Economics of Direct Soil Sensing In Agriculture

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Objectives:

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- Summarize experience in worldwide adoption of precision agriculture
- Drivers of soil sensor innovation and economics
- Example of sensor for soil pH
- Characteristics of soil sensor technology most likely to be profitable and widely adopted.

> Hypothesis: Agricultural sensing will be economically successful only if leads to embodied knowledge systems for managing crops and livestock

"Information-intensive" vs. "Embodied knowledge"

Information-intensive	Embodied knowledge
• Field level data to make decisions	• Information purchased in the form of an input
• Requires additional data and skill	• Requires minimal additional data/skill
• IPM	• Hybrid seed
• Map based VRT	• GPS Auto-guidance
	• Real Time VRT using on-the-go sensors

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Intense Interest in the US N Sensor Industry: But Future Unclear

- Trimble Navigation has taken over NTech and its GreenSeeker technology
- Crop Circle is Partnering with Ag Leader
- Future of Soil Doctor unclear with death of John Colburn on Dec. 23, 2008
- In US, crop area managed with N sensors still small.

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Drivers of PA Economics

Regardless of the source of spatial information, for the practice of site-specific agriculture vs. a whole field approach to generate positive net returns, the following must be in place:

- A crop response to one or more inputs with a relatively narrow optimal range
- A factor that can be measured reliably that relates to crop response to an input
- Accurate and precise measurement of field variability
- Accurate and precise application of crop inputs
- Input(s) and output valuable enough to justify the cost of data collection, decision making and variable rate application

Example: Sensing soil pH What is the cost of measurement error?

- Farmers are motivated to consider VRT lime because in the US Midwest soil pH varies widely and lime application is expensive.
- Intensive soil sampling is one of the main costs of VRT lime.
- Hallman and Lowenberg-DeBoer (2000) developed a theoretical framework and used data from Adamchuk to simulate the cost and/or benefit of soil pH sensing.

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Analytic Solutions for Soils Sensor Profitability

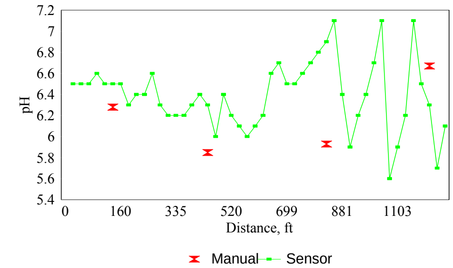
For example, the net profits from continuously variable lime application compared to grid application:

$\pi|pH_k$, continuous $- \pi \mid \overline{pH}_k$, grid

$= \Sigma[P\{a + b(pH_{ki} + \Delta pH_{li}^*) + c(pH_{ki} + \Delta pH_i^*)^2\} - r\Delta pH_{li}^*]/N - w_c - z_c - \Sigma[P\{a + b(pH_{ki} + \Delta pH_1^* + c(pH_{ki} + \Delta pH_1^*\}^2 - r\Delta pH_1^*]/N - w_c - z_g$

$= -PcVar(pH_k) + (z_g - z_c)$

Compare Sensor and Manual Data: Transect 2, Davis Farm, 1999



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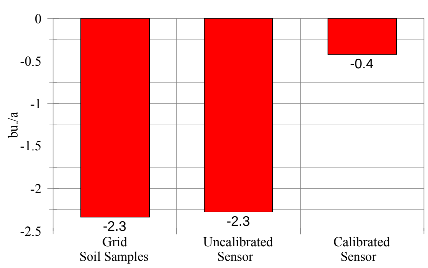
Source: Lowenberg-DeBoer & Hallman, 2000

Estimated Yield Loss due to pH Measurement and Spatial Error



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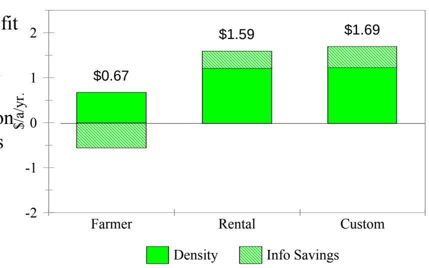
Source: Lowenberg-DeBoer & Hallman, 2000

Estimated Annual Benefit of Calibrated Sensor on Example Field

- Most of sensor benefit is from greater data density
- Information cost savings depend on how the sensor is owned and managed.



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Source: Lowenberg-DeBoer & Hallman, 2000

Economic Studies of On-the-Go N Sensors

- Few studies on profitability of on-the-go N sensors.
- Many of the same problems that Tenkorang & Lowenberg-DeBoer found for remote sensing:
  - Data often from one year/one location
  - Standard budgeting practices not followed
- One of the better studies is Biermacher et al. (Ag Economics, 2009) which used nine years of data from nine sites to estimate benefits of Greenseeker use for N management for wheat in Oklahoma.

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Benefits for Greenseeker Use for N Management for Wheat in Oklahoma

Estimate	Zero N	Uniform Pre-Plant 90 kg/ha	Uniform Topdress based on Sensing	Variable Topdress based on Sensing	Variable Topdress using OSU algorithm
Average Yield (kg/ha)	2199	2723	2689	2740	2476
Average N (kg/ha)	0	90	53	37	18
Expected Profit ($/ha)	$242	$256	$265	$271	$255

Some Conclusions:

- Study shows potential profits of sensing.
- Non-economic OSU algorithm did not apply enough N to maximize profits.
- Use of variable rate UAN (28% solution) benefits did not outweigh the cost advantage of NH_3.

Ideal Embodied Knowledge Technology?

- Users do not need to understand the science for the technology to be effective
- Input decisions made by the computer, without a human being in the decision making loop
- Usable by workers with low educational levels
- Reliable – provide lower input use, higher yields, higher profits almost every use
- Relatively inexpensive compared to benefits – does not require a major investment

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Ag Sensing Technology Most Likely to be Commercially Successful

- Agricultural sensors more likely to become commercially successful as part of embodied knowledge technology.
- Higher crop values, higher input prices and lower technology costs favor ag sensing.
- Demonstrating value depends on third party assessment at multiple locations, over several years and using standard economic methods.

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Thank You

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