Salinity Assessment of the Red River Valley Using MODIS and Electromagnetic Induction Directed Soil Sampling: Phase I

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The Problem

Due to changes in climatic patterns, precipitation has increased in the Red River Valley (RRV) of northeastern North Dakota and northwestern Minnesota. The increased precipitation has raised water tables. The higher water tables and undulating topography, which creates areas of recharge and discharge, have caused an increase in salt accumulation within the crop root zone. Farmers, state conservationists, and federal agencies such as NRCS are concerned about the effect of increased salinity on crop productivity in the RRV, which produces substantial levels of wheat (moderately salt tolerant), soybeans (moderately salt tolerant), sugarbeets (salt tolerant), and alfalfa (moderately sensitive). Before the salinity issue in the RRV can be knowledgeably addressed an understanding of the extent of the salinity problem and a means of monitoring salinity at a regional-scale is needed.

Objectives

Overall Project Objective: To develop protocols to map soil salinity for the entire RRV using financial, labor, and equipment resources available to NRCS.

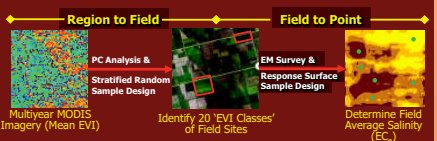
Phase I Objective: To evaluate salinity assessment methodology for RRV's Kittson County using MODIS (Moderate Resolution Imaging Spectroradiometry) Enhanced Vegetative Index (EVI) imagery calibrated with ground-truth measurements of salinity from electromagnetic induction (EMI) measurements of apparent soil electrical conductivity (EC_a) to direct soil sampling.

Mapping Soil Salinity at Field and Regional Scales is a Complex Task

- Soil salinity is a dynamic property that exhibits complex spatial patterns at local, field, and regional scales.
- Tools are needed that measure soil salinity rapidly at different scales:
  - Field scale: geospatial measurements of EC_a.
  - Landscape scale: MODIS EVI.

Study Site

Regional-scale Salinity Assessment Methodology



Seeking an answer to the question: Does multi-year mean EVI correlate with field average salinity (EC_e)?

MODIS Imagery of Kittson County, MN (Summer 2006)

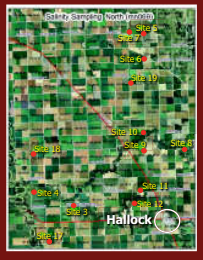
Advantages of Using MODIS:

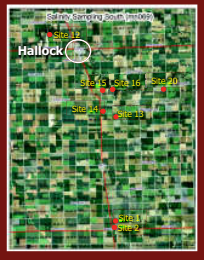
- MODIS EVI is less sensitive to fluctuations in atmospheric properties
- Daily images since 1999
- 250 m – 1 km resolution
- Freely available

$$\text{MODIS EVI} = 2.5\,\frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + 6\rho_{RED} - 7.5\,\rho_{BLUE} + 1}$$

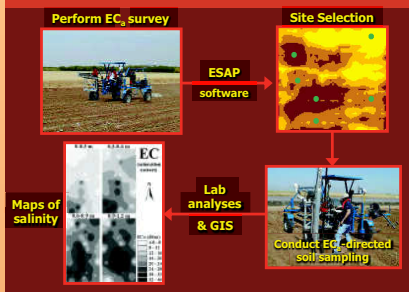
where ρ is the reflectance.

20 Fields Selected in Kittson County to Reflect a Range of MODIS EVI Classes:



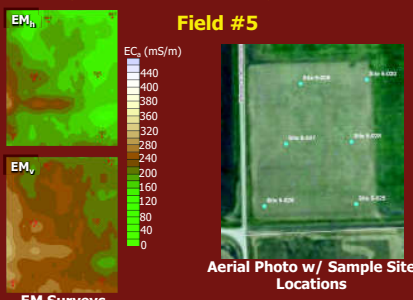


Ground-truth Field-scale Salinity Assessment with EC_a of 20 Fields



Typical EMI EC_a Survey and Site Selection to Quantify Field-Average Salinity:

Field #5



EM Surveys

Aerial Photo w/ Sample Site Locations

Results

- Initial results: Multi-year MODIS EVI, by itself, was not highly correlated with field average salinity for Kittson County, MN!
- Multiple linear regression model:
  - $\ln(EC_e)_i = 3.0 - 0.51(EVI_i) - 0.12(Crop_i) + 0.9(CRP_i) + \varepsilon_i$

where for the i^{th} site

$Crop_i = \begin{cases} 1 \text{ if crop is present} \\ 0 \text{ otherwise} \end{cases}$ $CRP_i = \begin{cases} 1 \text{ if land is in CRP} \\ 0 \text{ otherwise} \end{cases}$

CRP = Land in Conservation Reserve Program (environmentally sensitive, highly erodible land)

- $R^2 = 0.541$

Conclusion

Over 50% of the variability in soil salinity across Kittson County can be explained with MODIS EVI, presence or absence of a crop, and whether or not the land is in CRP; consequently, MODIS imagery appears to have potential for regional-scale salinity assessment.

Future Plans

- Evaluate lidar, distance to tributaries, and LF as additional independent model variables
- Test/validate Kittson County salinity model
- Purchase higher resolution Landsat data (30-m resolution)
- Phase II: evaluate approach in other Red River Valley counties

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