On-the-Go Soil Sensing Technology

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Agenda

- Family of on-the-go soil sensors
- Nebraska examples
  - Deep tillage implement
  - Integrated mapping of soil physical properties
    - Soil mechanical resistance
    - Dielectric characteristics (moisture)
    - Subsurface optical reflectance
  - Integrated agitation chamber module
    - Soil pH
    - Soluble potassium content
    - Residual nitrate content
  - Portable probe for on-the-spot measurements
- Sensor fusion

On-the-go Soil Sensors

Electrical and Electromagnetic Sensors

- Electrical Conductivity/Resistivity Sensors
- Capacitance Sensors
- Volumetric water content
- Soil type/structure
- Salinity

Optical and Radiometric Sensors

- Subsurface Soil Reflectance Sensors
- Microwave Sensors
- Ground Penetrating Radar
- Visual
- Near-infrared
- Mid-infrared
- Polychromatic light
- Hyperspectral Response
- Individual Wavelengths
  - Organic matter (carbon) content
  - Soil texture
  - Cation exchange capacity (CEC)
  - Soil water content
  - Soil pH
  - Mineral nitrogen and phosphorous
  - Water content
  - Geophysical soil structure

Subsurface Soil Reflectance Sensors

- Purdue University (West Lafayette, Indiana)
- UNL (Lincoln, Nebraska)

Individual Wavelengths

- 450 nm
- 500 nm
- 550 nm
- 600 nm
- 650 nm
- 700 nm
- 750 nm
- 800 nm
- 850 nm
- 900 nm
- 950 nm
- 1000 nm
- 1050 nm
- 1100 nm
- 1150 nm
- 1200 nm
- 1250 nm
- 1300 nm
- 1350 nm
- 1400 nm
- 1450 nm
- 1500 nm
- 1550 nm
- 1600 nm
- 1650 nm
- 1700 nm

Reflectance

- 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- 100%

Wavelength, nm
Real-time Soil Mapping with a Traveling Spectrophotometer

Mechanical Sensors

Discrete Depth Profiling Tools

Example

Instrumented Deep-Tillage Implement

Vertical Blade with Strain Gage Array
Apparent Soil Profiles

Integrated Load Comparison

Integrated Soil Physical Properties Mapping System

Acoustic and Pneumatic Sensors

Electrochemical Sensors
Automated Soil Solution Measurement

Purdue University (West Lafayette, Indiana)
JTI (Uppsala, Sweden)

Mobil Sensor Platform (MSP)

Veris Technologies, Inc. (Salina, Kansas)

Automated Direct Soil Measurement

Purdue University (West Lafayette, Indiana)
Veris Technologies, Inc. (Salina, Kansas)

Example

Soil pH Maps

Soil pH Maps of a 24-ha Kansas Field

Integrated Direct Soil Measurement

15 Nebraska soils with fixed field water content

Integrated Agitated Soil Measurement

Motor-Stirrer

Ion-selective Electrodes (ISE)

Agitation Chamber and Stirrer

Soil Sampler
Integrated Agitated Soil Measurement

1:1 solutions with 15 Nebraska soils

Reference pH

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R2 = 0.87 (0.91 means)
RMSE (Precision) = 0.15 pH
Reg. SE (Accuracy) = 0.20 pH

Reference nitrate-nitrogen (CR), mg/kg

Measured nitrate-nitrogen, mg/kg

R2 = 0.32 (0.40 means)
RMSE (Precision) = 0.17 pNO3
Reg. SE (Accuracy) = 0.22 pNO3

Reference soluble potassium (AAS), mg/kg

Measured soluble potassium, mg/kg

R2 = 0.54 (0.63 means)
RMSE (Precision) = 0.10 pK
Reg. SE (Accuracy) = 0.13 pK

ASM - Laboratory Test

Reference tests:
- Soil pH - glass ion-selective electrode
  - RMSE = 0.05 pH
- Soluble potassium - atomic adsorption spectroscopy (AAS)
  - RMSE = 0.01 pK
- Residual nitrate - cadmium reduction (CR)
  - RMSE = 0.02 pNO3

Precision vs. Accuracy Analysis

<table>
<thead>
<tr>
<th>Soil property</th>
<th>Soil texture (clay, silt and sand)</th>
<th>Soil organic matter or total carbon</th>
<th>Soil water (moisture)</th>
<th>Soil salinity (sodium)</th>
<th>Soil compaction (bulk density)</th>
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Applicability of On-the-Go Soil Sensors

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Portable Probe

On-the-Spot Measurement of Soil pH

Portable Probe

Reference Lab
Summary

- On-the-go soil sensors can provide high density information about soil properties
- Our ability to map specific agronomic soil attributes remains questionable
- Combining (fusion) different sensors may be beneficial
- New and improved sensors are under development
- Agro-economic evaluation of the value of information is needed

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