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Case Studies on the Accuracy of Soil pH and Lime Requirement Maps

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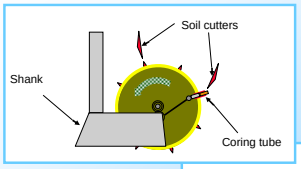
Soybeans Nebraska Soybean Board | University of Nebraska Lincoln | McGill

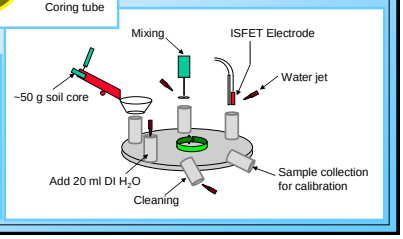
Problem Statement

- 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

Automated Soil Testing



Purdue University
(West Lafayette, Indiana)
1996

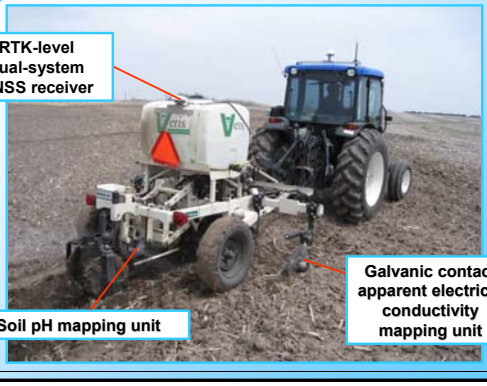


Automated Soil pH Mapping Systems

Purdue University
(West Lafayette, Indiana)
1998

US Patent No. 6,356,830

Field Mapping



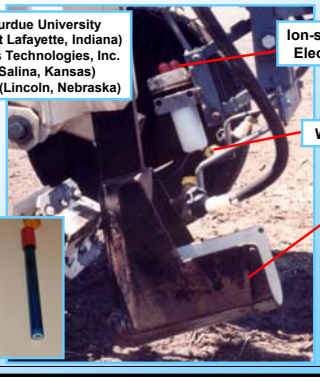
RTK-level dual-system GNSS receiver

Soil pH mapping unit

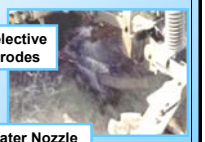
Galvanic contact apparent electrical conductivity mapping unit

Direct Soil Measurement

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



Ion-selective Electrodes

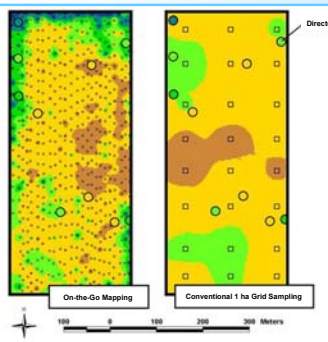


Water Nozzle

Soil Sampler

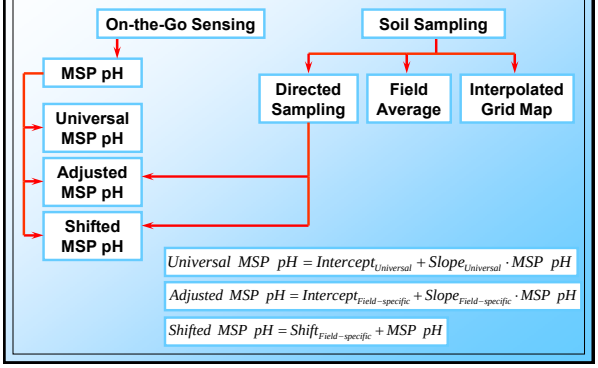
Example

Soil pH Mapping



Soil pH Maps of a Kansas Field

Mapping Alternatives

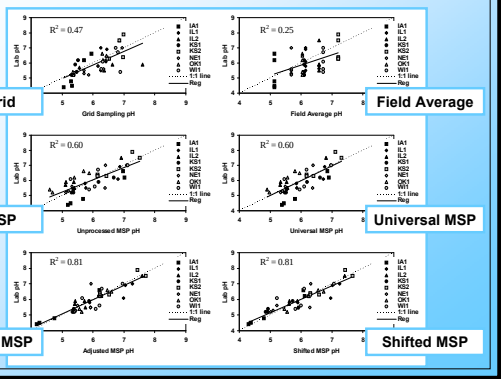


$$Universal\ MSP\ pH = Intercept_{Universal} + Slope_{Universal} \cdot MSP\ pH$$

$$Adjusted\ MSP\ pH = Intercept_{Field-specific} + Slope_{Field-specific} \cdot MSP\ pH$$

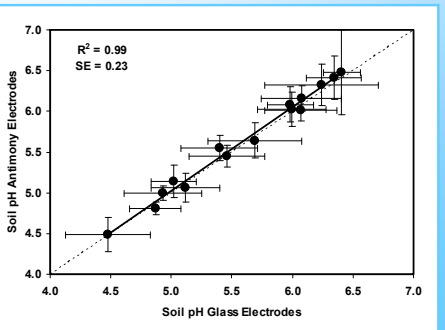
$$Shifted\ MSP\ pH = Shift_{Field-specific} + MSP\ pH$$

Soil pH Maps Evaluation

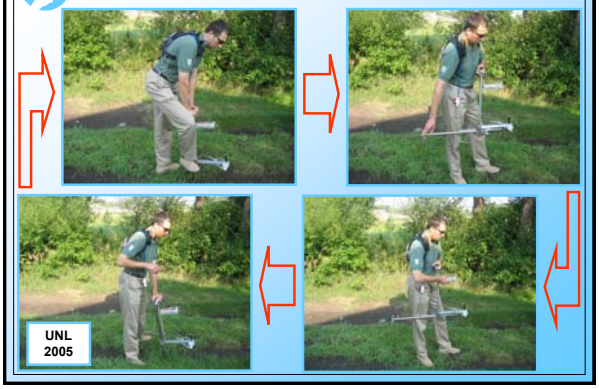


Antimony Electrode

Sandy and stony soils



Portable Probe

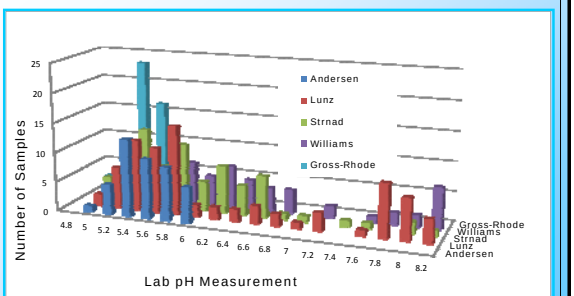


Objectives

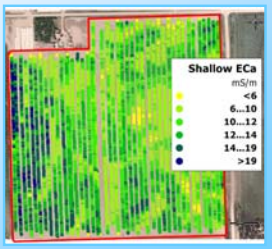
- To generate lime requirement maps using different mapping approaches
  - Average application rate
  - 1-ha grid sampling
  - On-the-go sensor mapping
- To compare these maps in terms of the accuracy of soil pH, buffer pH, and lime requirement predictions

Experimental Sites

Soil pH Distributions



Lunz Field

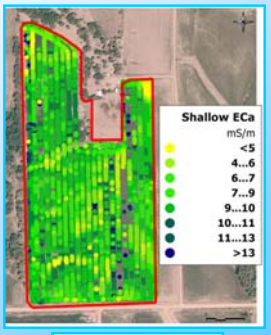


Soil Data | Shallow EC_a

Strnad Field

Soil Data | Shallow EC_a

Williams Field

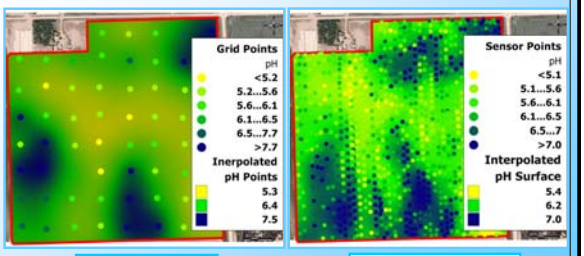


Soil Data | Shallow EC_a

Data Collection

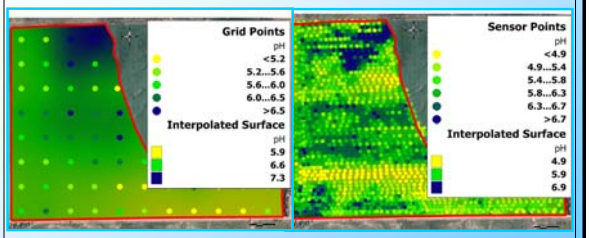
Sampling/measuring	Lunz field	Strnad field	Williams field
Grid-based samples (1-ha)	61	50	24
Calibration samples	10	10	10
Validation samples	12	14	15
On-the-go soil pH measurements	1125	1698	610
On-the-go EC_a measurements	13069	19717	7024

Lunz Field



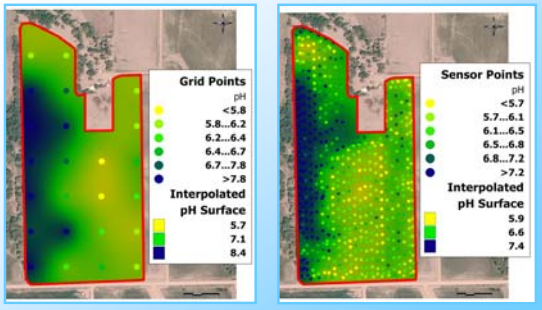
Grid-Based Map | Sensor-Based Map

Strnad Field



Grid-Based Map | Sensor-Based Map

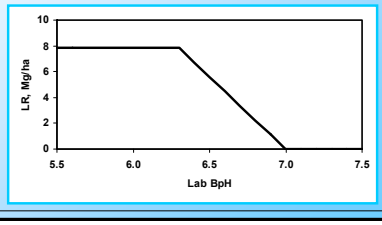
Williams Field



Grid-Based Map | Sensor-Based Map

Lime Requirement

$$LR = \begin{cases} 0 & if \quad BpH \geq 7.0 \\ (7.0 - BpH) \cdot 11.2 & if \quad 6.3 < BpH < 7.0 \\ 7.85 & if \quad BpH \leq 6.3 \end{cases}$$



BpH Prediction for Alkaline Soils

- $BpH = a_0 + a_1 pH$
  - *pH* **is soil pH in a 1:1 soil-water solution**
  - a_0 **and** a_1 **are regression parameters**
- *BpH = 7.0+a(pH-6.5)*
  - *BpH* **of 7.0 corresponds to** *pH* **of 6.5**
- *BpH = 2.7+0.67pH*
  - *BpH* **of 7.0 corresponds to** *pH* **of 6.5**
  - *BpH* **of 8.0 corresponds to** *pH* **of 8.0**

Lab pH Predictions

$$Lab\ pH = b_0 + b_1 \cdot Sensor\ pH$$

1) $b_0 = 0$ **and** $b_1 = 1$ **– original data**
2) $b_0 \neq 0$ **and** $b_1 = 1$ **– data shift**
3) $b_0 = 0$ **and** $b_1 \neq 1$ **– data scale**
4) $b_0 \neq 0$ **and** $b_1 \neq 1$ **– linear regression**

Lab BpH Prediction

$$Lab\ BpH = c_0 + c_1 \cdot Sensor\ pH + c_2 \cdot EC_a + c_3 \cdot Sensor\ pH \cdot EC_a$$

1) $c_1 = 1$, $c_0 = c_2 = c_3 = 0$ – raw data
2) $c_0 \neq 0$, $c_1 = 1$, $c_2 = c_3 = 0$ – data shift
3) $c_0 \neq 0$, $c_1 \neq 1$, $c_2 = c_3 = 0$ – linear regression without ECa
4) $c_1 \neq 1$, $c_0 \neq c_2 \neq 0$, $c_3 = 0$ – linear regression with EC_a but without the product of sensor pH and EC_a
5) $c_1 \neq 1$, $c_0 \neq c_2 \neq c_3 \neq 0$ – full regression

RMSE (Lab pH Prediction)

Field	Data Set	pH Partial Case 1	2	3	4
Lunz	calibration	0.81	0.59	0.54	0.32
	validation	0.93	0.82	0.81	0.78
Strnad	calibration	0.49	0.42	0.40	0.36
	validation	0.47	0.52	0.53	0.52
Williams	calibration	0.52	0.50	0.49	0.29
	validation	0.64	0.62	0.61	0.46

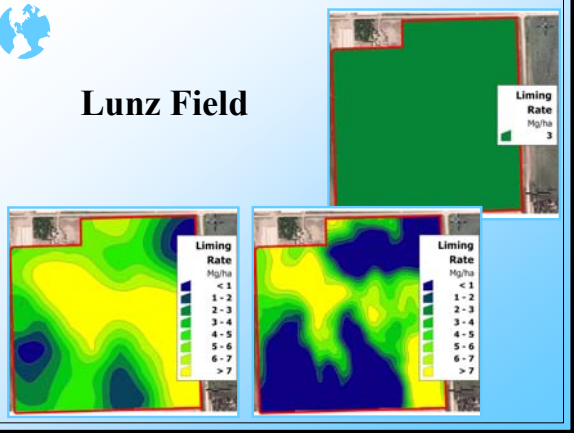
1	$b_0 = 0$ and $b_1 = 1$ (raw data)
2	$b_0 \neq 0$ and $b_1 = 1$ (data shift)
3	$b_0 = 0$ and $b_1 \neq 1$ (data scale)
4	$b_0 \neq 0$ and $b_1 \neq 1$ (linear regression)

RMSE (Lab BpH Prediction)

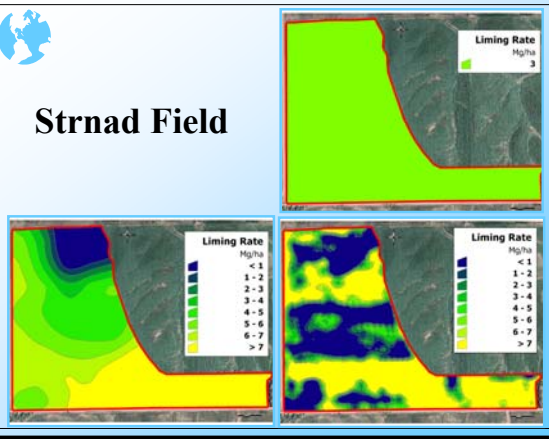
Field	Data Set	BpH Partial Case 1	2	3	4	5
Lunz	calibration	0.56	0.19	0.16	0.13	0.12
	validation	0.63	0.34	0.32	0.38	0.39
Strnad	calibration	0.84	0.25	0.24	0.27	0.22
	validation	0.79	0.41	0.41	0.42	0.44
Williams	calibration	0.61	0.30	0.16	0.16	0.16
	validation	0.77	0.37	0.33	0.34	0.42

1	c0 = 0, c1 = 1, c2 = 0, and c3 = 0 (raw data)
2	c0 ≠ 0, c1 = 1, c2 = 0, and c3 = 0 (data shift)
3	c0 ≠ 0, c1 ≠ 1, c2 = 0, and c3 = 0 (sensor regression)
4	c0 ≠ 0, c1 ≠ 1, c2 ≠ 0, and c3 = 0 (sensor + ECa regression)
5	c0 ≠ 0, c1 ≠ 1, c2 ≠ 0, and c3 ≠ 0 (full regression)

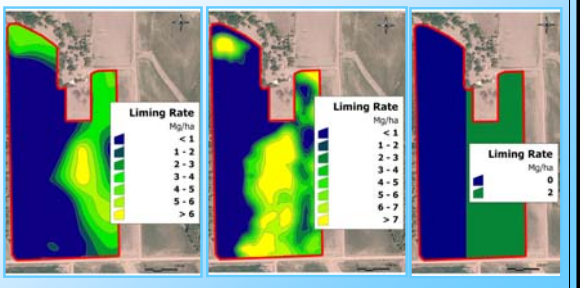
Lunz Field



Strnad Field



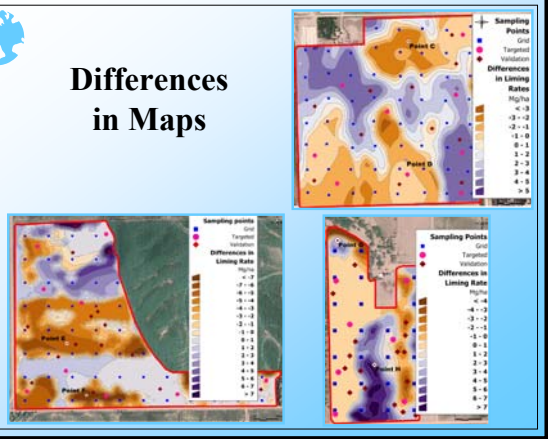
Williams Field



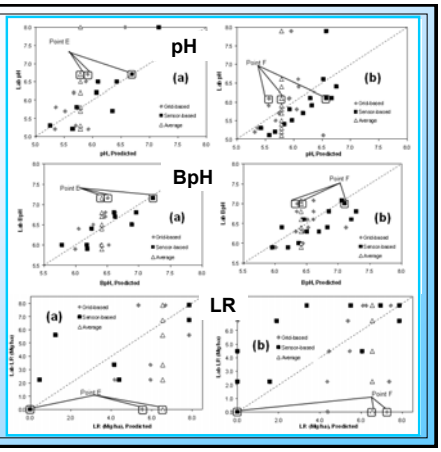
Coefficients of Determination

Map	Dataset	Lunz		Strnad		Williams	
		Grid	Sensor	Grid	Sensor	Grid	Sensor
Lab pH	Calibration	0.47	0.92	0.62	0.81	0.91	0.91
	Validation	0.50	0.52	0.05	0.58	0.37	0.79
Lab BpH	Calibration	0.61	0.91	0.65	0.85	0.90	0.96
	Validation	0.67	0.60	0.15	0.50	0.54	0.84
LR	Calibration	0.55	0.97	0.45	0.75	0.73	0.87
	Validation	0.75	0.61	0.03	0.64	0.36	0.46

Differences in Maps



Strnad Field



Mean Absolute Error

Fields		Calibration			Validation		
		Sensor	Grid	Average	Sensor	Grid	Average
Lunz	pH	0.254^{a}	0.824^{b}	1.280^{b}	0.506^{a}	0.533^{a}	0.970^{a}
	BpH	0.160^{a}	0.390^{b}	0.580^{c}	0.229^{a}	0.231^{a}	0.460^{b}
	LR	0.144^{a}	0.914^{ab}	1.800^{b}	0.395^{a}	0.503^{a}	1.700^{b}
Strnad	pH	0.402^{a}	0.700^{a}	0.810^{a}	0.560^{a}	0.487^{a}	0.580^{a}
	BpH	0.309^{a}	0.524^{a}	0.642^{a}	0.398^{a}	0.359^{a}	0.378^{a}
	LR	0.420^{a}	1.007^{ab}	1.500^{b}	1.138^{a}	1.332^{a}	1.150^{a}
Williams	pH	0.194^{a}	0.244^{b}	0.650^{b}	0.422^{a}	0.398^{a}	0.391^{a}
	BpH	2.552^{a}	2.713^{a}	2.709^{a}	0.840^{a}	0.889^{a}	0.834^{a}
	LR	1.824^{a}	2.277^{a}	2.550^{a}	1.177^{a}	1.522^{a}	1.450^{a}

Conclusions

- Lime application maps based on sensor data with ten calibration points provided better delineation of acidic soil areas that needed lime than grid sampling or field average methods
- When defining a site-specific relationship between corresponding sensor pH and lab pH/BpH measurements, it is not always necessary to adjust each parameter of a corresponding regression model

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