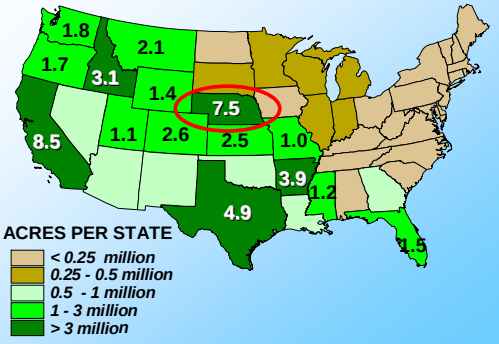
The 8th ECPA (Prague, Czech Republic)
July 13, 2011

Combining On-the-Go Soil Sensing and a Wireless Sensor Network to Increase Irrigation Water Use Efficiency

Luan Pan *Viacheslav I. Adamchuk*
Bioresource Engineering
McGill University

Derrel L. Martin *Mark A. Schroeder* *Richard Ferguson*
University of Nebraska-Lincoln

2003 Farm & Ranch Irrigation Survey



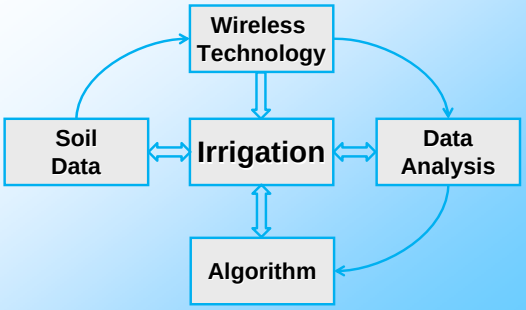
What is the Problem?

Objective

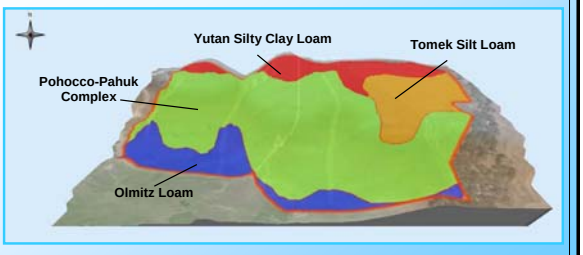
To optimize irrigation management through temporal monitoring of soil matric potential using a wireless sensor network based on fine-resolution maps of apparent soil electrical conductivity (EC_a) and field elevation

- Water use restrictions
- Irrigation timing
- Variable rate irrigation

Objectives

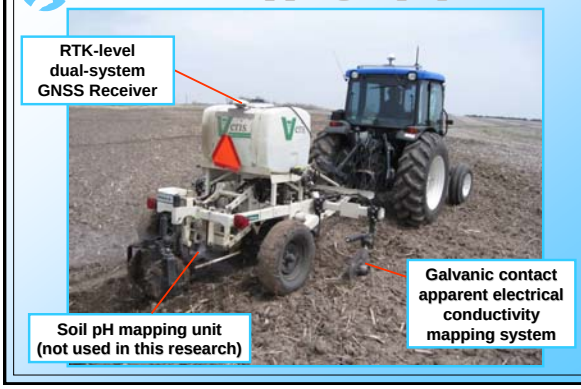


Experimental Field



37-ha Field 1.14 at the University of Nebraska-Lincoln Agricultural Research and Development Center (Mead, Nebraska)

Field Mapping Equipment



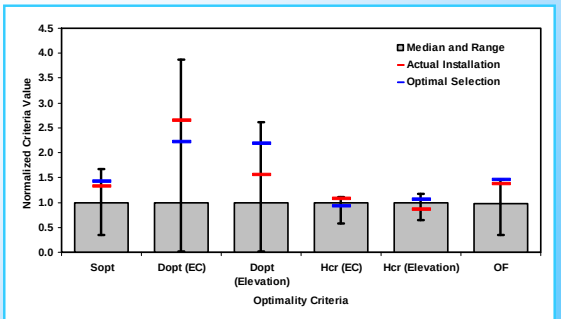
Objective Function

$$OF = \sqrt[5]{S_{opt} \cdot D_{opt-EC} \cdot D_{opt-Elevation} \cdot H_{cr-EC} \cdot H_{cr-Elevation}}$$

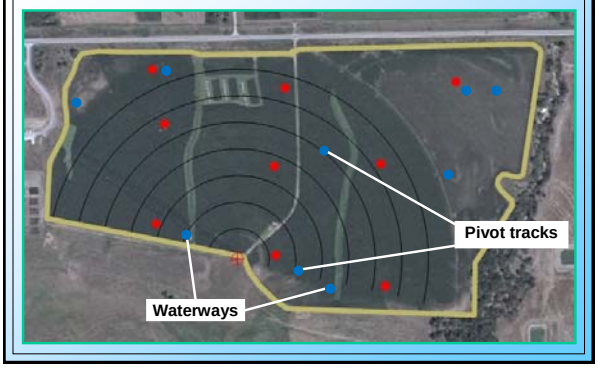
- S-optimality
- D-optimality (EC_a)
- D-optimality (Elevation)
- H-criteria (EC_a)
- H-criteria (Elevation)

Each criteria was normalized by median

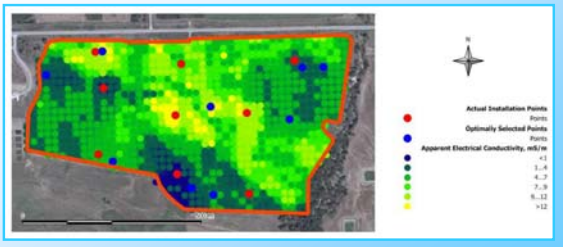
Optimality Criteria Performance



Sensor Placement Restrictions

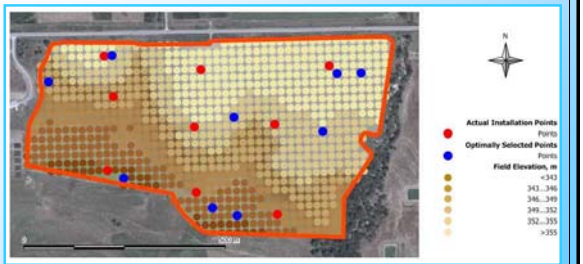


Apparent Electrical Conductivity (0-30 cm)

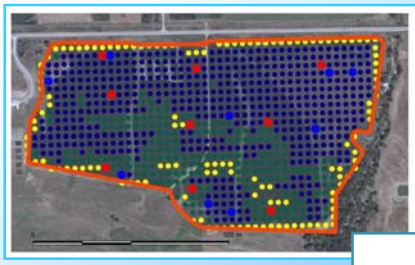


Optimal selection represents the random set of nine locations among 100,000 trials with the highest value of OF

Field Elevation

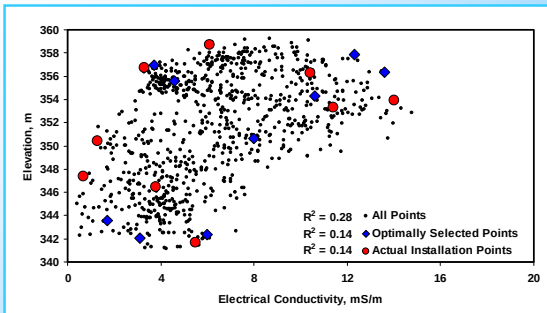


Local Homogeneity Criteria

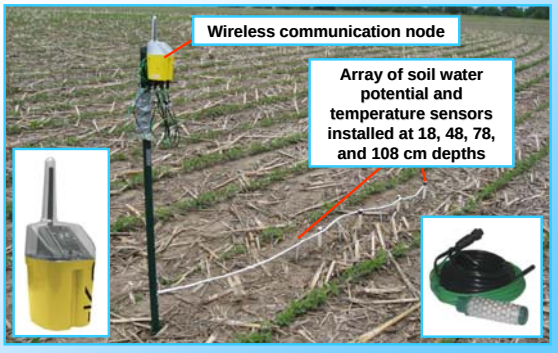


$$H_{cr} = 1 - \frac{\sum_{i=1}^{N}\sum_{j=1}^{n_i}\left(z_i - z_j\right)^2}{\sum_{i=1}^{N} n_i \cdot H_{\max}}$$

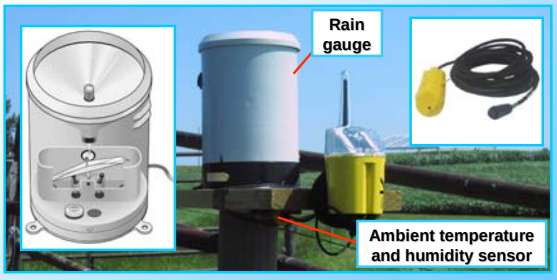
Relationship between Soil EC_a and Field Elevation



Telemetry Monitoring System



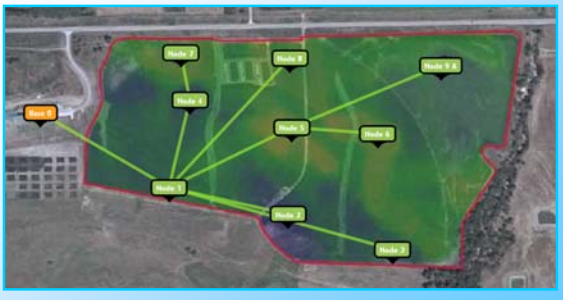
Atmospheric Conditions Monitoring



Wireless System Software

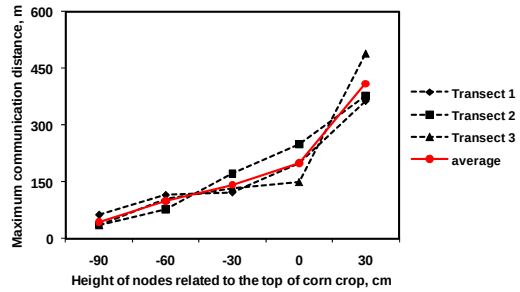
Data Visualization Software – eKoView

Wireless Sensor Network

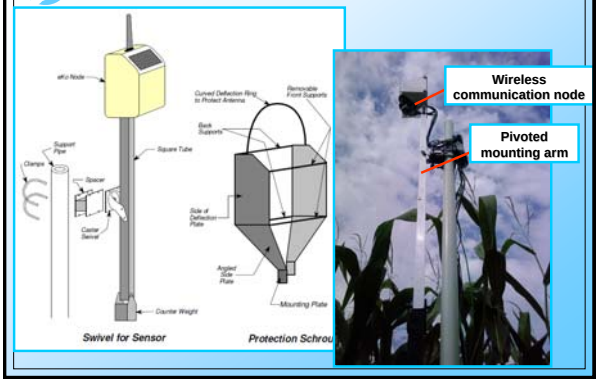


Wireless Signal Test

Wireless Signal Test



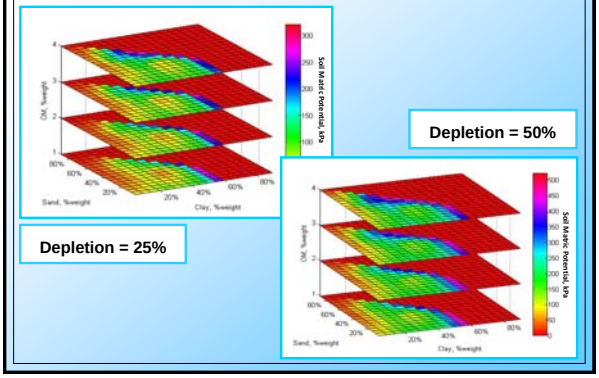
Pivoted Mounting Arms



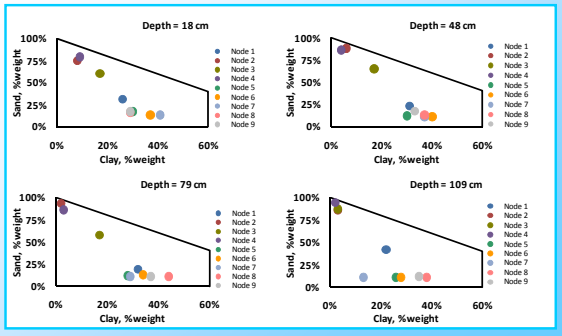
Supplemental Data

- Water Supply
  - Precipitation
  - Irrigation Record
- Soil Parameters
  - Particle Size Analysis
  - Soil Organic Matter

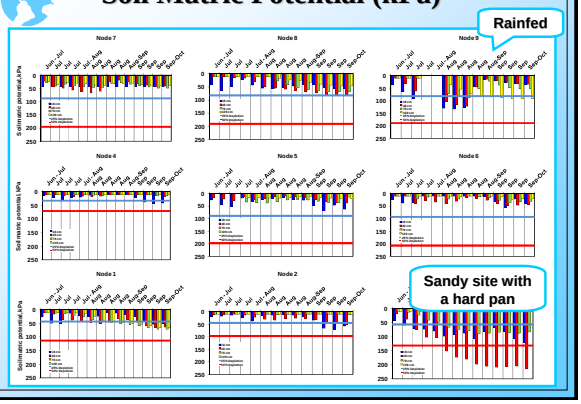
Soil Matric Potential for Different Soils



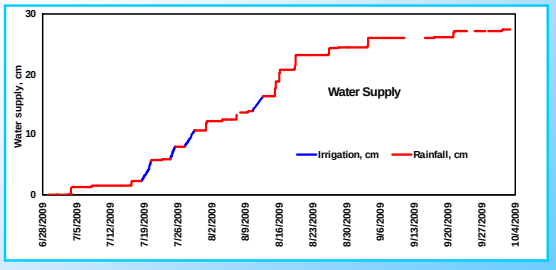
Soil Particle Size of Nine Nodes



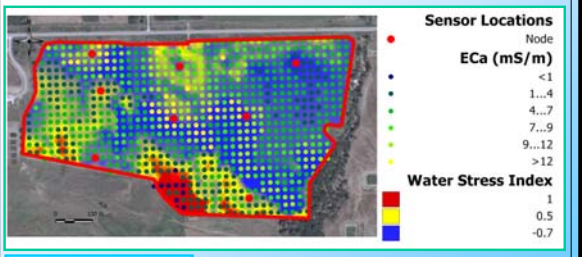
Soil Matric Potential (kPa)



Water Supply



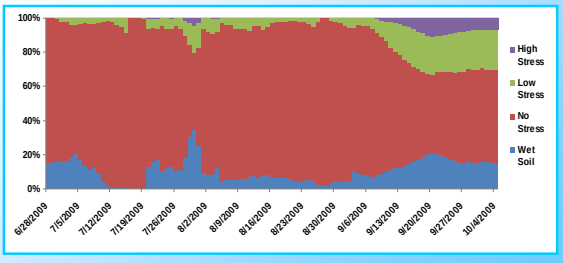
Water Stress Index



$$WSI = \sum_{i=1}^{4} w_i \cdot \left(\frac{\psi_i}{\psi'_i} - 1 \right)$$

$$WSI = \beta_0 - \beta_1 \cdot EC - \beta_2 \cdot Elev + \beta_3 \cdot EC \cdot Elev$$

Temporal Change of Water Stressed Area



Summary

- Apparent soil electrical conductivity and field elevation maps were used to locate a wireless network of nine nodes to monitor soil matric potential and temperature at four depths
- A soil water retention model was used to predict the volumetric water content and, ultimately, the depletion of available water throughout the growing season
- Coarse-textured soils located predominantly along the lower field elevations had water regimes that differed from the rest of the field
- Crop canopy height limited performance of the wireless sensor network, which was accounted for by raising the nodes using a pivoted mounting arm

http://adamchukpa.mcgill.ca
E:mail: viacheslav.adamchuk@mcgill.ca