The Second Global Workshop on Proximal Soil Sensing
(Montreal, Quebec, Canada)

On-the-Go Soil Sensors
Are We There Yet?

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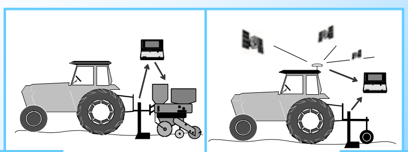
McGill University

May 17, 2011

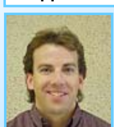
McGill

Sensor Use Approaches

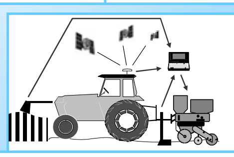


Real-Time Application

Map-Based Approach

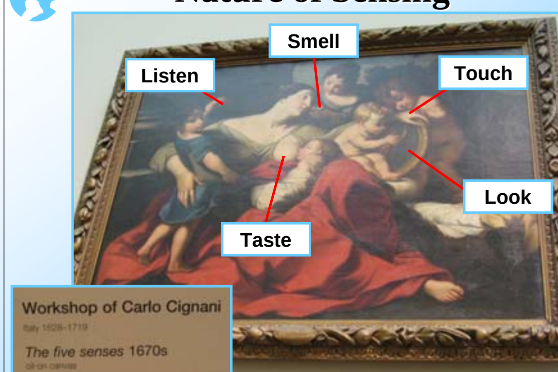


Mark Morgan
Purdue University

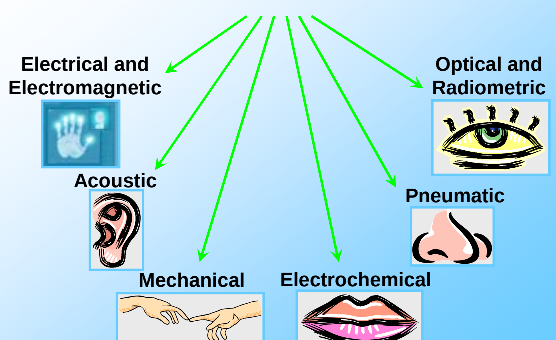


Integrated Approach
(Real-Time with Supplemental Base Map)

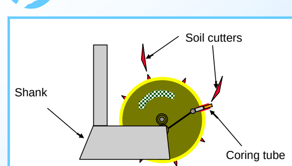
Nature of Sensing



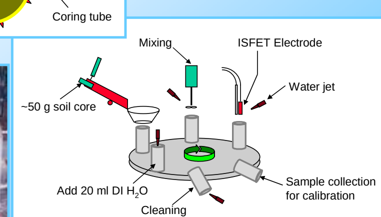
On-the-go Proximal Soil Sensors

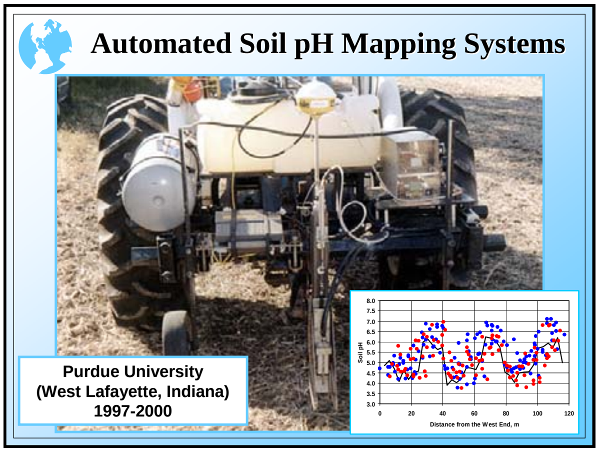


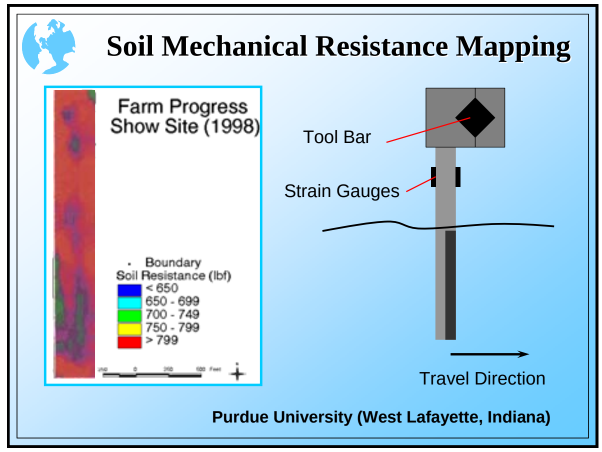
Automated Soil Testing

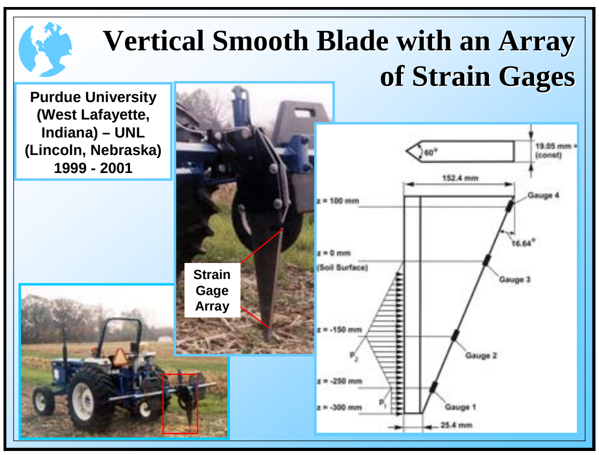


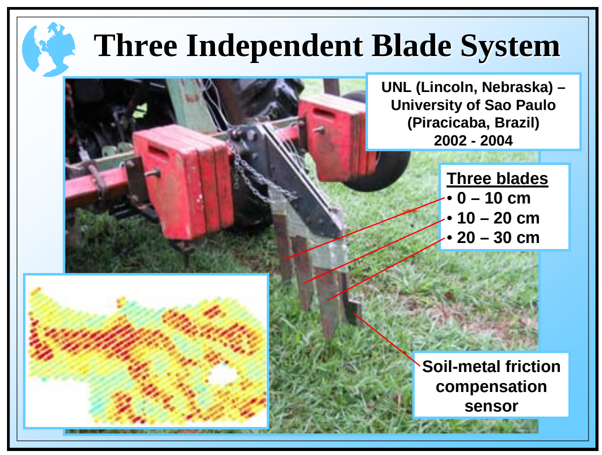
Purdue University
(West Lafayette, Indiana)
1993-1996

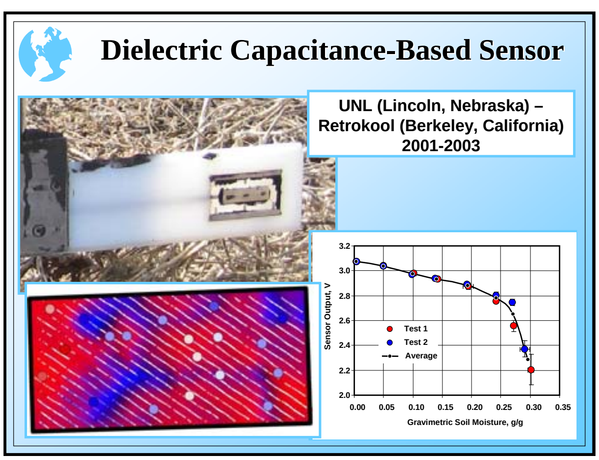


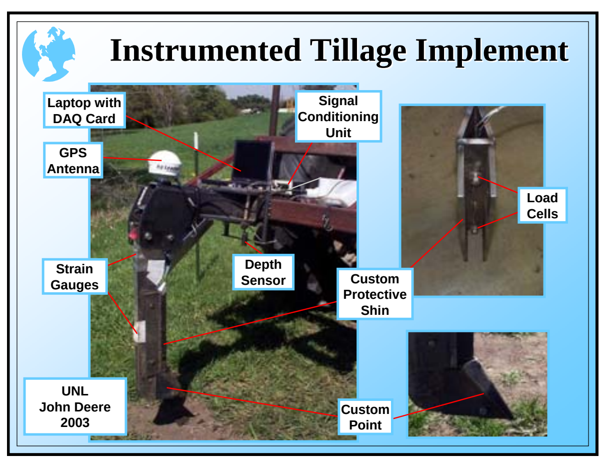

Automated Soil pH Mapping Systems
Purdue University
(West Lafayette, Indiana)
1997-2000
Soil pH
Distance from the West End, m

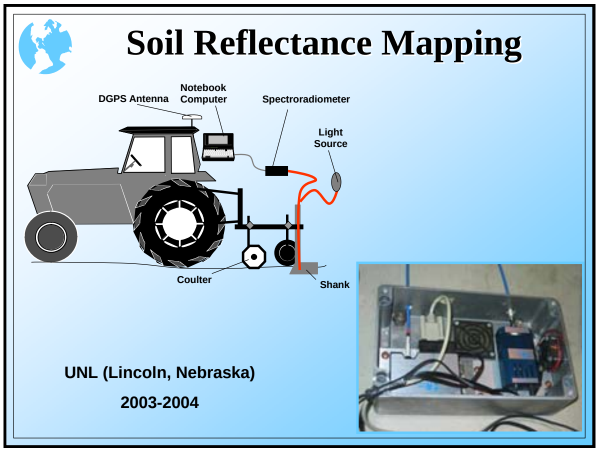

Soil Mechanical Resistance Mapping
Farm Progress
Show Site (1998)
Boundary
Soil Resistance (lbf)
< 650
650 - 699
700 - 749
750 - 799
> 799
Tool Bar
Strain Gauges
Travel Direction
Purdue University (West Lafayette, Indiana)

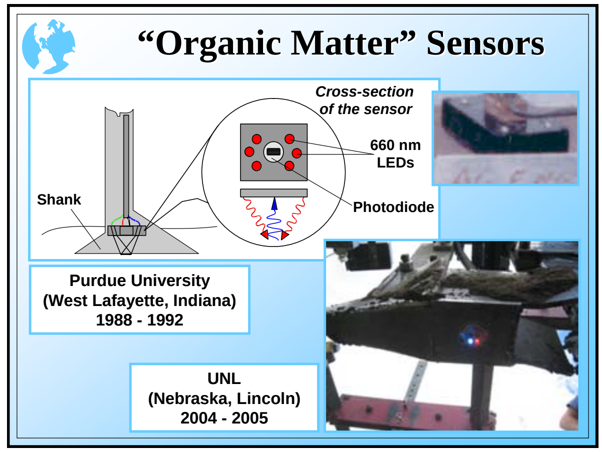

Vertical Smooth Blade with an Array
of Strain Gages
Purdue University
(West Lafayette,
Indiana) – UNL
(Lincoln, Nebraska)
1999 - 2001
Strain
Gage
Array
60°
152.4 mm
19.05 mm
(const)
z = 100 mm
z = 0 mm
(Soil Surface)
z = -150 mm
z = -250 mm
z = -300 mm
Gauge 4
Gauge 3
Gauge 2
Gauge 1
16.64°
25.4 mm

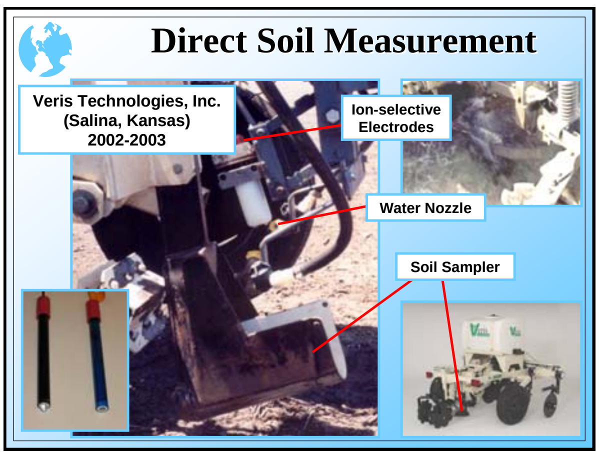

Three Independent Blade System
UNL (Lincoln, Nebraska) –
University of Sao Paulo
(Piracicaba, Brazil)
2002 - 2004
Three blades
• 0 – 10 cm
• 10 – 20 cm
• 20 – 30 cm
Soil-metal friction
compensation
sensor

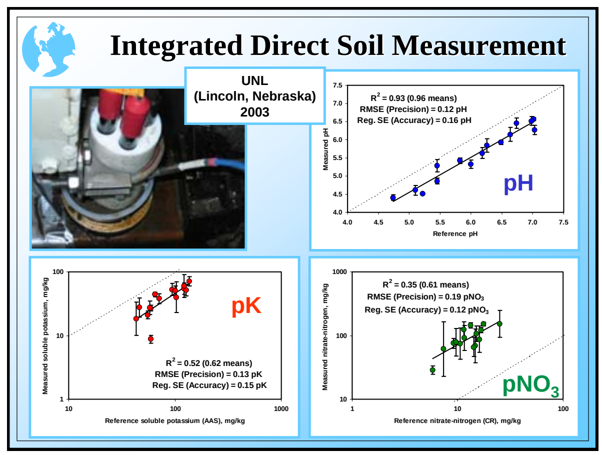

Dielectric Capacitance-Based Sensor
UNL (Lincoln, Nebraska) –
Retrokool (Berkeley, California)
2001-2003
Sensor Output, V
Test 1
Test 2
Average
Gravimetric Soil Moisture, g/g

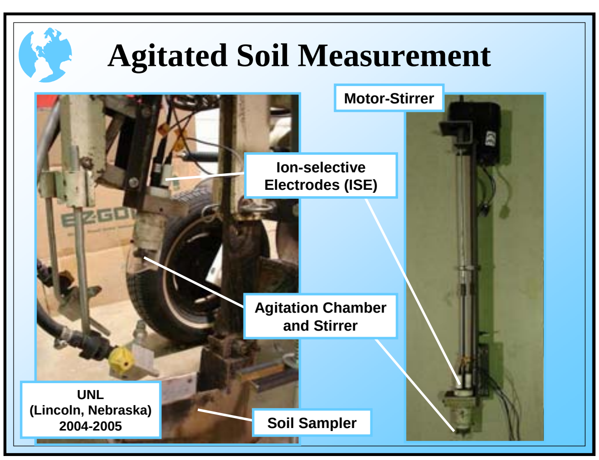

Instrumented Tillage Implement
Laptop with
DAQ Card
Signal
Conditioning
Unit
GPS
Antenna
Load
Cells
Strain
Gauges
Depth
Sensor
Custom
Protective
Shin
UNL
John Deere
2003
Custom
Point

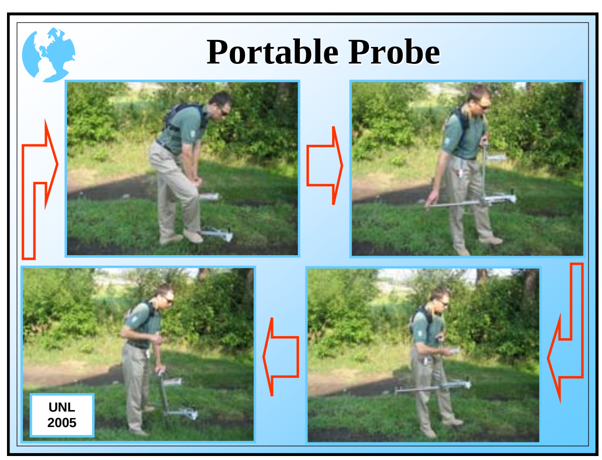

Soil Reflectance Mapping
DGPS Antenna
Notebook Computer
Spectroradiometer
Light Source
Coulter
Shank
UNL (Lincoln, Nebraska)
2003-2004

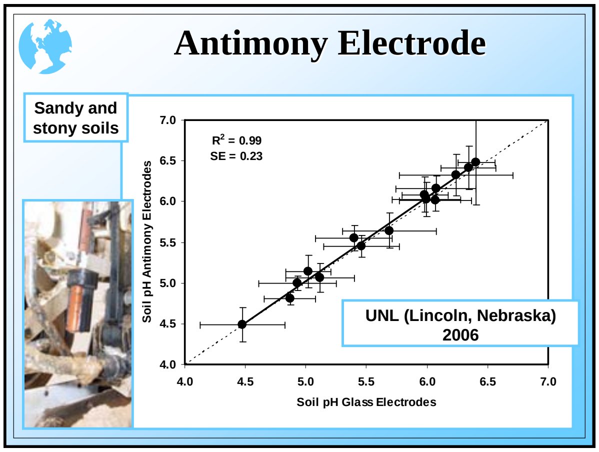

“Organic Matter” Sensors
Cross-section of the sensor
660 nm LEDs
Shank
Photodiode
Purdue University
(West Lafayette, Indiana)
1988 - 1992
UNL
(Nebraska, Lincoln)
2004 - 2005


Direct Soil Measurement
Veris Technologies, Inc.
(Salina, Kansas)
2002-2003
Ion-selective Electrodes
Water Nozzle
Soil Sampler


Integrated Direct Soil Measurement
UNL
(Lincoln, Nebraska)
2003
R^2 = 0.93 (0.96 means)
RMSE (Precision) = 0.12 pH
Reg. SE (Accuracy) = 0.16 pH
pH
Measured pH
Reference pH
pK
R^2 = 0.52 (0.62 means)
RMSE (Precision) = 0.13 pK
Reg. SE (Accuracy) = 0.15 pK
Measured soluble potassium, mg/kg
Reference soluble potassium (AAS), mg/kg
R^2 = 0.35 (0.61 means)
RMSE (Precision) = 0.19 pNO_3
Reg. SE (Accuracy) = 0.12 pNO_3
pNO_3
Measured nitrate-nitrogen, mg/kg
Reference nitrate-nitrogen (CR), mg/kg

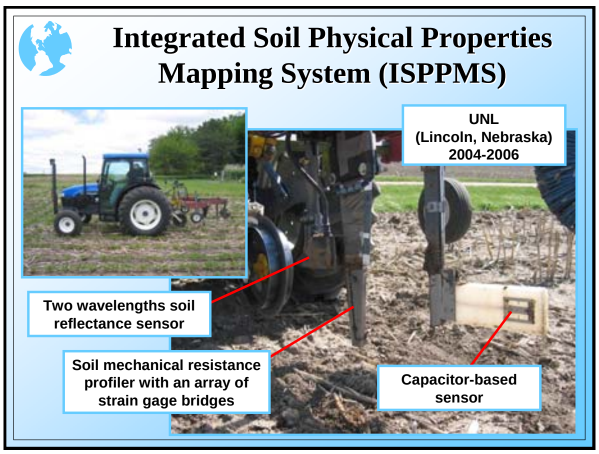

Agitated Soil Measurement
Motor-Stirrer
Ion-selective Electrodes (ISE)
Agitation Chamber and Stirrer
UNL
(Lincoln, Nebraska)
2004-2005
Soil Sampler

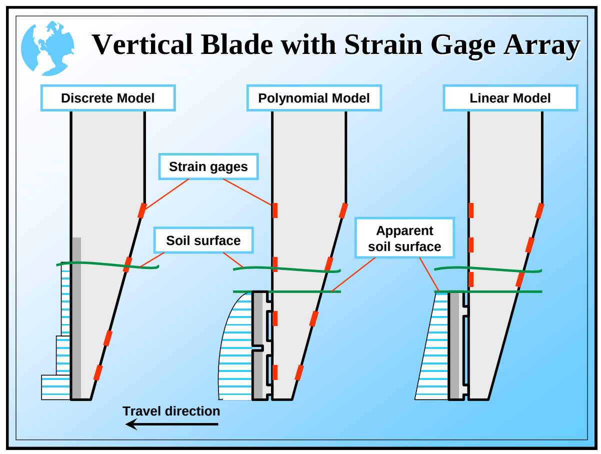

Portable Probe
UNL
2005

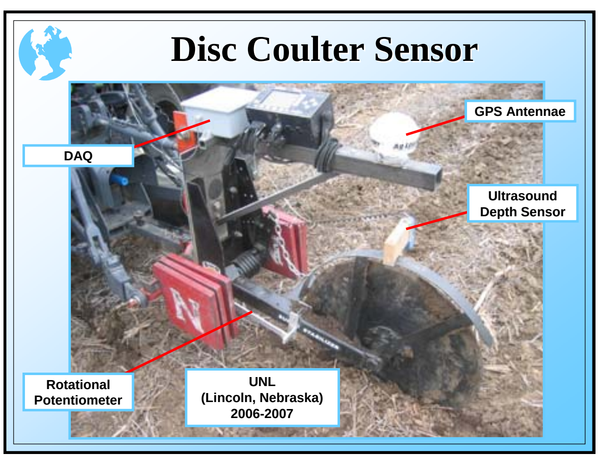


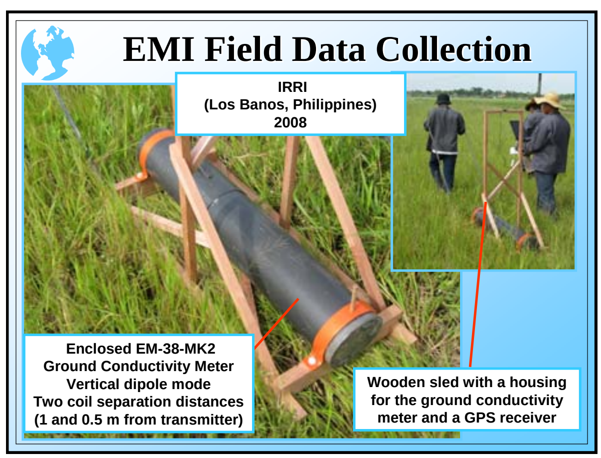
Applicability of On-the-Go Soil Sensors

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			

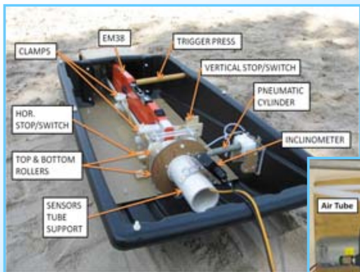


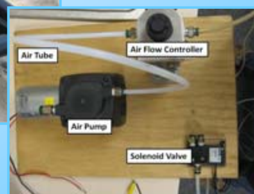






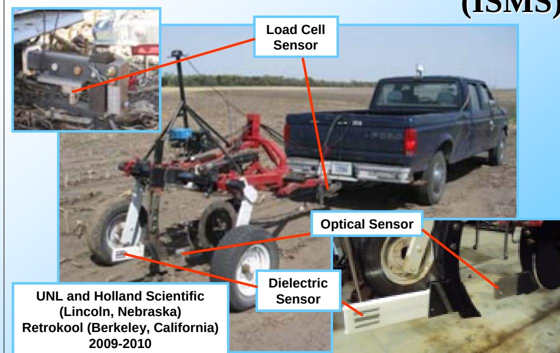
Pneumatic Angular Scanning System (PASS)





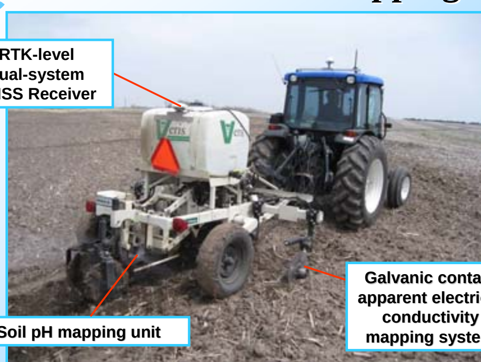
UNL (Lincoln, Nebraska)
2008-2009

Integrate Soil Mapping System (ISMS)



UNL and Holland Scientific (Lincoln, Nebraska)
Retrokool (Berkeley, California)
2009-2010

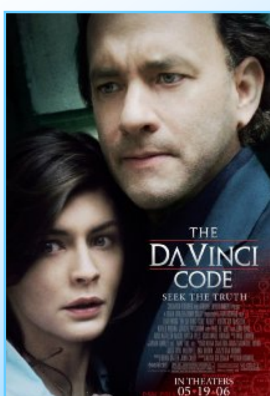
Field Elevation Mapping



Status of Implementation

- Commercial
  - Electrical conductivity
  - Topography
  - Soil pH
  - Visual/near-infrared spectroscopy
  - Gamma-ray radiometry
- Available solutions
  - Implement draft
  - Magnetic susceptibility
  - Ground penetrating radar
- Upcoming solutions
  - Capacitance (moisture)
  - Residual nitrate and soluble potassium
  - Soil mechanical resistance
  - Machine vision
  - X-ray and UV measurements
  - Neutron techniques

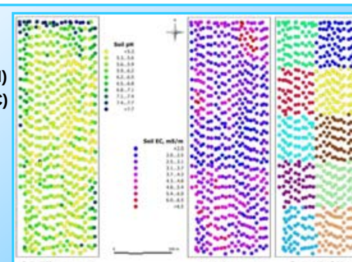
+ Sensor fusion and New applications



Targeted Soil Sampling

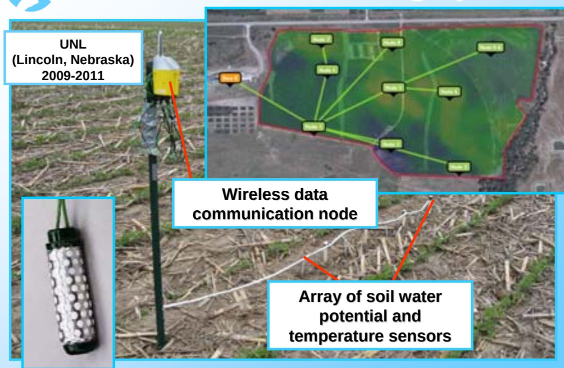
$$OF = \sqrt[5]{S_{opt} \cdot D_{opt-pH} \cdot D_{opt-EC} \cdot H_{cr-pH} \cdot H_{cr-EC}}$$

- S-optimality
- D-optimality (soil pH)
- D-optimality (soil EC)
- H-criteria (soil pH)
- H-criteria (soil EC)

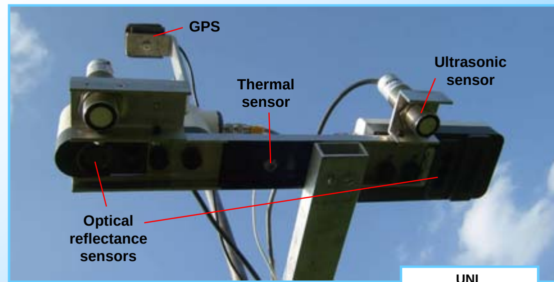


UNL
(Lincoln, Nebraska)
2007-2008

Telemetry Monitoring System



Crop Canopy Sensing



Summary

- On-the-go soil sensors can provide high density information about soil properties
- Many sensor approaches are past initial commercialization stage
- Sensor fusion provides the ability to separate various agronomic effects
- Site-specific sensor calibration and validation are essential steps of the mapping process
- Integration with living component sensing is promising

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