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An Integrated System for Mapping Soil Physical Properties On-the-Go (the Mechanical Sensing Component)

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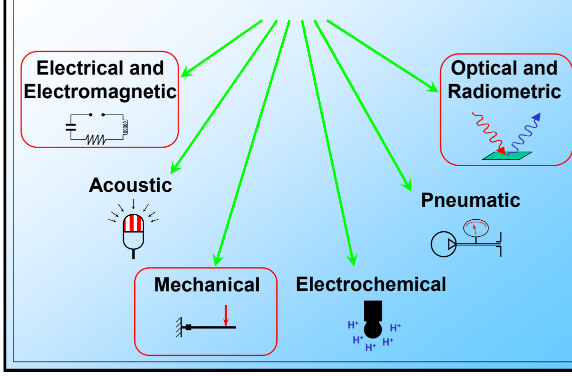
Presentation Outline

- Background
  - Problem statement and history of sensor development
  - Overview of integrated mapping of soil physical attributes
- Materials and Methods
  - Vertical blade with an array of strain gage bridges
  - Ling-term tillage plots experiment
- Results and Discussion
  - Comparison of tillage practices using on-the-go measurements of soil mechanical resistance
  - Field mapping
  - Overview of the latest prototype system
  - Summary

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

On-the-go Soil Sensors

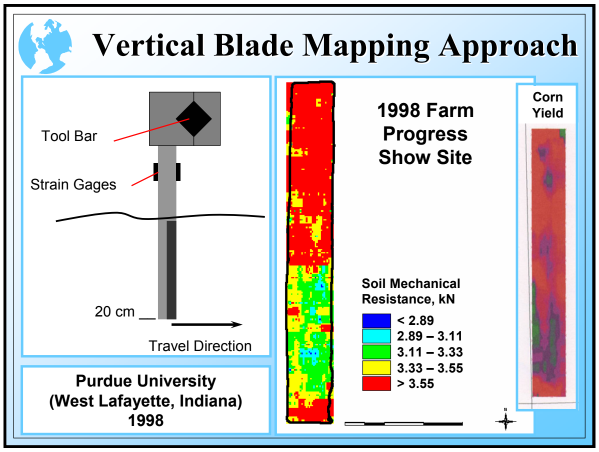


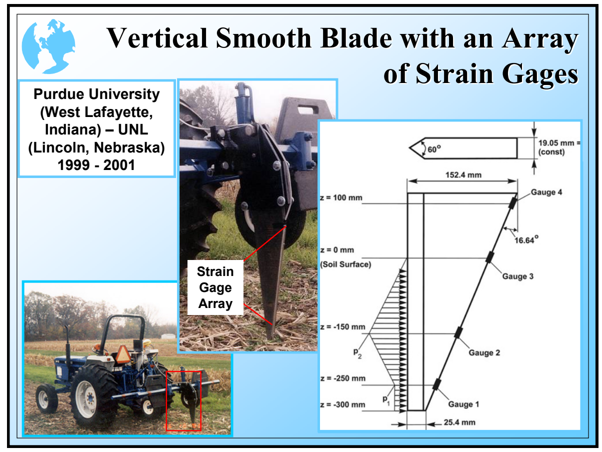
Applicability of On-the-Go Soil Sensors

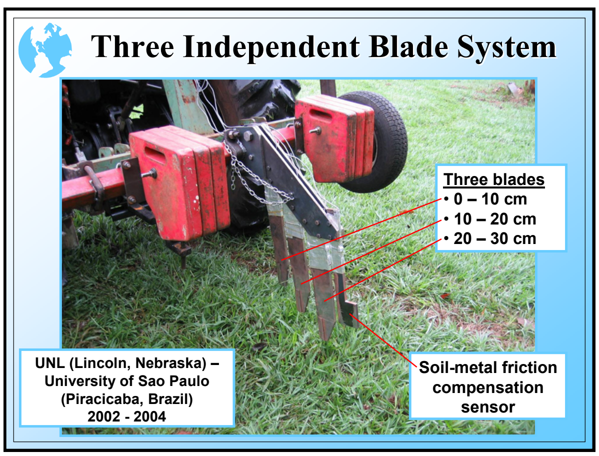
Soil property	Electrical and Electromagnetic	Optical and Radiometric	Mechanical	Acoustic	Electrochemical
Soil texture (clay, silt and sand)	Good	OK		Some	
Soil organic matter or total carbon	Some	Good			
Soil water (moisture)	Good	Good			
Soil salinity (sodium)	OK				Some
Soil compaction (bulk density)			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			

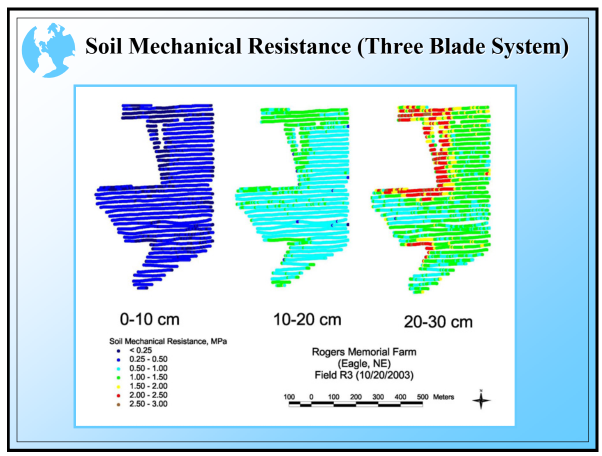
Integrated Mapping Approach

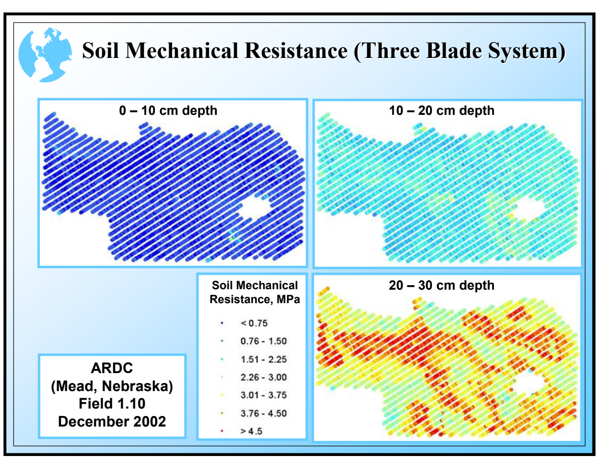
- Instrumented blade
  - Compacted field areas
  - Soil mechanical resistance profile
  - Blade with an array of strain gage bridges
  - Sensing depth down to 30 cm
  - Minimum soil disturbance
- Capacitor-type sensor
  - Volumetric water content
  - Dielectric soil properties measurement
- Optical sensor
  - Organic matter content
  - Soil reflectance at 470 and 660 nm
  - Direct soil contact through a sapphire window

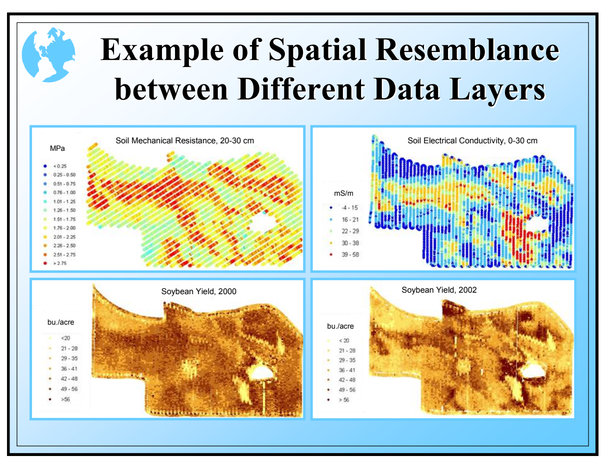

Vertical Blade Mapping Approach
Tool Bar
Strain Gages
20 cm
Travel Direction
Purdue University
(West Lafayette, Indiana)
1998
1998 Farm
Progress
Show Site
Soil Mechanical
Resistance, kN
< 2.89
2.89 – 3.11
3.11 – 3.33
3.33 – 3.55
> 3.55
Corn
Yield


Vertical Smooth Blade with an Array
of Strain Gages
Purdue University
(West Lafayette,
Indiana) – UNL
(Lincoln, Nebraska)
1999 - 2001
Strain
Gage
Array
60°
19.05 mm =
(const)
152.4 mm
z = 100 mm
Gauge 4
16.64°
z = 0 mm
(Soil Surface)
Gauge 3
z = -150 mm
p2
Gauge 2
z = -250 mm
z = -300 mm
p1
Gauge 1
25.4 mm

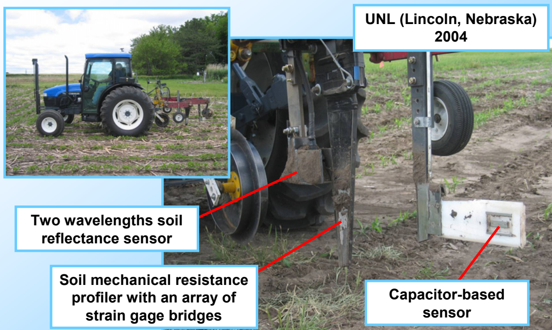

Three Independent Blade System
Three blades
• 0 – 10 cm
• 10 – 20 cm
• 20 – 30 cm
UNL (Lincoln, Nebraska) –
University of Sao Paulo
(Piracicaba, Brazil)
2002 - 2004
Soil-metal friction
compensation
sensor


Soil Mechanical Resistance (Three Blade System)
0-10 cm
10-20 cm
20-30 cm
Soil Mechanical Resistance, MPa
< 0.25
0.25 - 0.50
0.50 - 1.00
1.00 - 1.50
1.50 - 2.00
2.00 - 2.50
2.50 - 3.00
Rogers Memorial Farm
(Eagle, NE)
Field R3 (10/20/2003)
100 0 100 200 300 400 500 Meters

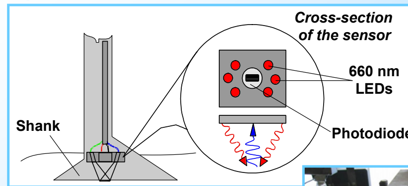

Soil Mechanical Resistance (Three Blade System)
0 – 10 cm depth
10 – 20 cm depth
Soil Mechanical
Resistance, MPa
< 0.75
0.76 - 1.50
1.51 - 2.25
2.26 - 3.00
3.01 - 3.75
3.76 - 4.50
> 4.5
20 – 30 cm depth
ARDC
(Mead, Nebraska)
Field 1.10
December 2002


Example of Spatial Resemblance
between Different Data Layers
Soil Mechanical Resistance, 20-30 cm
MPa
Soil Electrical Conductivity, 0-30 cm
mS/m
Soybean Yield, 2000
bu./acre
Soybean Yield, 2002
bu./acre

Integrated Soil Physical Properties Mapping System (ISPPMS)



"Organic Matter" Sensor

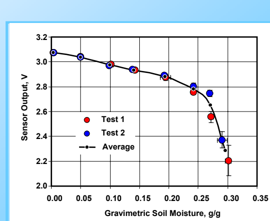


Purdue University
(West Lafayette, Indiana)
1988 - 1992

UNL
(Nebraska, Lincoln)
2004 - 2005

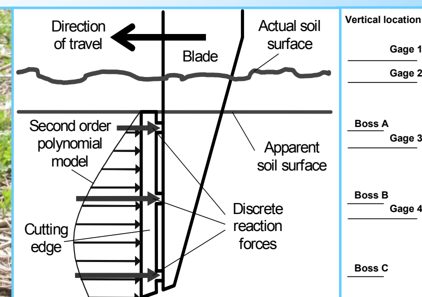
Capacitor-Based Sensor

UNL (Lincoln, Nebraska) – Retrokool (Berkeley, California)
2001-2003



- Silty clay loam soil
- Triple replicates
- Two tests

Instrumented Blade with a Half-Split Cutting Edge



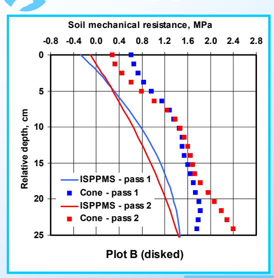
5 – 30 cm measurement depth

Tillage Treatment Experimental Plots

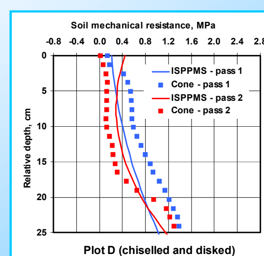
Plot	Tillage treatment	Maximum depth of tillage, cm	Gravimetric moisture content, g/g
A	plowed and double disked	20	0.26 - 0.28
B	disked	13	0.24 - 0.26
C	no-till with cultivation	5	0.24 - 0.27
D	chiselled and disked	30	0.23 - 0.26
E	double disked	13	0.24 - 0.25
F	no-till w/o cultivation	0	0.25 - 0.29

- Twenty years history
- Controlled wheel traffic
- Five cone penetrometer profiles
- Five on-the-go measurements (1 Hz)

Apparent Soil Profiles



Plot B (disked)



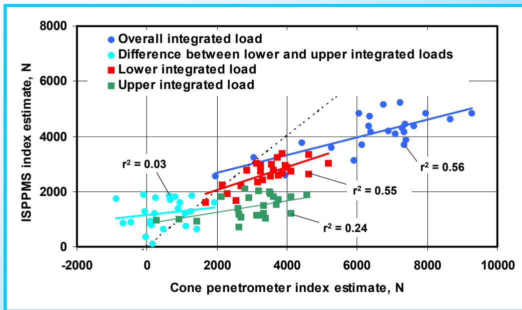
Plot D (chiselled and disked)

$$p(y) = a_2 y^2 + a_1 y + a_0$$

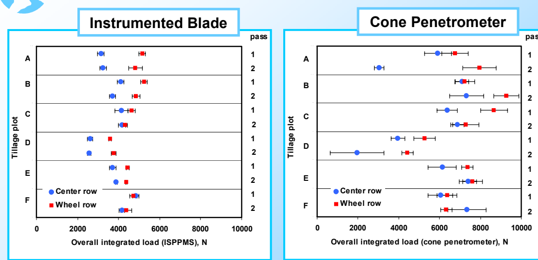
$$\begin{bmatrix} a_2 \\ a_1 \\ a_0 \end{bmatrix} = \begin{bmatrix} 1.68903*10^{-8} & -7.13568*10^{-8} & 4.24800*10^{-8} \\ -6.78951*10^{-6} & 1.79098*10^{-5} & -6.67377*10^{-6} \\ 6.65388*10^{-4} & -5.51320*10^{-4} & 1.65002*10^{-4} \end{bmatrix} \begin{bmatrix} R_A \\ R_B \\ R_C \end{bmatrix}$$

$$\begin{bmatrix} R_A \\ R_B \\ R_C \end{bmatrix} = \begin{bmatrix} 18.720 & 19.008 & -53.202 & 25.995 \\ -1.5727 & -1.5969 & 37.587 & -39.104 \\ 0.014025 & 0.014241 & 1.0893 & 15.284 \end{bmatrix} \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \end{bmatrix}$$

Integrated Load Indices

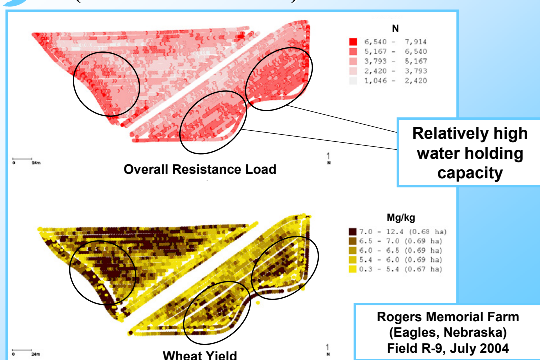


Overall Integrated Load Comparison

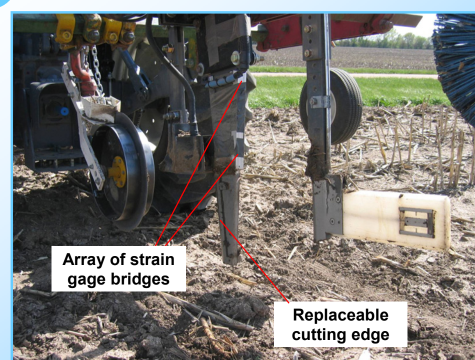


Tillage Plot	Treatment	Tillage Plot	Treatment
A	plowed and double disked	D	chiselled and disked
B	disked	E	double disked
C	no-till with cultivation	F	no-till w/o cultivation

Maps of Soil Mechanical Resistance (Instrumented Blade) and Wheat Yield



The Latest Prototype



Summary

- On-the-go mapping of soil mechanical resistance allows delineation of field areas with relatively hard or soft cultivated layer of soil
- High-order polynomial representation of topsoil profile is not beneficial
- Estimates of soil mechanical resistance attained using cone penetrometer and on-the-go sensing approaches have different nature
- Integration of sensing systems with alternative measurement concepts is critical
- Maps of physical soil properties can be used to prescribe spatially differentiated field management

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