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

The Philosophy of On-the-Go Soil Sensing

(Technology Update)

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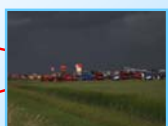
University of Nebraska - Lincoln

Problem Statement

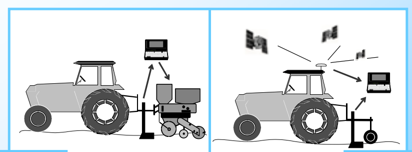
- The assessment of soil variability is one of the most important steps in site-specific management
- Conventional means to attain soil variability data are incapable of accurately identifying spatial inconsistency within a production field at an economically feasible cost
- There is a need to develop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

Agricultural Machine Systems



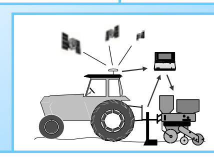
Tillage
Harvesting
Planting
Irrigation
Fertilization
Crop protection
Spatial data collection

Sensor Use Approaches



Real-Time Application

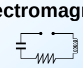
Map-Based Approach



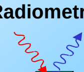
Integrated Approach
(Real-Time with Supplemental Base Map)

On-the-go Soil Sensors

Electrical and Electromagnetic



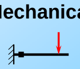
Optical and Radiometric



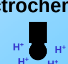
Acoustic

Pneumatic

Mechanical



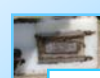
Electrochemical



Electrical and Electromagnetic Sensors

Electrical Conductivity/Resistivity Sensors

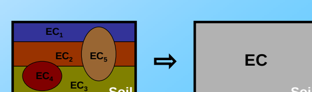
- Galvanic Contact Resistivity Method
- Electromagnetic Induction Method
- Capacitively-Coupled Resistivity Method



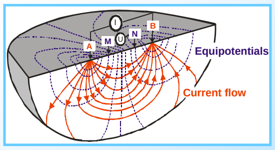
Capacitance Sensors

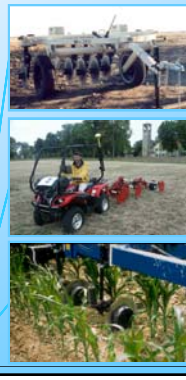
- *Soil type/texture*
- *Salinity*
- *Water content*
- *Organic matter content*
- *Depth variability*
- *Soil pH / nitrate content*

- *Volumetric water content*
- *Soil type/structure*
- *Salinity*



Galvanic Contact Resistivity Method





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

Veris® 3100 and MSP
(0.3 and 0.9 m)

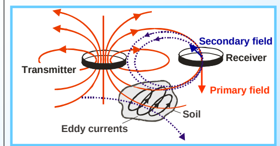
Geocarta (Paris, France)
http://www.geocarta.net

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



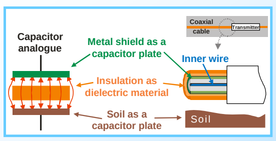
Geonics Limited
(Mississauga, Ontario)
http://www.geonics.com

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

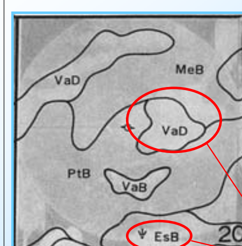
Capacitively-Coupled Resistivity Method

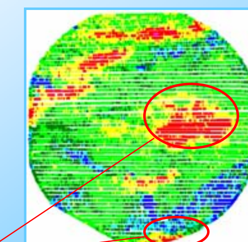


Geometrics, Inc.
(San Jose, California)
http://www.geometrics.com

Geometrix OhmMapper TR1

Example 1
Electrical Conductivity Map



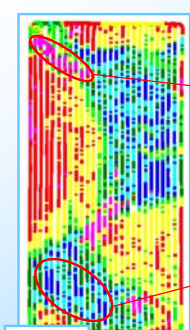


Soil Survey

Improved Soil Type Separation

EC Map

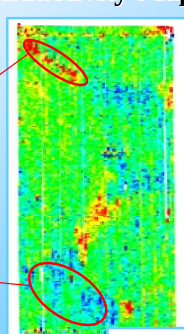
Example 2
Electrical Conductivity Map



Yield Map

Low Yielding Area

High Yielding Area



EC Map

Optical and Radiometric Sensors

Subsurface Soil Reflectance Sensors

- Visual
- Near-infrared
- Mid-infrared

Image analysis

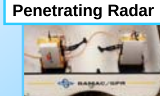
Polarized light

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

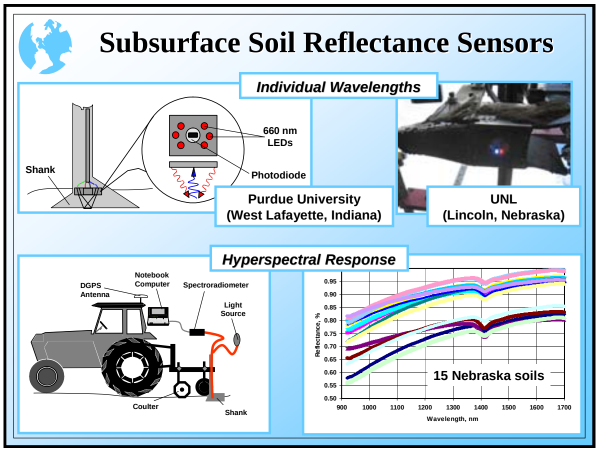
Microwave Sensors

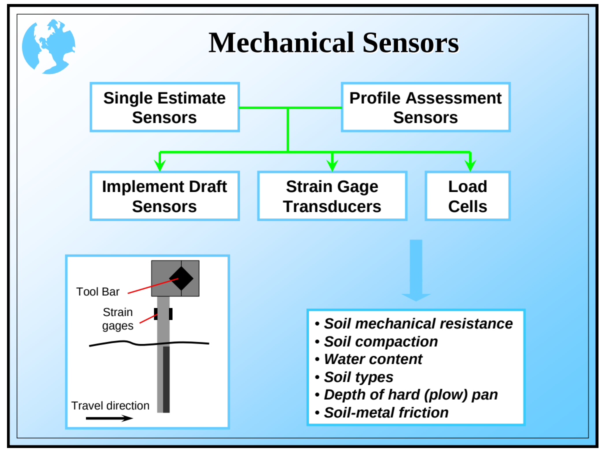
- *Water content*

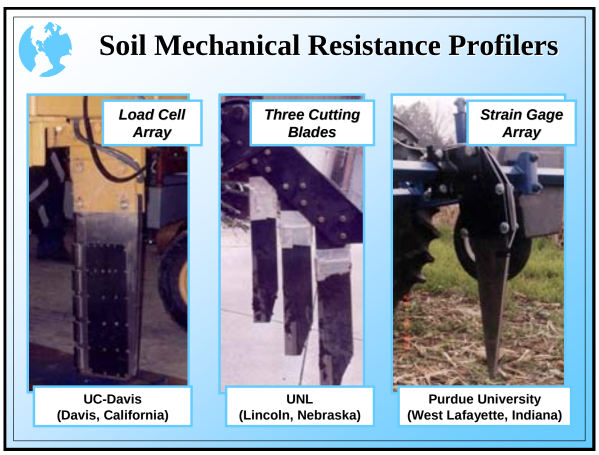
Ground Penetrating Radar

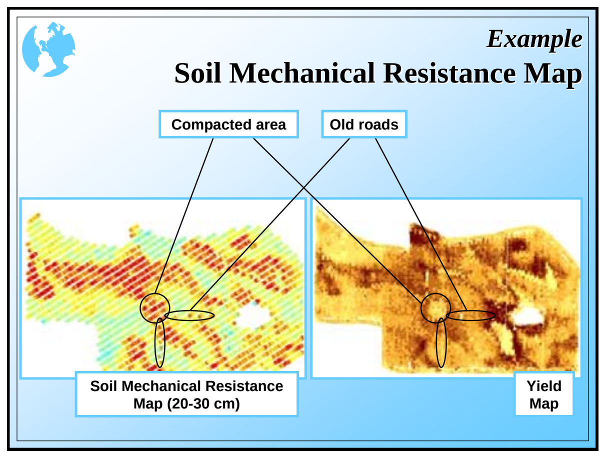


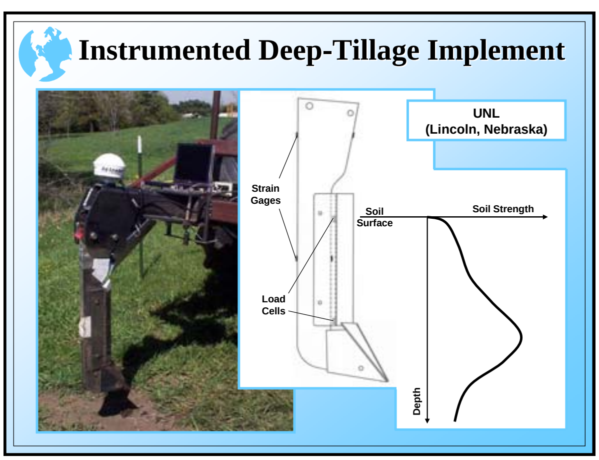
- *Water content*
- *Geophysical soil structure*

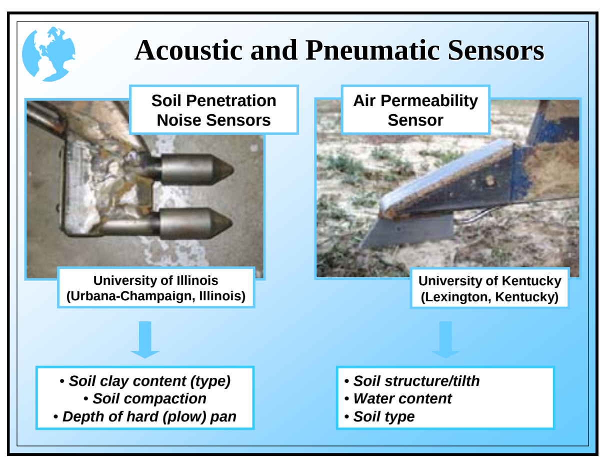

Subsurface Soil Reflectance Sensors
Individual Wavelengths
660 nm LEDs
Shank
Photodiode
Purdue University (West Lafayette, Indiana)
UNL (Lincoln, Nebraska)
Hyperspectral Response
Notebook Computer
DGPS Antenna
Spectroradiometer
Light Source
Coulter
Shank
15 Nebraska soils
Reflectance, %
Wavelength, nm


Mechanical Sensors
Single Estimate Sensors
Profile Assessment Sensors
Implement Draft Sensors
Strain Gage Transducers
Load Cells
Tool Bar
Strain gages
Travel direction
• Soil mechanical resistance
• Soil compaction
• Water content
• Soil types
• Depth of hard (plow) pan
• Soil-metal friction


Soil Mechanical Resistance Profilers
Load Cell Array
Three Cutting Blades
Strain Gage Array
UC-Davis (Davis, California)
UNL (Lincoln, Nebraska)
Purdue University (West Lafayette, Indiana)


Example
Soil Mechanical Resistance Map
Compacted area
Old roads
Soil Mechanical Resistance Map (20-30 cm)
Yield Map


Instrumented Deep-Tillage Implement
UNL (Lincoln, Nebraska)
Strain Gages
Load Cells
Soil Surface
Soil Strength
Depth


Acoustic and Pneumatic Sensors
Soil Penetration Noise Sensors
Air Permeability Sensor
University of Illinois (Urbana-Champaign, Illinois)
University of Kentucky (Lexington, Kentucky)
• Soil clay content (type)
• Soil compaction
• Depth of hard (plow) pan
• Soil structure/tilth
• Water content
• Soil type

Electrochemical Sensors

Ion-Selective Electrodes (ISEs)

Ion-Selective Field Effect Transistors (ISFETs)

Soil Solution Measurement

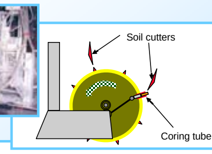
New Automated Methods

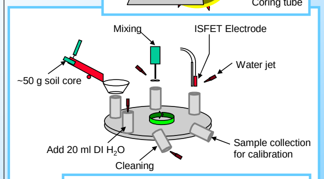
Direct Soil Measurement

Conventional Laboratory Analysis

Activity of selected ions
- *Soil pH (H^+)*
- *Potassium content (K^+)*
- *Residual nitrogen (NO_3^--N)*
- *Sodium content (Na^+)*

Automated Soil Solution Measurement



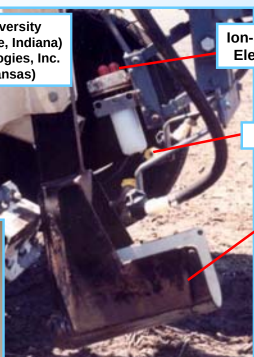


Purdue University
(West Lafayette, Indiana)

JTI
(Uppsala, Sweden)

Automated Direct Soil Measurement

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

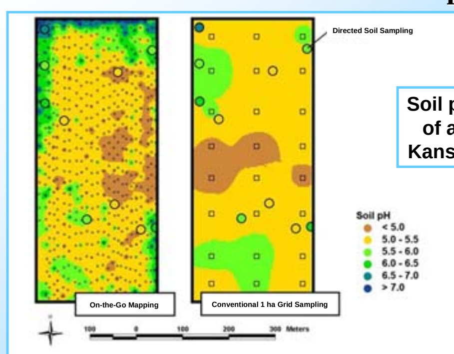


Ion-selective Electrodes

Water Nozzle

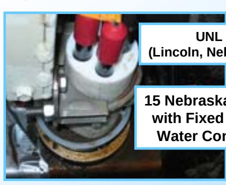
Soil Sampler

Example
Soil pH Maps



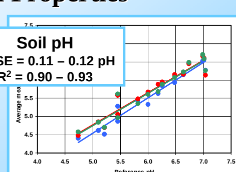
Soil pH Maps of a 24-ha Kansas Field

Simultaneous Direct Measurement of Soil Chemical Properties

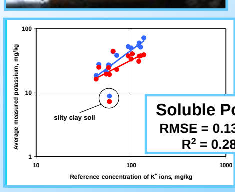


UNL
(Lincoln, Nebraska)

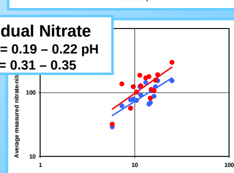
15 Nebraska Soils with Fixed Field Water Content



Soil pH
RMSE = 0.11 – 0.12 pH
R^2 = 0.90 – 0.93



Soluble Potassium
RMSE = 0.13 – 0.17 pH
R^2 = 0.28 – 0.52

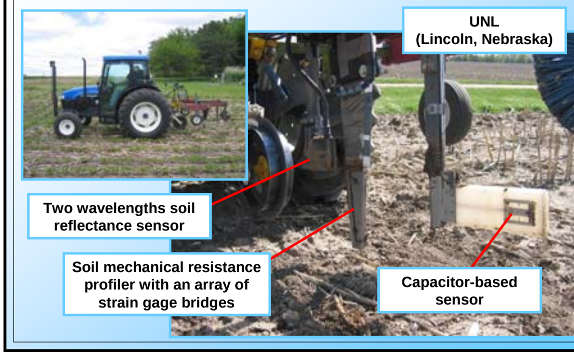


Residual Nitrate
RMSE = 0.19 – 0.22 pH
R^2 = 0.31 – 0.35

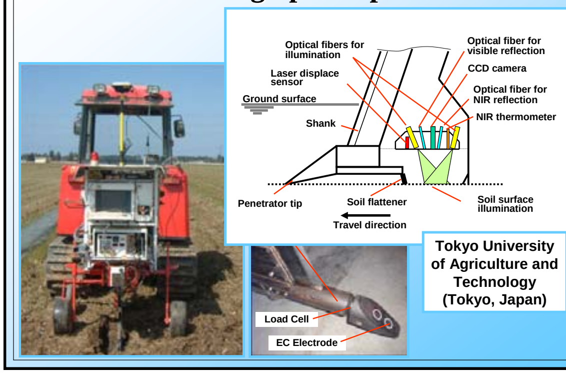
Applicability of On-the-Go Soil Sensors

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			

Integrated Soil Physical Properties Mapping System

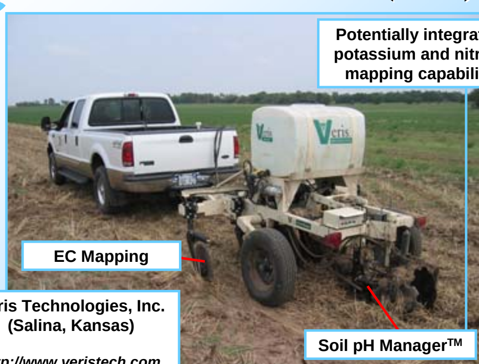


Real-time Soil Mapping with a Traveling Spectrophotometer



Tokyo University of Agriculture and Technology (Tokyo, Japan)

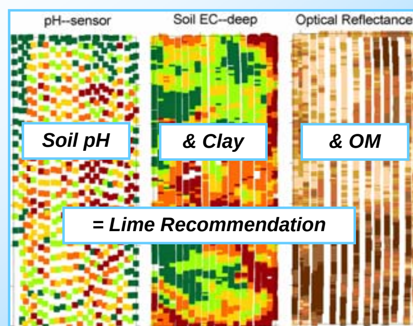
Mobil Sensor Platform (MSP)



Veris Technologies, Inc. (Salina, Kansas)

http://www.veristech.com

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

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E:mail: vadamchuk2@unl.edu