cm, and 93 cm) to monitor water content in the cores over time. Results from two leaching events indicate varied hydrological response in regards to falling head infiltration. Average time for complete infiltration of the high salinity cores was 15 minutes, and 45 days for the low salinity cores. Modeling of water flow (HYDRUS 1D) using van Genuchten parameters and experimental water content measured by the tensiometers illustrate variance between the two results. Variance between the modeled and experimental results increase with depth, indicating deep water flow through the cracked clay that is not well accounted for in a basic water flow model. Solute removal from the two leaching events indicated an average of 131 leaching events would be needed to remove excess cations from the high salinity soil to a reduce it to a low salinity status. Water flow through the dry soil is preferential through macropore cracks. The short time span for infiltration in the high salinity cores indicate an increase presence of macropores. The long time span for infiltration in the low salinity cores indicate a decrease presence of macropores. This response in infiltration between the high and low salinity cores may suggest that the presence of excess salts may induce cracking in these shrink-swell soils.

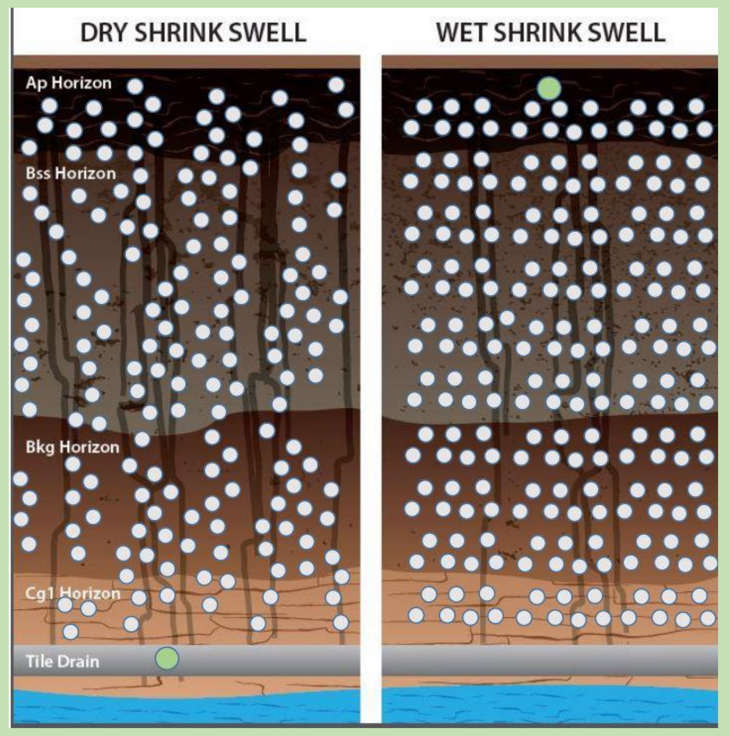

## Introduction and Methods

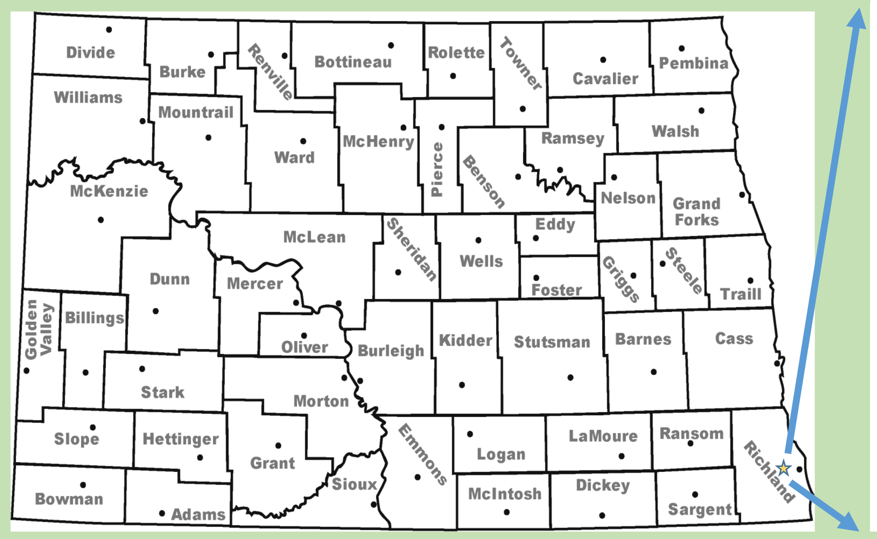
### Research Justification

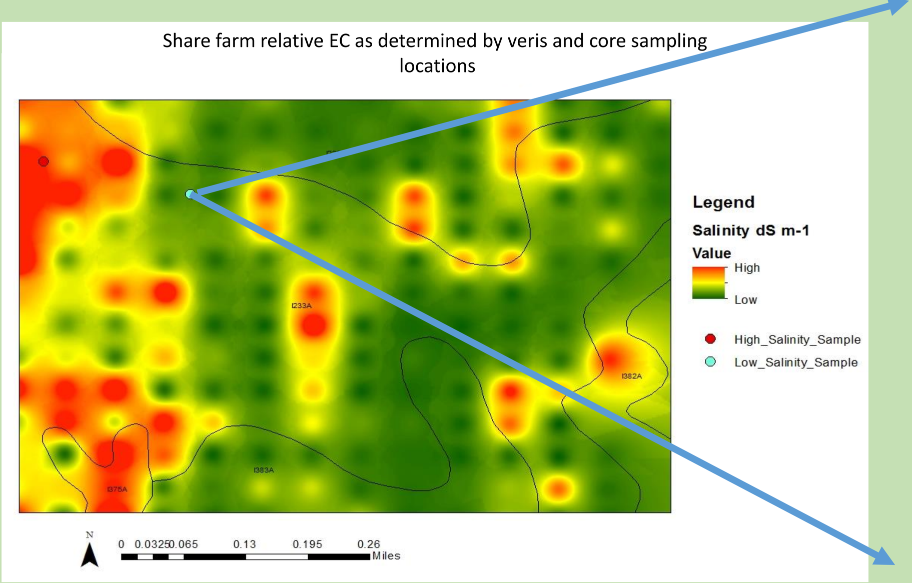
- North Dakota groundwater tables have risen recently due to a wet cycle enabling transport of dissolved salt upwards through capillary rise (Euliss et al., 2011) .
- Tile drain installation is an option for soil salinity remediation. When precipitation falls, leaching water can be intercepted by the tile drain and removed permanently (Brown et al., 1982).
- This research focuses on the amount of salt removed by a tile drain in a Fargo silty clay soil. With these results, an economic return time estimate can be provided to producers of the Red River Valley who wish to use tile drain management to remediate soil salinity.

### Methods




## Preliminary Results

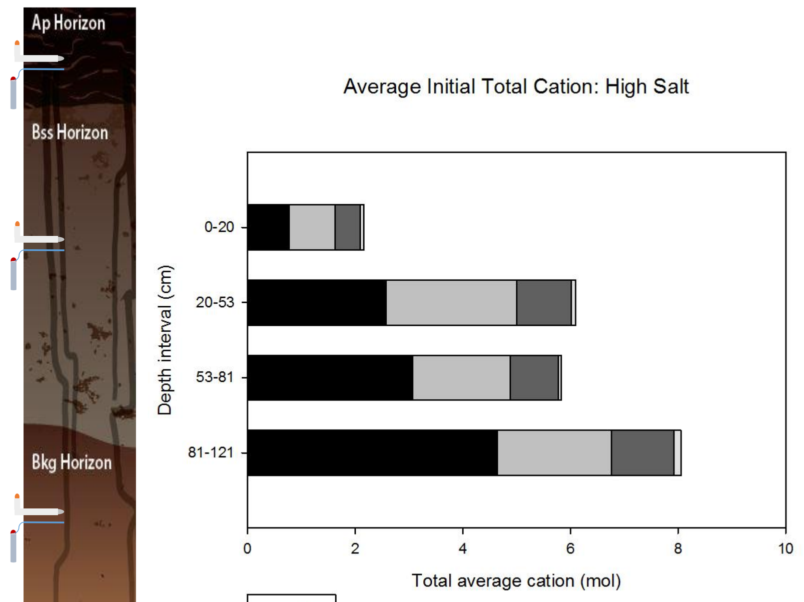



Figure 1. Average total cation with depth estimated in the high salt cores determined by a $NH_4OAc$ extract (Page and Moller, 1982) from small core harvest.

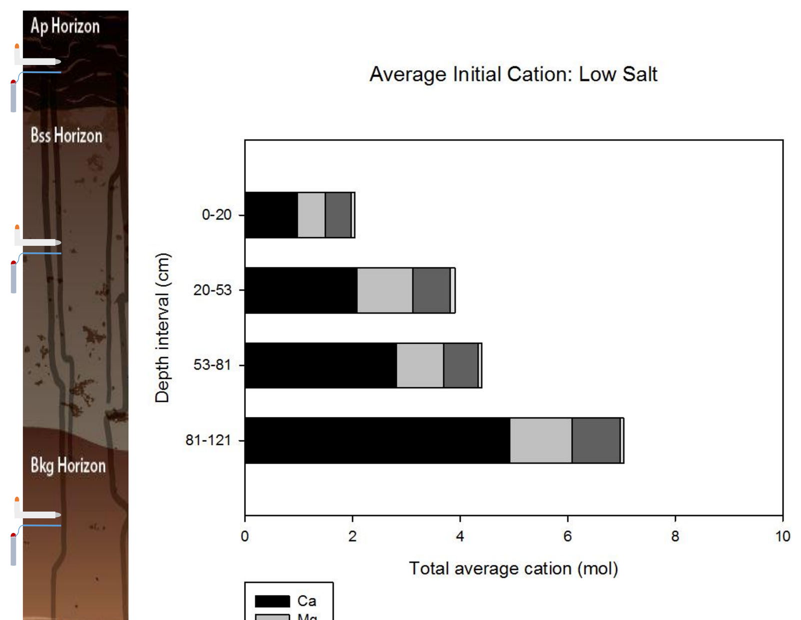



Figure 2. Average total cation with depth estimated in the low salt cores determined by a $NH_4OAc$ extract (Page and Moller, 1982) from small core harvest.

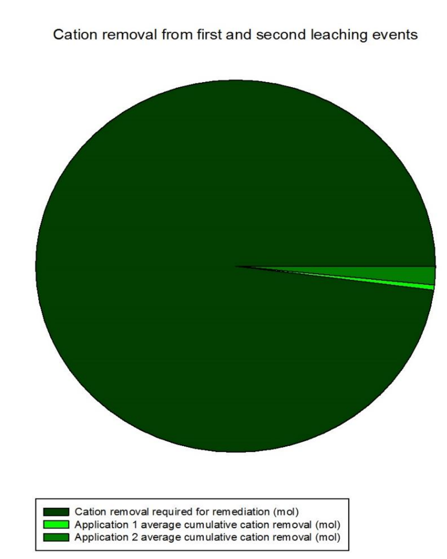



Figure 3. Total average cation removal required for high salt core remediation. Average cumulative cation removal is illustrated from leaching event 1 and 2.

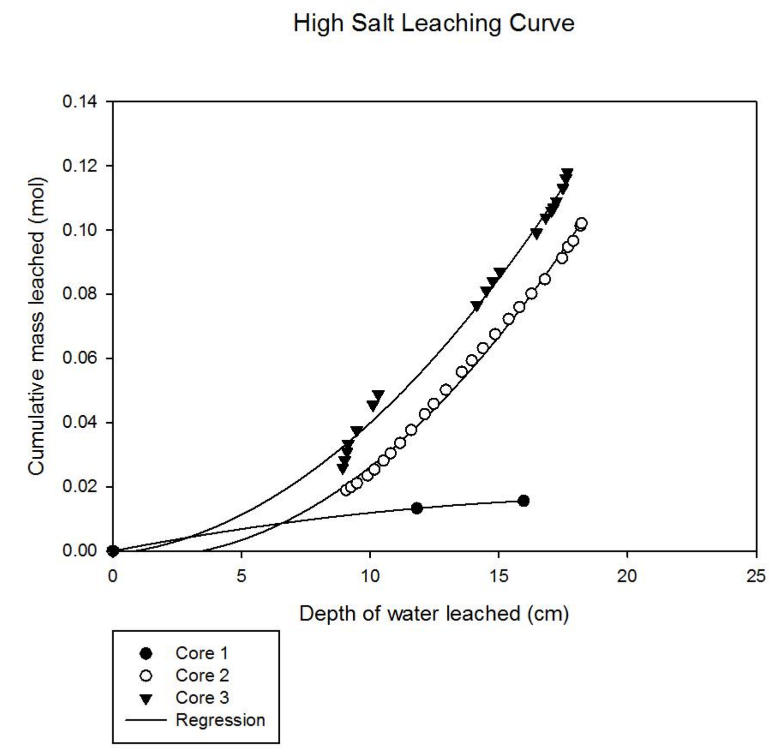



Figure 4. Cumulative mass leached per cumulative depth of water leached from the high salt cores. Leaching events 1 and 2 are combined. High salt cores have an average of 0.0502 mol cumulative cation mass leached between the two leaching events.

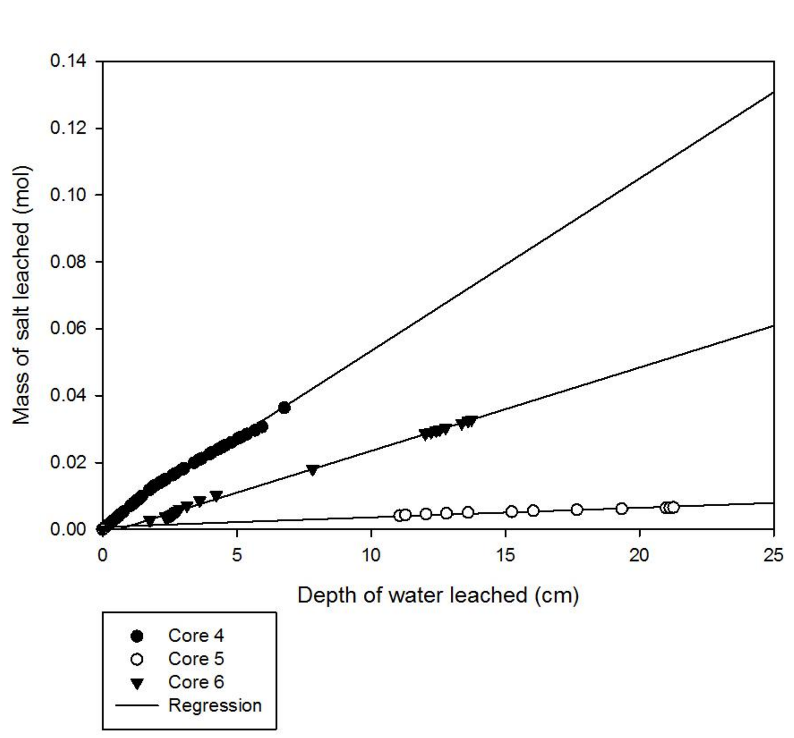



Figure 5. Cumulative mass leached per cumulative depth of water leached from the low salt cores. Leaching events 1 and 2 are combined. Low salt cores have an average of 0.0165 mol cumulative mass leached between the two leaching events.

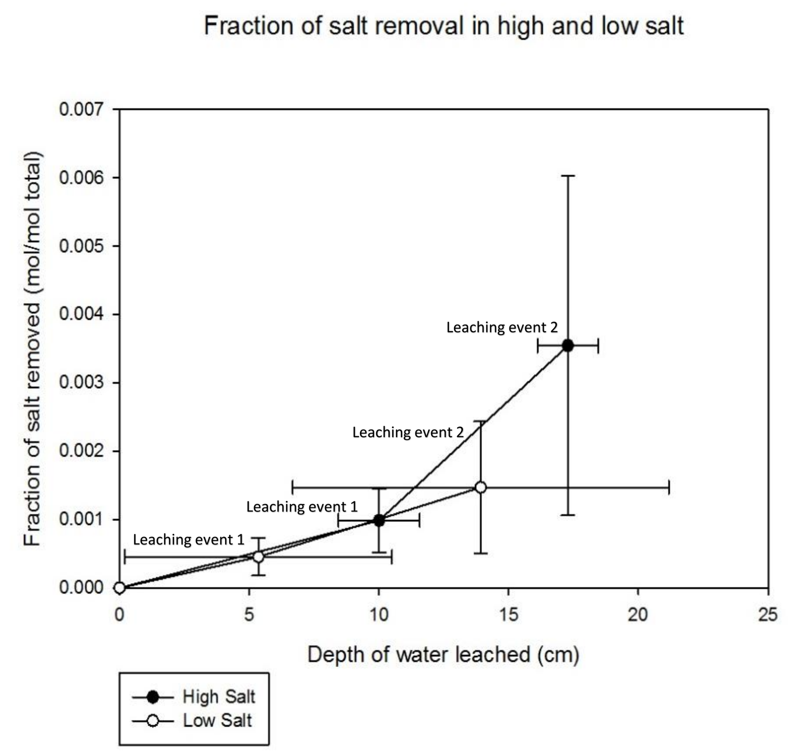



Figure 6. Average cumulative fraction of salt leached from the three high salt and the three low salt cores for leaching events 1 and 2. Error bars represent the standard deviation of the water leached and the fraction of salt removed.

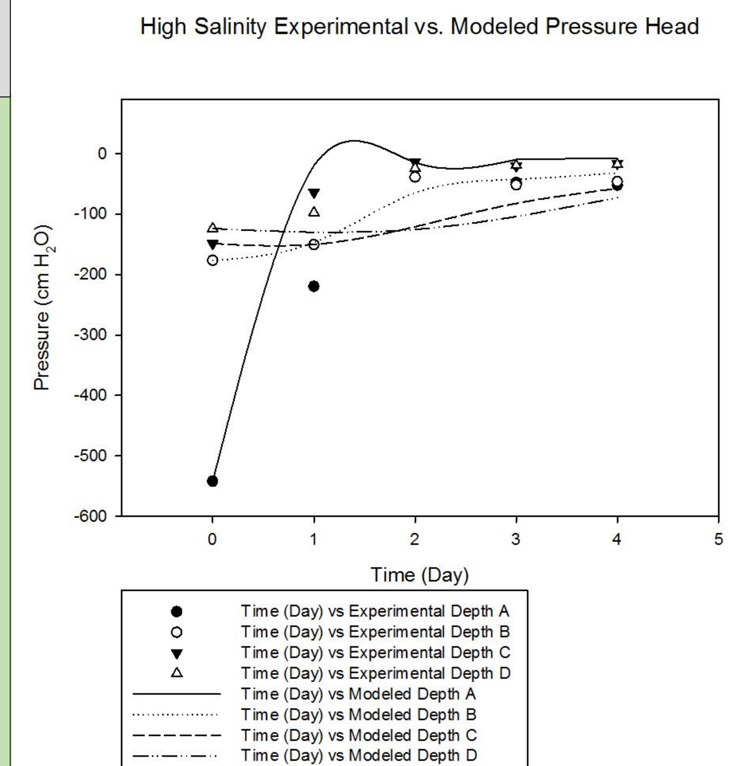



Figure 7. Averaged HYDRUS 1-D modeling of the three high salt cores vs. experimental data from leaching event 1.

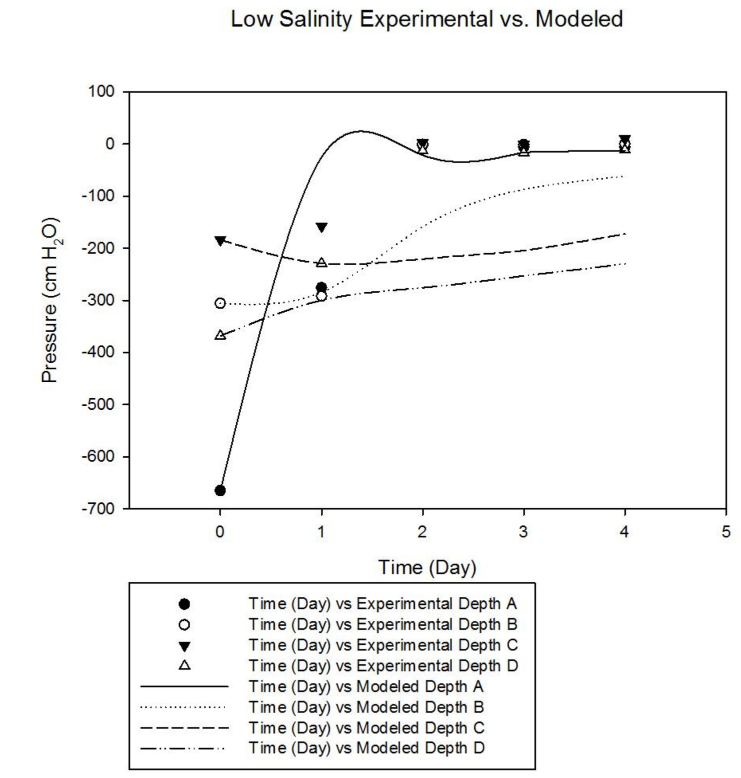



Figure 8. Averaged HYDRUS 1-D modeling of the three high salt cores vs. experimental data from leaching event 1.

## Discussion

- Preliminary results from the two leaching events of a Fargo silty clay indicated that salt removal is limited with a tile drain system. An estimated 131 leaching events may be required for high salt soils to be reduced to low salt status.
- The success of a tile drain system is dependent upon weather variability. Smectitic clay will swell when wetted and shrink when dried. The macropores created from a dry, smectitic clay allows water to infiltrate quickly through the soil. These macropores disappear when the soil is wetted, greatly limiting water flow through the soil (Odom, 1984). North Dakota is a semi-arid region, therefore precipitation events with enough volume to leach water to the tile drain 3-4 ft below the soil surface is limited throughout the year. Prime conditions for salt removal in this management system include a dry, cracked soil followed by heavy rainfall.
- Management techniques can help reduce the time-return of salt removal. Although the weather and smectitic macropore cracks cannot be manipulated, well-drained systems are key for successful salt removal in a tile drained system. Increasing the ability of water to reach the tile drain may increase the cumulative mass of salt removed over time. Improving soil structure with cover crops and eliminating compaction layers will aid in the ability for water to reach the tile drain and remove salts.
- Figures 7 and 8 represent HYDRUS 1D modeling illustrates the ability of cracked clays to transmit water. Depth A (0-20 cm) experimental and modeled results illustrate a good visual fit. However, depths B, C, and D show disagreement between the experimental and modeled results. The HYDRUS 1D model used did not incorporate the information for cracked clay, therefore the discrepancy can be attributed to the dry state of the smectitic clay.

## References


Baker, Claud, H., Paulson, Q. F. 1967. County Groundwater Studied 7. Richland County, North Dakota. North Dakota State Water Commission. Bulletin 46.

Benz, L. C., Sandoval, F. M., Doering, E. J., Willis, W. O. 1976. Managing Saline Soils in the Red River Valley of the North. United States Department of Agriculture, Agricultural Research Service.

Bernstein, Leon. 1975. Effects of Salinity and Sodicity on Plant Growth. United States Department of Agriculture, US Salinity Laboratory. 295-312.

Brown, P. L., Halvorson, A. D., Siddoway, F. H., Mayland, H. F., Miller, M. R. 1982. Saline-seep diagnosis, control, and reclamation. USDA Conservation and Research Report No. 30.

Cameron, K. C., Smith, N. P., C. D. A. McLay, Fraser, P. M., McPherson, R. J., Harrison, D. F., Harbottle, P. 1992. Lysimeters without Edge Flow: An Improved Design and Sampling Procedure. Soil Science Society of American Journal. 56: 1625-1628.

Euliss, N. H., D. M. Mushet, A Multi-Year Comparison of IPCI Scores for Prairie Pothole Wetlands: Implications of Temporal and Spatial Variation. Wetlands 31, 713 (Aug, 2011).

Franzen, David. 2003. Managing saline soils in North Dakota. North Dakota State University Extension Service

Natural Resources Conservation Service. 2013. Map Unit Description: Fargo silty clay. Richland County, North Dakota. Version 23: Dec 31, 2013.

North Dakota Agricultural Weather Network (NDAWN) http://ndawn.ndsu.nodak.edu/. Wahpeton Station Location (2002-2014).

Page, R., Moller, R. 1982. Soluble Cations. In: D., Keeney, editor, Methods of soil analysis-chemical and microbiological properties 2nd ed. Madison, WI . American Society of Agronomy, Soil Science Society of America.

Philips, I. R. 2001. Collection and Automation of Large Undisturbed Soil Cores for Laboratory Leaching Studies. Communication in Soil Science and Plant Analysis. 32: 5-6, 843-862.

Sands, Gary, R., Kandel, Hans, Hay, Chris, Scherer, Tom. 2012. Frequently Asked Questions about Subsurface (Tile) Drainage in the Red River Valley. University of Minnesota Extension.
http://www.extension.umn.edu/agriculture/water/publications/pdfs/faqs_of_tile_drainageprint_61313.pdf
http://ndstudies.gov/blank_nd_county_seats

van Genuchten, Th., M. 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Science Society of American Journal. 44: 892-898.

Veris Technologies http://www.veristech.com/the-soil/soil-ec.