The Philosophy of On-the-Go Soil Sensing
(Technology Update)
Viacheslav I. Adamchuk

Biological Systems Engineering
University of Nebraska - Lincoln

First Asian Conference on Precision Agriculture
August 4-7, 2005

Problem Statement
- The assessment of soil variability is one of the most important steps in site-specific management
- Conventional means to attain soil variability data are incapable of accurately identifying spatial inconsistency within a production field at an economically feasible cost
- There is a need to develop equipment for mapping soil attributes on-the-go
- On-the-go sensing technology must be reliable, rapid, simple, inexpensive, repeatable

Agricultural Machine Systems

Tillage
Planting
Fertilization
Harvesting
Irrigation
Crop protection
Spatial data collection

Sensor Use Approaches

Real-Time Application
Map-Based Approach
Integrated Approach
(Real-Time with Supplemental Base Map)

On-the-go Soil Sensors

Electrical and Electromagnetic Sensors
- Electrical Conductivity/Resistivity Sensors
- Electromagnetic Induction Method
- Capacitively-Coupled Resistivity Method

Optical and Radiometric Sensors
- Capactance Sensors

Mechanical Sensors
- Mechanical

Acoustic Sensors
- Acoustic

Electrochemical Sensors
- Electrochemical

Pneumatic Sensors
- Pneumatic

Problem Statement
- The assessment of soil variability is one of the most important steps in site-specific management
- Conventional means to attain soil variability data are incapable of accurately identifying spatial inconsistency within a production field at an economically feasible cost
- There is a need to develop equipment for mapping soil attributes on-the-go
- On-the-go sensing technology must be reliable, rapid, simple, inexpensive, repeatable

Agricultural Machine Systems

Tillage
Planting
Fertilization
Harvesting

Irrigation
Crop protection
Spatial data collection

Sensor Use Approaches

Real-Time Application
Map-Based Approach
Integrated Approach
(Real-Time with Supplemental Base Map)

On-the-go Soil Sensors

Electrical and Electromagnetic Sensors
- Electrical Conductivity/Resistivity Sensors
- Electromagnetic Induction Method
- Capacitively-Coupled Resistivity Method

Optical and Radiometric Sensors
- Capactance Sensors

Mechanical Sensors
- Mechanical

Acoustic Sensors
- Acoustic

Electrochemical Sensors
- Electrochemical

Pneumatic Sensors
- Pneumatic
Galvanic Contact Resistivity Method

Veris Technologies, Inc. (Salina, Kansas)
http://www.veristech.com

Veris® 3100 and MSP
(0.3 and 0.9 m)

Geocarta (Paris, France)
http://www.geocarta.net

Geocarta ARP
(0.5, 1, and 2 m)

Crop Technologies, Inc. (Spring, Texas)
http://www.soildoctor.com

Soil Doctor® System
(real-time approach)

Electromagnetic Induction Method

Geonics Limited (Mississauga, Ontario)
http://www.geonics.com

Geonics EM-38
horizontal – 0.75 m
vertical – 1.5 m

Dualem, Inc. (Milton, Ontario)
http://www.dualem.com

DUALEM – 1S
co-planar – 0.4 m
perpendicular – 0.95 m

Capacitively-Coupled Resistivity Method

Geometrics, Inc. (San Jose, California)
http://www.geometrics.com

Geometric OhmMapper TR1

Example 1
Electrical Conductivity Map

Soil Survey
Improved Soil Type Separation
EC Map

Example 2
Electrical Conductivity Map

Low Yielding Area
High Yielding Area

Optical and Radiometric Sensors

Subsurface Soil Reflectance Sensors
Microwave Sensors
Ground Penetrating Radar

Visual
Near-infrared
Mid-infrared
Polarized light

- Organic matter (carbon) content
- Soil texture
- Cation exchange capacity (CEC)
- Soil water content
- Soil pH
- Mineral nitrogen and phosphorous

Visual
Image analysis
Polarized light

- Water content
- Geophysical soil structure
Electrochemical Sensors

- Ion-Selective Electrodes (ISEs)
- Ion-Selective Field Effect Transistors (ISFETs)

Soil Solution Measurement
New Automated Methods
Direct Soil Measurement

Activity of selected ions
- Soil pH (H+)
- Potassium content (K+)
- Residual nitrogen (NO₃⁻-N)
- Sodium content (Na+)

Ion-Selective Electrodes (ISEs)

Conventional Laboratory Analysis

Automated Soil Solution Measurement

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

Automated Direct Soil Measurement

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

Ion-selective Electrodes
Water Nozzle
Soil Sampler

Example Soil pH Maps

Soil pH Maps of a 24-ha Kansas Field

Simultaneous Direct Measurement of Soil Chemical Properties

UNL (Lincoln, Nebraska)

15 Nebraska Soils with Fixed Field Water Content

Soil pH
RMSE = 0.11 – 0.12 pH
R² = 0.90 – 0.93

Residual Nitrate
RMSE = 0.19 – 0.32 pH
R² = 0.30 – 0.33

Soluble Potassium
RMSE = 0.13 – 0.17 pH
R² = 0.28 – 0.32

Applicability of On-the-Go Soil Sensors

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

Two wavelengths soil reflectance sensor
Soil mechanical resistance profiler with an array of strain gage bridges
Capacitor-based sensor

UNL (Lincoln, Nebraska)

Real-time Soil Mapping with a Traveling Spectrophotometer

Optical fiber for illumination
Laser displacement sensor
Soil surface
Penetration tip
Shank
Laser displacement
Optical fiber for NIR reflection
Soil surface illumination

Tokyo University of Agriculture and Technology
(Tokyo, Japan)

Mobil Sensor Platform (MSP)

Potentially integrated potassium and nitrate mapping capability

Veris Technologies, Inc. (Salina, Kansas)
http://www.veristech.com

Soil pH Manager™

Integrated Multiple Data Layers

Maps produced by Veris Technologies (Salina, Kansas)

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

http://bse.unl.edu/adamchuk
E-mail: vadamchuk2@.unl.edu