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Site-Specific Calibration of Multiple Soil Sensor Data Layers

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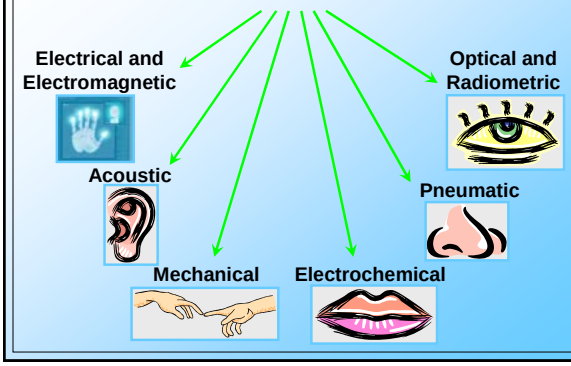
On-the-go Soil Sensors



Applicability of On-the-Go Soil Sensors

Soil property					
Soil texture (clay, silt and sand)	Good	OK		Some	
Soil organic matter or total carbon	Some	Good			
Soil water (moisture)	Good	Good			
Soil salinity (sodium)	OK				Some
Soil compaction (bulk density)			Good	Some	
Depth variability (hard pan)	Some		OK	Some	
Soil pH		Some			Good
Residual nitrate (total nitrogen)	Some	Some			OK
Other nutrients (potassium)		Some			OK
CEC (other buffer indicators)	OK	OK			

Targeted Sampling Rules

- **Prescription rules:**
  1) Cover the entire range of data from each source
  2) Avoid field boundaries and other transition zones
  3) Spread samples over the entire field
- **Current difficulties:**
  1) Poor ability to simultaneously consider multiple data layers
  2) Uncertain number of needed targeted samples
  3) Inconsistent validation and comparison of a sampling scheme with alternatives

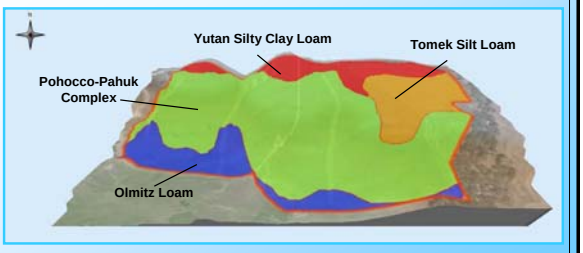
Objective

- To define a set of criteria that may be used to compare alternative schemes of soil sensor telemetry placement that is based on parallel consideration of apparent soil electrical conductive and field elevation maps

RTK-level Dual-system GNSS Receiver

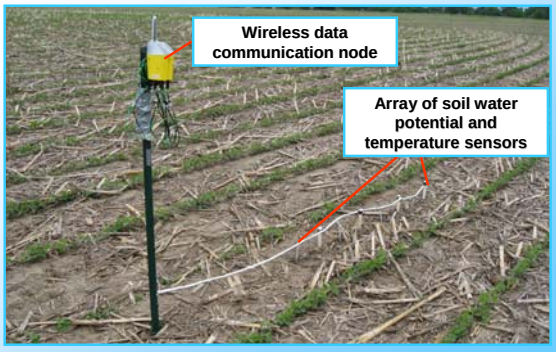
Galvanic contact apparent electrical conductivity mapping system

Experimental Site



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

Telemetry Monitoring System



Spatial Separation (S-optimality)

$$S_{opt} = \frac{N(N-1)}{2\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\frac{1}{\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}}$$

- N is the number of targeted samples (N = 9)
- x and y are the spatial coordinates for i^{th} and j^{th} locations

Data Spread (D-optimality)

$$D_{opt} = |Z'Z|$$

$$Z = \begin{bmatrix} 1 & z_1 \\ 1 & z_2 \\ \vdots & \vdots \\ 1 & z_N \end{bmatrix}$$

- z_i is the value of pH or EC for i^{th} measurement

Local Homogeneity (H-criterion)

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

- n_i is the number of existing nearest neighbors for i^{th} location (n_i = 2 to 4)
- H_{max} is the maximum value of 1-H_{cr} for the given dataset, obtained using ten points with the greatest mean squared difference with neighbors

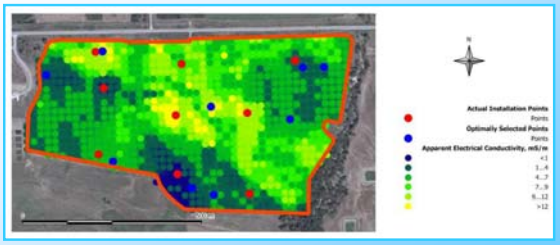
Objective Function

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

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

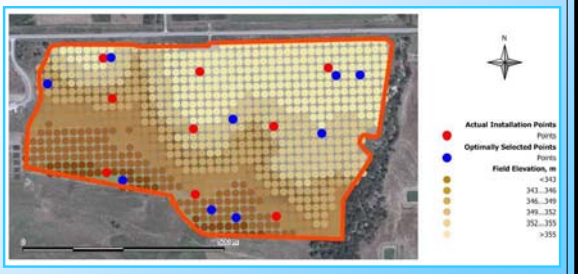
Each criteria was normalized by median

Apparent Electrical Conductivity (0-30 cm)

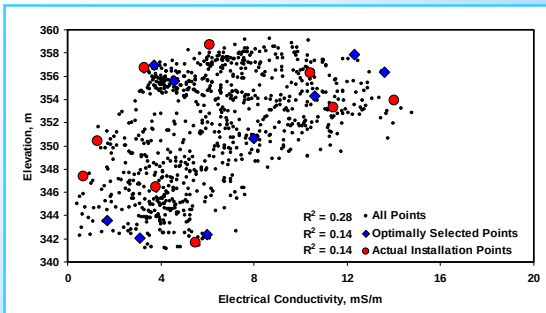


Optimal selection represents the random set of nine locations among 100,000 trials with the highest value of OF

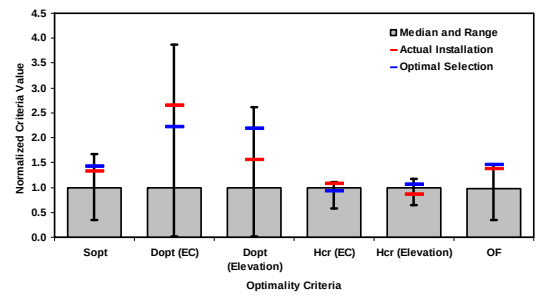
Field Elevation



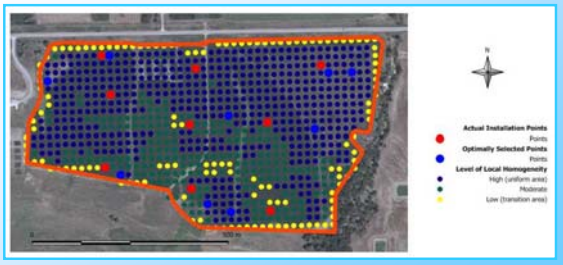
Relationship between Soil EC_a and Field Elevation



Optimality Criteria Performance



Local Homogeneity Criteria



Summary

- An objective function that accounts for representing the entire range of sensor data (Dopt), spreading around the field (Sopt) and local homogeneity (Hcr) was developed
- Partially subjective selection of nine locations to install soil water potential and temperature monitoring equipment was found to provide relatively high value of OF that was, however, less than the maximum value for 100,000 random selections
- The optimally selected points had drawbacks with practical implementation that were avoided with manual interference
- A more involved process of automatic selection of the most appropriate set of targeted sampling/monitoring locations is needed

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