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# Using Ion-Selective Electrodes to Map Soil Properties

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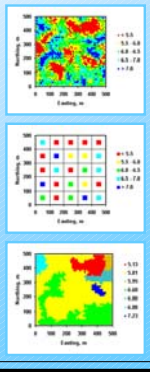
## Outline

- Conventional methods of soil mapping
- Automated soil mapping system
- Ion-selective electrodes (pH, $K^+$, $NO_3^-$)
- Laboratory evaluation
- Examples of field mapping
- Agro-economic analysis
- Summary

## Conventional Soil Sampling

- Random
- Grid (Systematic) Sampling
  - Grid Point (Cluster) Method
    - Regular (Center)
    - Staggered and Random Start
    - Systematic Unaligned
    - Random
  - Grid Cell Method
- Adaptive
  - By Soil Types
  - By Management Zones



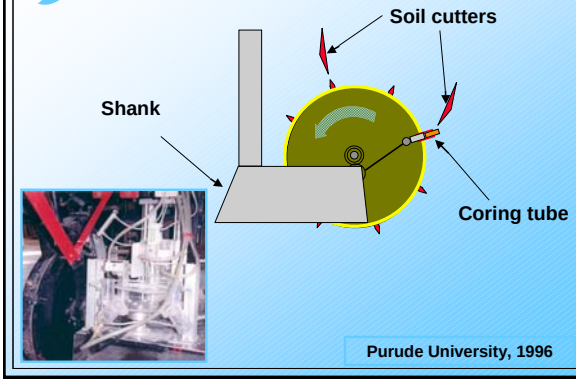
## Standard Chemical Soil Test

- Preparation (drying, crushing, sieving)
- Solution
  - 1:1 (Soil Soil pH)
  - 1:2.5 (Nitrate-Nitrogen)
  - 1:10 (Potassium)
- Extraction
  - Water (Soil pH, Nitrate-Nitrogen)
  - SMP Buffer Solution (Buffer pH)
  - Ammonia Acetate Solution (Potassium)
- Measurement
  - Ion-Selective Electrode (pH)
  - Atomic Absorption Spectroscopy (Potassium)
  - Cadmium Reduction Method (Nitrate-Nitrogen)

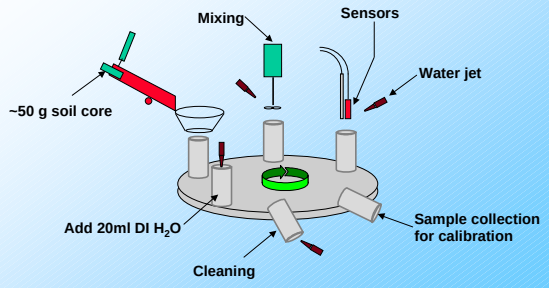
## Problem Statement

- The sensing of soil variability is one of the most important steps in site-specific management
- Varying application rates is inappropriate without accurate soil maps
- Obtaining this descriptive information about a field is expensive using conventional methods
- There is a need to develop equipment for mapping chemical soil attributes on-the-go
- Offered technology must be reliable, rapid, simple, inexpensive, repeatable

## Soil Nutrients Mapping



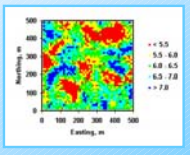
## Soil Nutrients Mapping

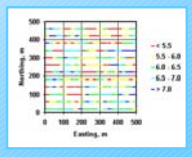



Purude University, 1996

## Direct Soil Measurement

- Preparation
  - Field conditions
- Solution
  - Naturally moist soil
- Extraction
  - Available ion activity
- Measurement
  - Ion-selective electrode





## Automated Soil pH Mapping Systems

US Patent No. 6,356,830

Purude University, 2000

## Automated Soil pH Mapping Systems

Veris Technologies, 2002

## Ion-selective Electrodes

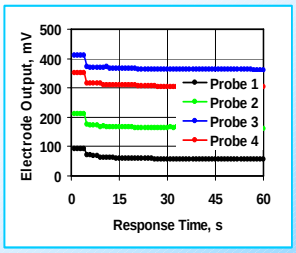
- Combination
- Flat Surface
- Jell-Filled
- Epoxy Body
- Glass (pH)
- PVC Membrane ($K^+$, $NO_3^-$)

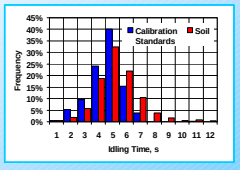
## Laboratory Evaluation of Direct Soil Mapping

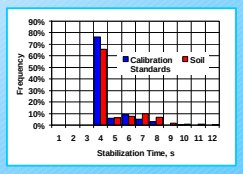
- Stability
- Calibration
- Repeatability
- Accuracy
- Reliability

- Crete Silt Loam
- Wymore Silty Clay Loam
- Brocksburg Sandy Loam
- Hall Silt Loam
- Thurman-Anselmo Fine Sandy Loam

## Electrode Stability

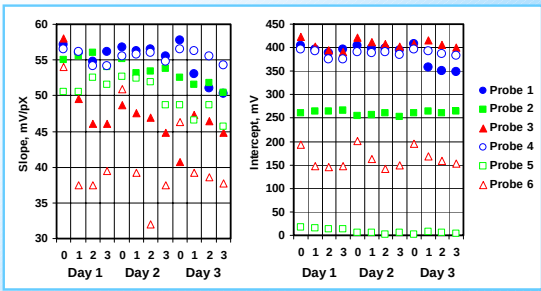



It takes approximately 10-15 s to obtain a relatively stable reading

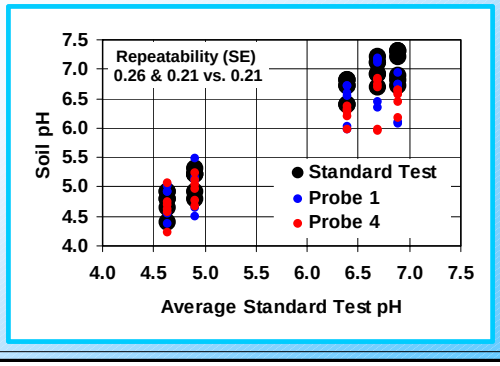
## Electrode Calibration



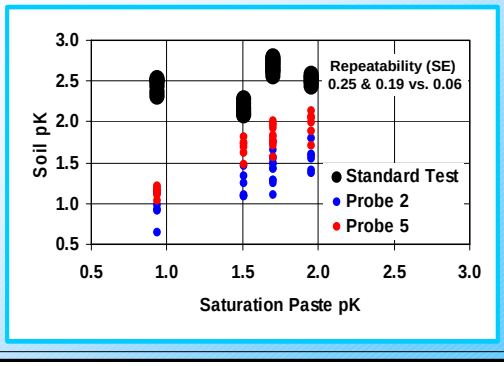

Electrode (Nernst) Slope

Intercept (Standard Potential)

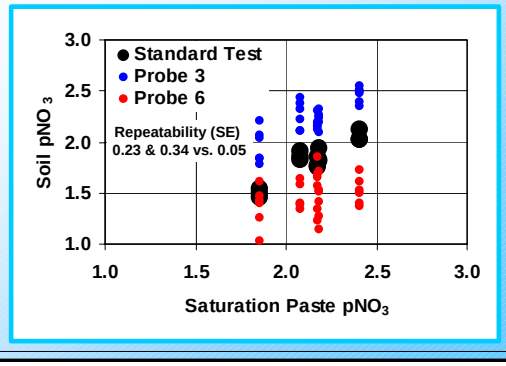
## Soil pH (DSM vs. Standard Test)




## Potassium (DSM vs. Atomic Absorption Spectroscopy)




## Nitrate (DSM vs. Cadmium Reduction)

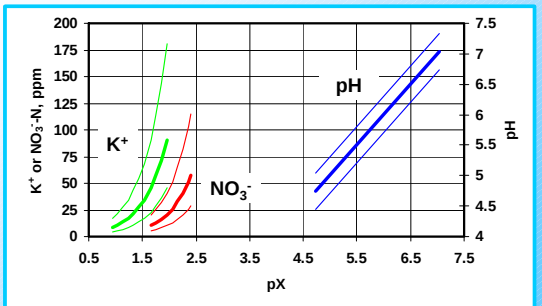



## Electrode Accuracy

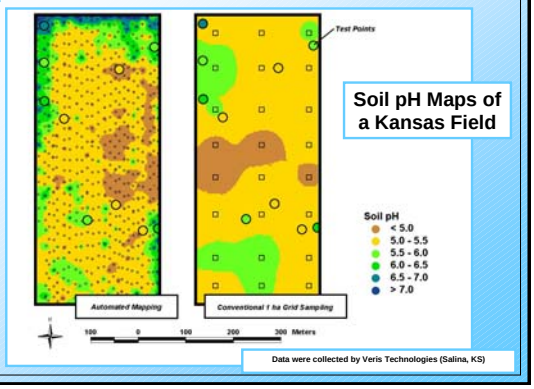
| | Probe 1 | Probe 2 | Probe 3 | Probe 4 | Probe 5 | Probe 6 |
|---|---|---|---|---|---|---|
| | pH | pK | $pNO_3$ | pH | pK | $pNO_3$ |
| | Brand 1 | | | Brand 2 | | |
| Individual $R^2$ | 0.89 | 0.40 | 0.30 | 0.93 | 0.67 | 0.03 |
| Daily Mean $R^2$ | 0.96 | 0.61 | 0.60 | 0.97 | 0.83 | 0.08 |
| Mean $R^2$ | 0.98 | 0.89 | 0.89 | 0.99 | 0.95 | 0.56 |

Reference:
Average Standard Test for pH
Saturation Paste and Atomic Absorption Spectroscopy for pK
Saturation Paste and Cadmium Reduction for $pNO_3$

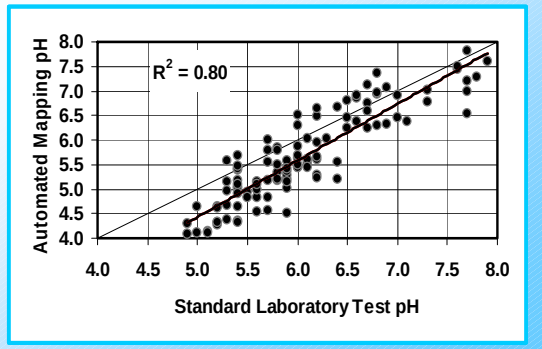
## Distinguishing between Levels of Soil Properties



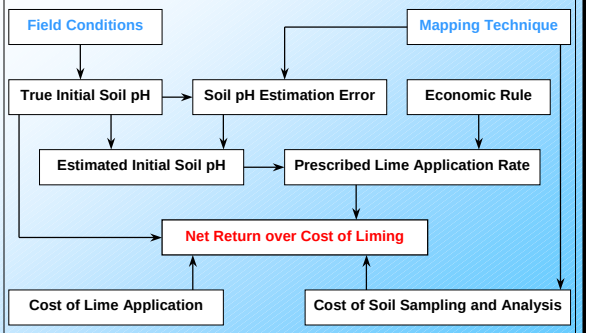

## Field Mapping



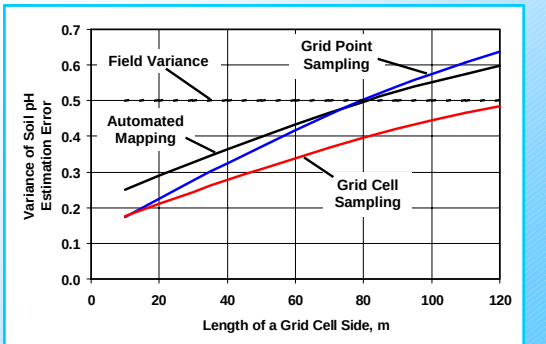

## Field Test (Soil pH Mapping)



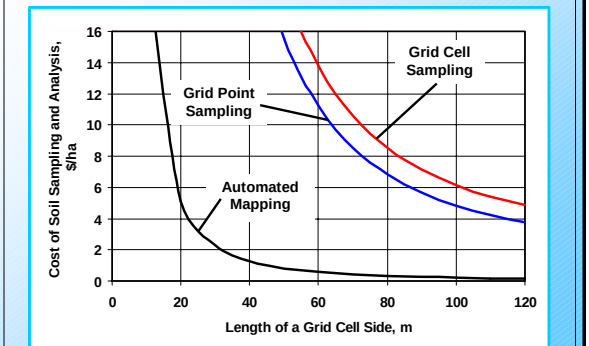

## Agro-Economic Analysis



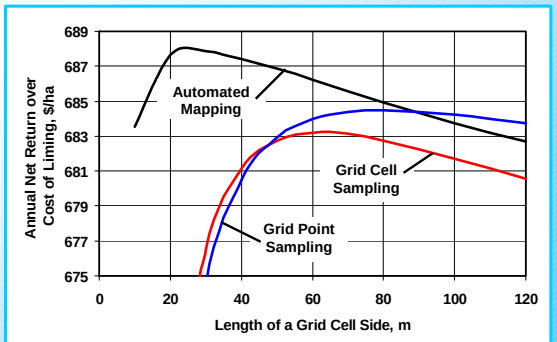

## Variance of Estimation Error



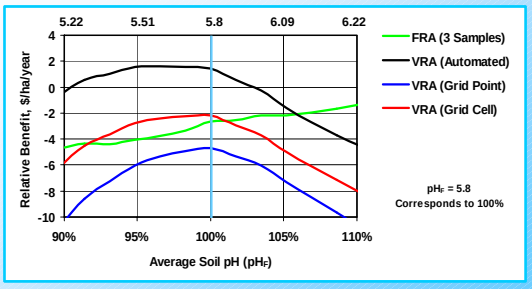

## Cost of Soil Sampling and Analysis



## Optimum Grid Size

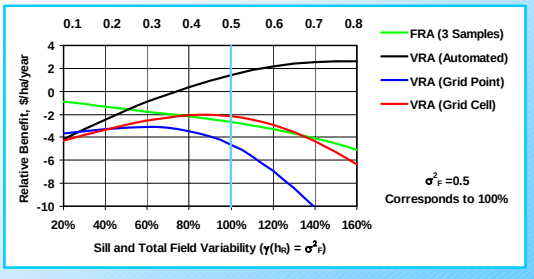



## Effect of Average Soil pH



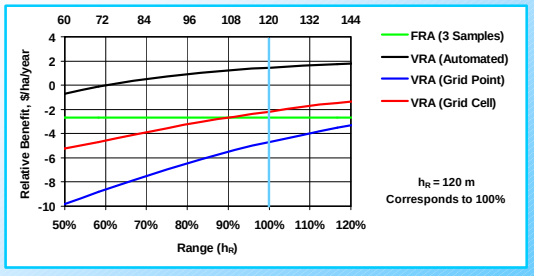

FRA – Fixed Rate Application
VRA – Variable Rate Application

## Effect of the Sill (Total Variance)



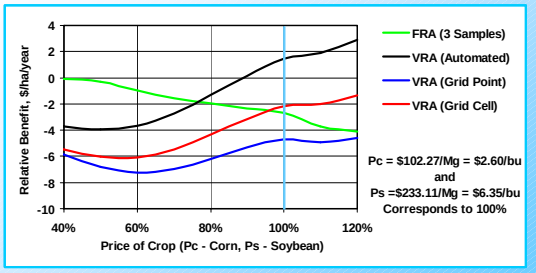

FRA – Fixed Rate Application
VRA – Variable Rate Application

## Effect of the Range (Scale of Variance)




FRA – Fixed Rate Application
VRA – Variable Rate Application

## Effect of Crop Prices




FRA – Fixed Rate Application
VRA – Variable Rate Application

## Summary

- Direct soil measurement of $H^+$, $K^+$ and $NO_3^-$ have root mean squared errors less than 0.3 pX (pH, pK, $pNO_3$)
- Automated soil pH mapping is a promising alternative to conventional sampling and analysis methods due to increased sampling density
- Estimating exchangeable potassium content or buffer pH requires additional information about soil tested
- Direct automated mapping of phosphorus content remains non-feasible

## Acknowledgements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