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

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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 (ECa) and field elevation

- Water use restrictions
- Irrigation timing
- Variable rate irrigation

Objectives

Wireless Technology  Soil Data  Irrigation  Data Analysis  Algorithm

Experimental Field

2003 Farm & Ranch Irrigation Survey

ACRES PER STATE

- < 0.25 million
- 0.25 - 0.5 million
- 0.5 - 1 million
- 1 - 3 million
- > 3 million
### Field Mapping Equipment

- RTK-level dual-system GNSS Receiver
- Soil pH mapping unit (not used in this research)
- Galvanic contact apparent electrical conductivity mapping system

### Objective Function

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

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

Each criteria was normalized by median

### Optimality Criteria Performance

- **S-optimality**
- **D-optimality (ECa)**
- **D-optimality (Elevation)**
- **H-criteria (ECa)**
- **H-criteria (Elevation)**

Each criteria was normalized by median

### Sensor Placement Restrictions

- Waterways
- Pivot tracks

### 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

Actual installation points
- Optimal installation points
- Field Elevation
- 0-30 cm
- 30-60 cm
- 60-90 cm
- >90 cm

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

\[ H_{ij} = 1 - \frac{\sum_{i=1}^{N} n_i (z_i - z_j)^2}{\sum_{i=1}^{N} n_i H_{\text{max}}} \]

Telemetry Monitoring System

- Wireless communication node
- Array of soil water potential and temperature sensors installed at 18, 48, 78, and 108 cm depths

Relationship between Soil EC and Field Elevation

- R² = 0.28 for All Points
- R² = 0.14 for Optimally Selected Points
- R² = 0.14 for Actual Installation Points

Atmospheric Conditions Monitoring

- Rain gauge
- Ambient temperature and humidity sensor

Wireless Sensor Network

Wireless System Software

- Data Visualization Software – eKoView

- Wireless Sensor Network
**Wireless Signal Test**

- Maximum communication distance, m
- Height of nodes related to the top of corn crop, cm

**Pivoted Mounting Arms**

- Wireless communication node
- Pivoted mounting arm

**Supplemental Data**

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

**Soil Matric Potential for Different Soils**

- Depletion = 25%

**Soil Particle Size of Nine Nodes**

- Depth = 18 cm
- Depth = 48 cm
- Depth = 109 cm
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.