Economics of Direct Soil Sensing
In Agriculture

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Objectives:

• 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

• Field level data to make decisions
• Requires additional data and skill
• IPM
• Map based VRT

Embodied knowledge

• Information purchased in the form of an input
• Requires minimal additional data/skill
• Hybrid seed
• GPS Auto-guidance
• Real Time VRT using on-the-go sensors

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.

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.
Analytic Solutions for Soils Sensor Profitability

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

$$\pi_{\text{pH}_{k, \text{continuous}}} - \pi_{\text{pH}_{k, \text{grid}}} = \Sigma \left[ P \left\{ a + b (pH_{ki} + \Delta pH_{ki}) + c (pH_{ki} + \Delta pH_{ki})^2 \right\} - r \Delta pH_{ki} \right] / N - w_c - z_c - \Sigma \left[ P \left\{ a + b (pH_{1i} + \Delta pH_{1i}) + c (pH_{1i} + \Delta pH_{1i})^2 - r \Delta pH_{1i} \right\} / N - w_c - z_g \right] = -PcVar(pH_{k}) + (z_g - z_c)$$

Compare Sensor and Manual Data:

Transect 2, Davis Farm, 1999

<table>
<thead>
<tr>
<th>Distance, ft</th>
<th>Manual</th>
<th>Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5.4</td>
<td>5.6</td>
</tr>
<tr>
<td>160</td>
<td>5.6</td>
<td>5.8</td>
</tr>
<tr>
<td>335</td>
<td>6</td>
<td>6.2</td>
</tr>
<tr>
<td>520</td>
<td>6.2</td>
<td>6.4</td>
</tr>
<tr>
<td>699</td>
<td>6.4</td>
<td>6.6</td>
</tr>
<tr>
<td>881</td>
<td>6.6</td>
<td>6.8</td>
</tr>
<tr>
<td>1103</td>
<td>6.8</td>
<td>7</td>
</tr>
</tbody>
</table>

Source: Lowenberg-DeBoer & Hallman, 2000

Estimated Yield Loss due to pH Measurement and Spatial Error

-2.5 -2.3 -2.1 -2 -1.8 -1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2

Grid Soil Samples Uncalibrated Sensor Calibrated Sensor

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.

<table>
<thead>
<tr>
<th>Farmer</th>
<th>Rental</th>
<th>Custom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>$0.67</td>
<td>$1.59</td>
</tr>
<tr>
<td>Info Savings</td>
<td>$0</td>
<td>$0</td>
</tr>
</tbody>
</table>

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.

Benefits for Greenseeker Use for N Management for Wheat in Oklahoma

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Uniform Pre-Plant 90 kg/ha</th>
<th>Uniform Topdress based on Sensing</th>
<th>Variable Topdress based on Sensing</th>
<th>Variable Topdress using OSU algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Yield (kg/ha)</td>
<td>2199</td>
<td>2723</td>
<td>2689</td>
<td>2740</td>
</tr>
<tr>
<td>Average N (kg/ha)</td>
<td>0</td>
<td>90</td>
<td>53</td>
<td>37</td>
</tr>
<tr>
<td>Expected Profit ($/ha)</td>
<td>$242</td>
<td>$256</td>
<td>$265</td>
<td>$271</td>
</tr>
</tbody>
</table>

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 NH₃.
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

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.

Thank You

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