Evaluating the Wisdom of Monitoring Networks for Invasive Species: The Case of Soybean Rust

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Research Goals

- To develop a mathematical model to value information from sentinel plots
- To use this model to find the optimal placement of sentinel plots
Previous work

- Roberts et al.
- Want to expand on their work in two regards
  - Move from a static to dynamic model
  - Apply farm level model to county level data to optimize placement of sentinel plots
Calculating the value of information

- Information is only valuable if it improves decision making on average
- Focus on the benefits of the information, not the cost of generating it
Soybean Rust Management Strategies

- Apply preventative fungicide
- Scout fields for soybean rust and apply curative fungicide if found
- Spray only if rust is detected at a nearby sentinel plot
- No Action
Tradeoffs

- Preventative strategy has lowest yield loss but limits ability to learn.
- Curative allows learning but requires scouting.
- Following signal from sentinel plot requires accurate signal.
## Cost of different management strategies (dollars/acre)

<table>
<thead>
<tr>
<th>Management Strategy</th>
<th>No Infection</th>
<th>Infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventative</td>
<td>$25.63</td>
<td>25.63+1% yield loss</td>
</tr>
<tr>
<td>Curative</td>
<td>$6.71</td>
<td>$20.52+7% yield loss</td>
</tr>
<tr>
<td>No Action</td>
<td>$0.00</td>
<td>25% yield loss</td>
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Source: Roberts et al. (2007)
Cost of following management strategies, including a within season signal (dollars/acre)

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<td>25% yield loss</td>
</tr>
<tr>
<td>Follow the within season signal with accuracy, S</td>
<td>$S*0+(1-S)$25.63</td>
<td>$S*(25.63+1% yield loss)+(1-S)(25% yield loss)</td>
</tr>
</tbody>
</table>
Expected Cost Minimizing Strategy Depends on the Probability of Infection

- Soybeans = $8.00 a bushel
- Average yield of 37 bu/acre
- If $p<17\%$ optimal strategy is no action
- If $17\%<p<59\%$ optimal strategy is curative
- If $59\%<p$ optimal strategy is preventative
The farmer’s problem

- Minimize the expected cost of managing soybean rust over time
- Focal point: tradeoff between current returns and learning about risk
- 2-armed Bandit Problem - Rothschild (1974)
Bayesian updating

- Use Beta distribution
- Start with prior belief Beta(m,n)
- If observe an infection, posterior belief is Beta(m+1,n)
- If do not observe an infection, posterior belief is Beta(m,n+1)
Bayesian Updating Cont
Stopping Rules: No Monitoring

Diagram showing decision-making process with nodes labeled by {i, j} and actions labeled as Curative or No Action for each decision point.

The process starts at the top with {1, 1} and branches down with curative or preventative actions at each node until reaching the bottom nodes {1, 6}.
Stopping Rules: 4- Period Monitoring Network, within season signal of quality 0.75
Green: No action
Yellow: Curative
Red: Preventative
Blue: Follow Signal
Using this model to determine the optimal location of sentinel plots

- Create a representative farmer for each county
- Use data on average soybean yield and production from USDA National Agricultural Statistical Service
- Used estimated risk of rust from Bekkerman, Goodwin and Piggott (2008) for prior beliefs.
Quality of the within season signal as a function of distance to the nearest sentinel plot
## Results

<table>
<thead>
<tr>
<th></th>
<th>High Quality Signal</th>
<th>Medium Signal Quality Function</th>
<th>Low Signal Quality Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 plots</td>
<td>$106,876,866</td>
<td>$74,217,175</td>
<td>$59,901,124</td>
</tr>
<tr>
<td>400 plots</td>
<td>$102,672,631</td>
<td>$72,055,069</td>
<td>$57,697,522</td>
</tr>
<tr>
<td>300 plots</td>
<td>$97,919,715</td>
<td>$69,110,845</td>
<td>$54,760,403</td>
</tr>
<tr>
<td>200 plots</td>
<td>$92,166,473</td>
<td>$65,149,613</td>
<td>$52,435,480</td>
</tr>
</tbody>
</table>
Comparing to Roberts et al

- Roberts et al. considered several scenarios.
- Benefits of monitoring network in scenarios ranged from $11-$299 million.
Conclusions

- We looked at the value of information when the context is learning about a stable statistical process
- Estimated value of sentinel plots similar to Roberts et al.
- Value of network is sensitive to farmer’s prior beliefs
Questions?