United States Department of Agriculture

NRCS

Natural Resources Conservation Service
National Soil Survey Center
Federal Building, Room 152
100 Centennial Mall North
Lincoln, NE 68508-3866

Phone: (402) 437-5499
FAX: (402) 437-5366

Subject: MGT - Trip Report - Geophysical Assistance

Date: February 8, 2011

To: Paul J. Sweeney
State Conservationist, NRCS
Bismarck, North Dakota

File Code: 330-20-7

Purpose:

A conference was held to summarize the findings of two regional projects (*Regional Soil Salinity Assessment of the Red River Valley of the North (MLRA 56)*, and *Sodium and Salt-Affected Soils in MLRA 54*) and to discuss future uses of electromagnetic induction (EMI) in North Dakota and the Northern Great Plains Soil Survey Region (MO7).

Participants:

Keith Anderson, MLRA Soil Survey Leader, USDA-NRCS, Fargo, ND
Eric Brevik, Associate Professor of Geology and Soils, Dickinson State University, Dickinson, ND
Joe Brennan, Soil Data Quality Specialist (GIS/Remote Sensing), MO7, USDA-NRCS, Bismarck, ND
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Lance Duey, Senior MLRA Soil Scientist, USDA-NRCS, Devils Lake, ND
Alan Gulsvig, MLRA Soil Survey Leader, USDA-NRCS, Devils Lake, ND
Jeanne Heilig, MLRA Soil Survey Leader, USDA-NRCS, Dickinson, ND
John, Kempenich, Soil Scientist, USDA-NRCS, Dickinson, ND
Jerome Schaar, State Soil Scientist/MLRA Office Leader, MO7, USDA-NRCS, Bismarck, ND
Kyle Thomson, Soil Scientist, USDA-NRCS, Devils Lake, ND
Mike Ulmer, Senior Regional Soil Scientists, MO7, USDA-NRCS, Bismarck, ND
Kristin Wild, Soil Data Quality Specialist (Rapid Carbon Project Coordinator), MO7, USDA-NRCS, Bismarck, ND
David Zimmermann, Senior MLRA Soil Scientist, USDA-NRCS, Fargo, ND

Activities:

The conference was held in the Bismarck Federal Building on January 24 thru 27, 2011. Soil scientists from three Major Land Resource Area staffs (MLRA 54, 55, 56), the Northern Great Plains Soil Survey Region Office (MO 7), and the National Soil Survey Center attended this conference and discuss the work that had been accomplished on two regional studies, which evaluated saline and sodium-affected soils.

Summary:

1. The status of EMI in North Dakota and the need to have a small cadre of experienced and well equipped specialists to provide geophysical service throughout the state were discussed.
2. The need to develop and maintain a library on geophysical investigations in MO7 was discussed. This data, though presently available, are improperly filed and will be difficult to find, or even lost, if measures are not taken.

3. Participants felt that EMI is a very useful tool to acquire greater understandings of map unit composition and soil variability, and to improve map unit interpretations. Participants agreed that EMI should be integrated into projects dealing with soil-hydrologic-landscape relationships and known "*problems*" soils or soil map units.
4. Results from the salinity project in Kittson County, MN, indicate that MODIS vegetation indices provides a useful indicator of soil salinity levels in areas of relatively homogenous soils with relatively high soil moisture and clay contents.
5. Results from EMI surveys and soil characterization data collected in Walsh and Grand Forks Counties, North Dakota, were reviewed.
6. Based on the results of the field studies completed in the northern Red River Valley (RRV), it is recommended that in NRCS's soil database, EC_e levels should increase with increasing depth (increase RV for deeper depths rather than maintaining uniform levels) and SAR ratings should be added for soils with higher EC_e.
7. It was concluded that large variations in several soil physiochemical properties presently hamper the development of a reasonable accurate regional-scale salinity assessment methodology and the delineation of salinity levels in the RRV that will support customer's needs and NRCS programs.
8. Participants felt that a *Salinity Risk Index Map*, which was prepared by the North Dakota Soil Staff, presently provides a functional and rational product. However, the *Salinity Risk Index Map* must be promoted to conservationists working in the Red River Valley.
9. Jim Doolittle has agreed to prepare a manual on the protocol that should be used to assess field-scale salinity using EMI by the fall of 2011.
10. It is hoped that a Salinity and Sodium-Affected Soil (SAS) Workshop can take place this fall with personnel from the National Soil Survey Center (West, Wysocki, Libohova, and Doolittle). The purpose of this workshop will be to review the salinity and SAS projects, select appropriate field, statistical, and analytical procedures, and provide technical guidance.
11. Jim Doolittle, research soil scientist (NSSC) provided training on the use of ESAP (EC_e, Sampling, Assessment, and Prediction), a statistical software package designed to predict and display field-scale salinity and other physiochemical soil properties from EMI data.

It was the pleasure of Jim Doolittle and the National Soil Survey Center to work with and be of assistance to your fine staff.

ACTING

JONATHAN W. HEMPEL
Director
National Soil Survey Center

cc: (see attached)

cc:

Keith Anderson, MLRA Soil Survey Leader, NRCS, Fargo, ND
Eric Brevik, Associate Professor of Geology and Soils, Dickinson State University, Dickinson, ND
Jeanne Heilig, MLRA Soil Survey Leader, NRCS, Dickinson, ND
Micheal Golden, Director, Soil Survey Division, NRCS, Washington, DC
Alan Gulsvig, MLRA Soil Survey Leader, NRCS, Devils Lake, ND
Jerome Schaar, State Soil Scientist/MO Leader, NRCS, Bismarck, ND
John W. Tuttle, Soil Scientist, Soil Survey Research & Laboratory, NSSC, MS 41, NRCS, Lincoln, NE
Michael Ulmer, Senior Regional Soil Scientist, NRCS, Bismarck, ND
Larry T. West, National Leader, Soil Survey Research and Laboratory, NSSC, MS 41, NRCS, Lincoln, NE
Douglas A. Wysocki, Research Soil Scientist, Soil Survey Research & Laboratory, NSSC, MS 41, NRCS Lincoln, NE 68508-3866

Summary Report on the Conference for the Regional Assessment of Saline and Sodium-affected soils in North Dakota, January 24 to 27, 2011.

Jim Doolittle

1. Equipment:

North Dakota is well equipped with electromagnetic induction meters suitable for soil investigations and technical soil services. In North Dakota, NRCS has 6 EM38 meters. These meters are in MLRA Soil Survey Offices located in Dickinson (1), Devils Lake (2), and Fargo (2). One EM38 meter is located in Jamestown with a resource soil scientist. As in other states and MOs, major concerns of soil management are:

1. The rising costs of maintaining six fully integrated and operational EMI systems.
2. The inability of EMI operators to obtain sufficient experience and field time with the EMI systems.
3. The inability of staffs to stay abreast of rapidly advancing and leapfrogging technologies.

To address these concerns, the MO7 Office Leader will designated one to two soil scientists to be the North Dakota and Northern Great Plains Soil Survey Region (MO 7) principal EMI operators. This action will allow these operators to gain greater understanding and experiences with EMI, and increased confidence in interpretations. However, for this action to be successful, MLRA project leaders in North Dakota and MO7 must include these individuals and EMI in project proposals.

2. Geophysical Library:

The individuals designated to operate the EMI meters will be responsible for maintaining a geophysical library. It is recognized that a large amount of EMI and ground-penetrating radar (GPR) data have already been collected in North Dakota, Minnesota, South Dakota, and Montana. This data, though presently available, are improperly filed and will be difficult to find, or even lost, if measures are not taken in the near future.

3. Use of EMI:

Participants agreed that EMI is an effective quality-control tool for soil survey operations and technical soil assistance. Detailed EMI grid surveys represent high-intensity or order one soil surveys. This level of detail is not practical for soil surveys, but is useful when applied to selected fields or landscapes to obtain a greater understanding of map unit composition and soil variability, and to improve map unit interpretations. Participants agreed that EMI should be integrated into projects dealing with soil-hydrologic-landscape relationships. The use of EMI would benefit those studies that investigate soil map unit composition and known "problems" soils and delineations. Participants felt that the EM38 meter provides quantitative and qualitative information that is useful for soil map unit composition studies. These studies use random EMI traverses and focus on the location and proportion of different soils on diverse landscapes and delineations. Participants felt that EMI helps to build confidence in soil mapping decisions and to improve map unit concepts and interpretations. However, to effectively interpret EMI data, the operator must be knowledgeable of soils and soil/landscape relationship. In addition, soil borings are required to confirm interpretations.

Expanded use of EMI as a soil technical service tool is envisioned to improve soil survey interpretations and meet ever-changing needs. A small cadre of designated EMI operators is planned. These soil scientists will provide EMI assistance throughout North Dakota and MO7. They will have greater time and experiences with EMI and can therefore be more proficient in their work and interpretations.

4. **Regional Scale Soil Salinity Assessment of Red River Valley of the North (MLRA 56).** The purpose of this research is to (1) develop protocol for the rapid and effective assessment of soil salinity at field-scales using EMI; (2) estimate regional-scale salinity levels and patterns within the Red River Valley of the North (RRV) by combining information on soils, landforms, and hydrology using remote-sensing imagery (both Moderate Resolution Imaging Spectroradiometer (MODIS) and Light Detection and Ranging (LIDAR)) in conjunction with field-scale EMI and directed soil sampling data; and (3) develop regional soil salinity hazard maps with interpretations for this major land resource area.

a. Based on the experiences and lessons learned during this research project, Jim Doolittle will prepare a manual on the protocol that should be used to assess field scale salinity using EMI by the fall of 2011.

b. Presently, large variations in several soil physiochemical properties hamper the development of a reasonably accurate regional-scale salinity assessment methodology and the delineation of salinity levels in the RRV that will support customer's needs and NRCS programs.

c. Results from the salinity project in Kittson County, MN, indicate that MODIS vegetation indices provides a useful indicator of soil salinity levels in areas with relatively homogenous soils, substrates, and hydrology. Methods developed in this study were able to explain one-third to one-half of field-measured variations in salinity across Kittson County. Results from EMI surveys indicate that, based on the variability of measured apparent conductivity (EC_a) and estimated salinity, two separate and distinctly different areas of Northcote (very-fine, smectitic, frigid Typic Epiaquerts) soils exist in Kittson County. The results of this research project have been incorporated into the soil survey update for this county. A paper has been published (Lobell et al., 2010) that document the use of EMI and multi-year MODIS EVI and NDVI imagery to map salinity in areas of relatively homogenous, fine-textured soil materials in Kittson County, Minnesota. This methodology appears less reliable and salinity predictions less accurate within the larger Red River Valley of the North because of greater variability in soil types, particle-size distributions, and moisture contents, which affects the measured EMI response.

d. As a consequence of the RRV Salinity Project, the Soil Staff in North Dakota has investigated alternative methodologies to assess and map salinity. Salinity Risk Maps have been developed in Australia and Canada as an alternative method for mapping variations in soil salinity. Participants felt that the Salinity Risk Index Map[1], which was prepared by the North Dakota Soil Staff, provides a functional and rational product. The map identifies discharge areas in the RRV and is based on data (soil classification, drainage, particle size distribution and presences of contrasting layers) contained in SURRGO. However, the Salinity Risk Index Map must be promoted among the conservationists working in the RRV. Jerry Schaar and Alan Gulsvig will prepare a fact sheet that can be distributed to conservationists in RRV to help promote this product.

e. Additional Findings:

1) Mike Ulmer reviewed the different methods that were used to measure salinity in Kittson County (MLRA 56). Results from different methods (EC 1:1, EC saturated paste, EC water saturated extract) applied to the same samples were highly variable. It was stressed that greater care is necessary when using and comparing values derived from different procedures.

---

[1] Anderson, K., D. Zimmerman, and M. Ulmer, 2010. Development and application of a salinity risk index for the Red River Valley of the North (MLRA 56). Annual Meeting of the Soil Science Society of America, October 31–November 4, 2010, Long Beach, California.

2) Electromagnetic induction investigations in Grand Forks County, ND, suggest that soils (Calciaquolls) on slightly higher-lying convex surfaces with noticeably higher concentrations of lime have higher measured EC_a and estimated salinity. In Grand Forks County, relative difference in the levels of measured EC_a and estimated salinity were observed between units of Bearden silty clay loam (126) and Bearden silty clay loam, saline (270). These differences support mapping decisions.

3) The consensus of the participants was that surface layers (0 to 30 cm), although having generally lower EC_a, were too variable and should not be included in the analysis of salinity with EMI. For EMI surveys in the RRV, the preferred depth interval to be analyzed is 30 to 90 cm. For most soil map units that were surveyed with EMI, significant differences in measured EC_a and estimated salinity were observed. Concerns were expressed on how NASIS is populated for non-saline soils, which were found to contain a significant component of slightly saline soils.

4) As part of the salinity assessment in MLRA 56, a comparative study was conducted over several sets of adjoining fields in Walsh County. Each set contained a cultivated field and a field in CRP. The purpose of this investigation was to attain a snapshot view into the effects of different management practices on soil salinity. All fields were high variability in measured EC_a and estimated salinity, with no immediate indication that CRP contributed to amending soil salinity.

5) In the spring of 2008, twenty fields were surveyed with EMI in Walsh County. Using the response surface sampling design (RSSD) program of the ESAP (EC_e, Sampling, Assessment, and Prediction) Software Suite, six optimally-positioned sampling points were located within each of these fields. Soils were sampled to a depth of 150 cm at each of these points for characterization. This EMI study revealed that proximity to stream channels may create a drawdown of the water table and the lowering or absence of salinity. It was also noticed that a disproportionate number of sites were located near stream channels and may be unrepresentative of Walsh County as a whole. These sites typically had lower than anticipated EC_a. Site selection was often based on familiarity with and the permission of landowners, and therefore accessibility. Future county or regional studies need to ensure that site selection is representative of all areas.

6) In Walsh County, spatial EC_a patterns generally matched tonal patterns on aerial photographs of sites, with areas of higher EC_a (and salinity) conforming to lighter-colored areas and areas of lower EC_a (and salinity) conforming to darker-colored areas on aerial photographs. It was observed, that omitting surface layers (0 to 30 cm) from the analysis resulted in higher EC_e. Surface layers had lower, but more variable and unpredictable EC_e. It is doubtful that the tools and methodology used in this study can map very slight salinity (2 to 4 dS/m).

7) In Grand Forks County, high intensity EMI surveys were conducted in a field of Bearden sicl (126) and Bearden sicl, saline (270) on Burkland's farm. In each field, twenty optimally-spaced sampling points were selected. Each field had been previously surveyed with EMI, but at a lower intensity and with no sampling. Temporal changes in EC_a and estimated EC_e were evident between the two surveys, which were conducted in August 2006 and September 2008. Difference in EC_a and EC_e were evident between the two map units, with Bearden sicl, saline (270) having higher measured and estimated values. Some of the differences that appeared on spatial EC_a and EC_e plots were attributed to differences in soil moisture and salinity, or errors committed in instrument calibration, field methodology, modeling EC_a and EC_e data, and plotting algorithms.

8) Dave Zimmerman reported that for soil samples collected within the northern RRV, the correlation between EC_e and SAR was r = 0.68 (for 1036 data layers). For most soils, these parameters increase in value with increasing soil depth. Surface layers are highly variable in EC_e. In general, areas of strongly saline soils have SAR > 5 in the subsurface. Many soils (Calciaquolls) in the RRV have SAR between 4 and 8, but the NRCS soil database does not reflect this.

9) Researchers at North Dakota State University are preparing a bulletin for the installation of drainage tile. The bulletin directs landowners to go to Web Soil Survey and check the SAR level in the soil before installing drainage tiles. They recommend caution when installing drainage tiles in soils with SAR > 5. However, we have not populated SAR values in our database for many of these soils. It was recommended that in the NRCS's database, EC_e levels should increase with increasing soil depth (increase RV for deeper depths rather than maintaining uniform levels) and SAR ratings should be added for soils with higher EC_e. Dave noted that more time needs to be spent reviewing and analyzing the soil characterization data already collected in the RRV. Results in the northern portion may not be representative for the entire RRV. The MO7 Soil Staff will look into adding a "*Tiling Suitability*" rating.

5. **Sodium Affected Soils (SAS):**

The initial phase of this study is near completion. Soil characterization and EMI data collected in Slope and Foster Counties in May 2010 still needs to be processed and analyzed. Results from EMI surveys conducted in Billings and Griggs Counties disclosed that EMI is an effective tool for the appraisal of SAS soils, when sites are properly selected and partitioned into soil-landscape units. High variability in water and clay contents across topographical diverse and sedimentologically complex terrains contributed to lower than anticipated correlations between stochastic models of SAR and salinity with the sampled soil data. Results do confirm highly variable levels of both SAR and salinity within SAS landscapes. A short research paper is being prepared that will discuss the results of this study. Future work will be specified in MLRA Soil Survey Office's project plans as outlined in MO7's Standard Operating Procedures.

a. When the group looked at the predictability of EC_e using stochastic models, which are based on both measured EC_a and sampled soil profile data, correlations were variable with relative low levels of significance. For log transformed salinity data, the correlation (r^2) between modeled and calibrated data ranged from 0.240 to 0.918 with level of significance that ranged from 0.08 to 0.56. For non transformed salinity data, the correlation (r^2) between modeled and calibrated data ranged from 0.197 to 0.913 with level of significance that ranged from 0.01 to 0.72. For log transformed SAR data, the correlation (r^2) between modeled and calibrated data ranged from 0.100 to 0.823 with level of significance that ranged from 0.063 to 0.854. For non transformed SAR data, the correlation (r^2) between modeled and calibrated data ranged from 0.128 to 0.951 with level of significance that ranged from 0.01 to 0.815. While advised to use only log-transformed data, transformation made no significant difference in distribution curves and did not improve the accuracy of predictions in this study. Prediction accuracy can be increase if the calibration sample size is increased (Lesch et al., 1995); however, this is unreasonable for regional-scale assessments. Pertinent statistical data for the study sites are listed in Tables 1 and 2.

Table 1 Log-Transformed Data
Correlation (r^2) between Modeled and Calibrated Data

Billings 1	**Salinity**					**SAR**			
Depth	R^2	RMSE[2]	F-value	Prob>F		R^2	RMSE	F-value	Prob>F
0-30	0.3894	0.9606	0.96	0.4771		0.4812	3.7185	1.39	0.3737
30-60	0.4293	5.1938	1.13	0.4312		0.5058	8.3651	1.54	0.3475
60-90	0.4532	5.3069	1.24	0.4044		0.1695	7.4934	0.31	0.7569
0-90	0.4984	3.1896	1.49	0.3552		0.4163	6.0610	1.07	0.4459
Billings 2	**Salinity**					**SAR**			
Depth	R^2	RMSE	F-value	Prob>F		R^2	RMSE	F-value	Prob>F
0-30	0.3176	3.9595	0.70	0.5637		0.6751	6.5037	3.12	0.1852
30-60	0.7337	4.2021	4.13	0.1375		0.7891	5.1005	5.61	0.0969
60-90	0.5249	5.7822	1.66	0.3275		0.7289	5.2139	4.03	0.1412
0-90	0.6772	3.4530	3.15	0.1834		0.8235	4.1386	7.00	0.0742
Billings 3	**Salinity**					**SAR**			
Depth	R^2	RMSE	F-value	Prob>F		R^2	RMSE	F-value	Prob>F
0-30	0.3115	0.1821	0.68	0.5713		0.1883	4.4998	0.35	0.7313
30-60	0.7315	1.6798	4.09	0.1392		0.3994	5.5765	1.00	0.4655
60-90	0.7727	1.7191	5.10	0.1084		0.0999	7.5371	0.17	0.8540
0-90	0.9138	0.5397	15.91	0.0253		0.2566	5.0625	0.52	0.6410
Stark 1	**Salinity**					**SAR**			
Depth	R^2	RMSE	F-value	Prob>F		R^2	RMSE	F-value	Prob>F
0-30	0.6985	2.8218	6.95	0.0779		0.5173	9.5198	3.21	0.1709
30-60	0.2396	5.6343	0.95	0.4026		0.4991	9.5483	2.99	0.1823
60-90	0.6996	3.6738	6.99	0.0774		0.7364	6.1264	8.38	0.0627
0-90	0.5857	3.6624	4.24	0.1316		0.6133	7.8407	4.76	0.1172
Griggs 1	**Salinity**					**SAR**			
Depth	R^2	RMSE	F-value	Prob>F		R^2	RMSE	F-value	Prob>F
0-30	0.4542	2.9136	1.25	0.4032		0.8110	3.3317	6.44	0.0822
30-60	0.4733	4.1512	1.35	0.3822		0.7775	4.2543	5.24	0.1050
60-90	0.6774	2.8387	3.15	0.1832		0.1759	8.432	0.32	0.7481
0-90	0.5258	3.1569	1.66	0.3266		0.5403	4.9949	1.76	0.3117

b. The comparatively low predictability of salinity and SAR is attributed to the low water and the highly variable clay contents of the soils. Moisture contents within individual layers ranged from 4.95 % to 46 % with an average of 18%. In saline soils, EC_a is primarily a measure of the content of dissolved electrolyte per unit volume of soil (Rhoades et al., 1999). Many have recommended that EC_a measurements should be made at uniform and field capacity water contents (Kachanoski et al., 1988; Lesch et al., 1992). Rhoades et al. (1989) noted that "*small departures*" from field capacity water contents do not seriously interfere with EC_a-salinity appraisals because the salt concentration in the soil water increases as the volume of soil water decreases and the content of

[2] RMSE is abbreviation for root mean square error.

the electrolyte remains essentially constant. However, when the relative water content drops below 50 to 65% of field capacity, EMI signal readings are seriously dampened (Corwin and Lesch, 2005; Lesch and Corwin, 2003; Rhoades et al., 1999) and salinity cannot be accurately determined by EC_a (Rhoades and Corwin, 1990). Lesch and Corwin (2003) noted that when the relative water content drops too far below field capacity, then the spatial variations in water content can become the dominant factor influencing EC_a even in the presence of large spatial variations in salinity. The ability to accurately determine EC_e from EC_a decreases as the water content decreases (Rhoades et al,, 1999). As a consequence, Rhoades et al. (1999) note that it is inappropriate to attempt to infer soil salinity from EC_a measurements made on dry or nearly dry soils.

Table 2 Non-Transformed Data
Correlation (r^2) between Modeled and Calibrated Data

Billings 1	Salinity				SAR			
Depth	R^2	RMSE	F-value	Prob>F	R^2	RMSE	F-value	Prob>F
0-30	0.4396	0.920	1.18	0.4195	0.5328	3.528	1.71	0.3193
30-60	0.5325	3.701	1.71	0.3196	0.3341	9.710	0.75	0.5434
60-90	0.1968	6.432	0.37	0.7199	0.1278	7.679	0.22	0.8146
0-90	0.4405	3.369	1.18	0.4185	0.3154	6.564	0.69	0.5665
Billings 2	Salinity				SAR			
Depth	R^2	RMSE	F-value	Prob>F	R^2	RMSE	F-value	Prob>F
0-30	0.3579	3.8409	0.84	0.5145	0.9512	2.519	29.26	0.0108
30-60	0.9132	2.3986	15.79	0.0256	0.8510	4.236	8.57	0.0575
60-90	0.5267	5.7711	1.67	0.3256	0.6572	5.863	2.88	0.2007
0-90	0.7430	3.0809	4.34	0.1303	0.8632	3.643	9.47	0.0506
Billings 3	Salinity				SAR			
Depth	R^2	RMSE	F-value	Prob>F	R^2	RMSE	F-value	Prob>F
0-30	0.2883	0.1852	0.61	0.6004	0.2402	4.3540	0.47	0.6623
30-60	0.7465	1.6234	4.42	0.1276	0.6136	4.4729	2.38	0.2402
60-90	0.4884	2.5789	1.43	0.3659	0.1987	7.1112	0.37	0.7173
0-90	0.8033	0.8154	6.13	0.0872	0.4323	4.4241	1.14	0.4278
Stark 1	Salinity				SAR			
Depth	R^2	RMSE	F-value	Prob>F	R^2	RMSE	F-value	Prob>F
0-30	0.9104	1.5385	30.47	0.0117	0.7384	7.0075	8.47	0.0620
30-60	0.2932	5.4321	1.24	0.3459	0.5716	8.8298	4.00	0.1392
60-90	0.8348	2.7241	15.16	0.0300	0.8095	5.2088	12.75	0.0376
0-90	0.7242	2.9884	7.88	0.0675	0.7477	6.3332	8.89	0.0585
Griggs 1	Salinity				SAR			
Depth	R^2	RMSE	F-value	Prob>F	R^2	RMSE	F-value	Prob>F
0-30	0.6562	2.3125	2.86	0.2016	0.8634	2.8325	9.48	0.0505
30-60	0.6321	3.4696	2.58	0.2232	0.8783	3.1458	10.83	0.0424
60-90	0.9004	1.5771	13.56	0.0314	0.1610	8.5078	0.29	0.7684
0-90	0.7716	2.1907	5.07	0.1091	0.6457	4.385	2.73	0.2109

c. Excessive spatial and depth variations in soil moisture contents occur across the study sites because of difference in soils, stratigraphy, topography and hydrologic processes. Correlation can be improved by partitioning survey areas into different zones based on hydropedologic parameters, with separate parametric calibrations performed for each calibration zone.

d. The low predictability of salinity and SAR is also attributed to spatial and vertical variations in clay contents at these sites. In general, modeling method works well in fields having low to moderate textural variability (Lesch et al., 1992). As EC_a is associated with the cation exchange capacity, it is influenced by clay content and type (Rhoades et al., 1999). Apparent conductivity is also affected by the pore size distribution and structure of the soil; parameters that affect the amount of mobile and immobile water (Rhoades et al., 1999). In salinity and sodicity appraisals, correlations and results are improved when soils have relatively homogenous bulk density, water and clay contents and distributions.

6. **CESU Agreement with North Dakota State University.** This agreement with North Dakota State University was discussed. The consensus was that it is in good hands and is producing valuable information on the use of alternative methodologies for salinity and SAR assessments.

7. **Fall Salinity and Sodium-Affected Soil (SAS) Tour and Workshop.** It is hoped that a tour and workshop can take place this fall with personnel form the National Soil Survey Center (West, Wysocki, Libohova, and Doolittle). The purpose of this activity will review salinity and SAS project results and seek to optimize and direct future project activities.

References:

Corwin, D.L., and S.M. Lesch, 2005. Characterizing soil spatial variability with apparent conductivity. I. Survey protocols. *Computers and Electronics in Agriculture* 46: 103-133.

Kachanoski, R.G., E.G. Gregorich, and I.J. Van Wesenbeeck, 1988. Estimating spatial variations in soil water content using noncontacting electromagnetic inductive methods. *Canadian Journal of Soil Science* 68: 715-722.

Lesch, S.M. and D.L. Corwin, 2003. Using the dual-pathway conductance model to determine how different soil properties influence conductivity survey data. *Agronomy Journal* 95: 365-379.

Lesch, S.M., J.D. Rhoades, L.J. Lund, and D.L. Corwin, 1992. Mapping soil salinity using calibrated electromagnetic measurements. *Soil Science Society of America Journal* 56: 540-548.

Lesch, S.M., D.J. Strauss, and J.D. Rhoades, 1995. Spatial prediction of soil salinity using electromagnetic induction techniques 1. Statistical prediction models: A comparison of multiple linear regression and cokriging. *Water Resources Research* 31 (2) 373-386.

Lobell, D. B., S. M. Lesch, D. L. Corwin, M. G. Ulmer, K. A. Anderson, D. J. Potts, J. A. Doolittle, M. R. Matos, and M. J. Baltes. 2010. Regional-scale assessment of soil salinity in the Red River Valley using multi-year MODIS EVI and NDVI. *Journal of Environmental Quality* 39: 35-41.

Rhoades, J.D., F. Chanduvi, and S.M. Lesch, 1999. Soil salinity assessment; Methods and interpretation of electrical conductivity measurements. Food and Agricultural Organization, Paper 57.

Rhoades, J.D., and D.L. Corwin, 1990. Soil electrical conductivity: Effects of soil properties and application to soil salinity appraisal. *Communications in Soil Science and Plant Analysis* 21: 837-860.

Rhoades, J.D., N.A. Manteghi, P.J. Shouse, and W.J. Alves. 1989. Soil electrical conductivity and soil salinity: New formulations and calibrations. *Soil Science Society of America Journal* 53: 433-439.