MEASURING ADOPTION INTENSITY OF WEED RESISTANCE MANAGEMENT PRACTICES USING DATA ENVELOPE ANALYSIS WITH PRINCIPAL COMPONENTS

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Public Policies, Research and the Economics of Herbicide Resistance Management

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Motivation

• Herbicide resistant weeds are a problem and spreading
• Lots of reasons why has this problem has occurred
• Lots of reasons why we should be concerned
• Lots of ideas about what we should do about it
• Lots of reasons why it will be difficult to address

• Basic Management Principle: Measure to Manage
  • You cannot manage what you do not measure!
• My Goal Today: Present a method to measure farmer adoption of weed resistance management practices based on method we use to measure agricultural sustainability
Lots of Problems in Ag

• Double food production by 2050 (Tillman et al. 2011)
• Can already detect negative impacts of climate change on aggregate crop yields (Lobell et al. 2011)
• Dead zones will continue: Legacy N and P will pollute surface waters for decades, even if ag disappeared (Sebilo et al. 2013; Jarvie et al. 2013; Finlay et al. 2013)
• From 2006-2011, 1.3 million grassland acres converted to crops on the Great Plains (Wright & Wimberley 2013)
• Soil Erosion: “Losing Ground” (Cox et al. 2011)
• Groundwater declines (India, CA, Ogallala, etc.)
• Herbicide resistant weeds just one of the many problems

• **Solution: Agricultural Sustainability!**
Making Ag Sustainability Practical

• Lots of grand ideals, media events, colorful graphics, papers, reports, conferences, presentations, …
• How do you make Ag Sustainability practical?
• What do you measure? How do you measure it?
• Sustainability is multi-dimensional: How do you capture the tradeoffs?
• A first step is measuring farmer adoption of best management practices (BMPs) that have demonstrated positive outcomes
• Herbicide resistance management practices are just a special case of this more general problem
• Several active projects at UW in ag sustainability
  • Cranberry, soybeans, sweet corn, green beans, potatoes, plus whole farm
• National Initiative for Sustainable Agriculture (NISA): http://nisa.cals.wisc.edu/
• Developed an index of BMP adoption intensity for agricultural sustainability that also applies to adoption of weed resistance management practices
The Rest of the Presentation

1. Describe the General Measurement Problem
2. Describe the Analysis Method: Data Envelope Analysis with Principal Components
3. Present empirical results for weed BMP adoption among U.S. corn, soybean, and cotton growers
4. Summarize regression analysis to explore the determinants of weed BMP adoption intensity
The General Problem

- Conduct a survey and have data on farmer adoption of numerous practices
  - Weed BMPs for managing herbicide resistance
    - Our survey has 10 practices and we add 3 more
    - Norsworthy et al. (2012) has 12 practices
  - Sustainable Ag practices
    - Cranberry: ~20 practices, Soybean: ~70 practices, Sweet Corn & Green Bean: ~100, Whole Farm: ~200
    - Insect, disease, weed, soil, nutrient, water/irrigation mgmt, natural areas/biodiversity, employee mgmt, professional development, record keeping/planning, energy/GHG/recycling, community involvement, …
The General Problem

• Practice adoption highly correlated and/or interrelated:
  • Complementary and Competitive practices: scouting for insects, diseases, & weeds; RR adoption and use of residual herbicide or multiple modes of action
  • Commonly use Categorical/Discrete measures
    • Do you use this practice: Yes/No
    • How often do you use this practice: Always, Often Sometimes, Rarely, Never
  • Main point: Adoption data consists of many variables, some discrete, many correlated
Data Envelope Analysis with Principal Components

1. **Principal Component Analysis (PCA)** to reduce number of variables and transform variables to positive continuous variables with little loss of information

2. **Data Envelope Analysis (DEA)** to create composite index measuring how intensely each farmer adopts practices
   
   - **Output:**
     - Score between 0 and 1 for each farmer measuring BMP adoption intensity relative to peers
     - Distribution of scores describes BMP adoption intensity of the grower population
     - Way to measure changes over time at individual grower level and for a grower population
Non-Negative Polychoric PCA

- Non-Negative: Restrict PCA so weight matrix $U$ has all positive weights (preparing for DEA)
- Use polychoric correlation for discrete variables rather than typical Pearson’s correlation
- Data $X \in \mathbb{R}^{V \times N}$ $V = 1$ to $V$ variables $k = 1$ to $N$ farms
- Divide each observation $x_{vk}$ by each variable’s st. dev. $\sigma_v$ to form normalized data matrix $X \in \mathbb{R}^{V \times N}$
- New data $Y = U^T X$, where $Y \in \mathbb{R}^{I \times N}$ is matrix of retained PC’s $i = 1$ to $I$ and $U \in \mathbb{R}^{V \times I}$ is the PCA weight matrix
Non-Negative Polychoric PCA

- Dong et al. (2013) gives details for solving for $U$

$$\max_U \frac{1}{2} \| U^T X \|_F^2 - \frac{\alpha}{4} \| I - U^T U \|_F^2 , \text{ subject to } U \geq 0$$

- $\| \cdot \|_2^2 =$ Squared Frobenius norm = sum of squared elements
- Fairly intense optimization process
- With 70 PC’s and 300+ observations = 2 days on PC for each choice of number of PCs to retain
### Cranberry Example PCA weight matrix $U$

with elements $u_{iv}$

<table>
<thead>
<tr>
<th></th>
<th>% Ac Scout</th>
<th>Hired Scout</th>
<th>Times Scout</th>
<th>Dist Travel</th>
<th>Cultr Practc</th>
<th>Soil Test</th>
<th>Tissue Test</th>
<th>Weathr Station</th>
<th>Soil Moistr</th>
<th>Irrg</th>
<th>Unifm Test</th>
<th>Nut Mgmt Plan</th>
<th>Consrv Plan</th>
<th>Recycle</th>
<th>Emply Insrnc</th>
<th>Emply Retrmt</th>
<th>Safety Trng</th>
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<tbody>
<tr>
<td>PC1</td>
<td>1.014</td>
<td>0</td>
<td>0.001</td>
<td>0</td>
<td>0.025</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0.003</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>PC2</td>
<td>0</td>
<td>0.051</td>
<td>1.012</td>
<td>0</td>
<td>0</td>
<td>0.020</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.002</td>
<td>0</td>
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<td>0</td>
<td>0.016</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>PC3</td>
<td>0</td>
<td>0</td>
<td>0.009</td>
<td>0.034</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.958</td>
<td>0.339</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PC4</td>
<td>0.001</td>
<td>0</td>
<td>0</td>
<td>0.012</td>
<td>0.035</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.062</td>
<td>1.011</td>
<td>0.007</td>
<td>0.026</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>PC5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.080</td>
<td>0.605</td>
<td>0</td>
<td>0.091</td>
<td>0</td>
<td>0.822</td>
<td>0.023</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>PC6</td>
<td>0</td>
<td>0.078</td>
<td>0.431</td>
<td>0</td>
<td>0</td>
<td>0.018</td>
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<td>0</td>
<td>0</td>
<td>0.017</td>
<td>0.914</td>
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<td>0</td>
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<td>0</td>
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<tr>
<td>PC7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.029</td>
<td>0.003</td>
<td>0</td>
<td>0.069</td>
<td>0</td>
<td>0.728</td>
<td>0.708</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>PC8</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0.011</td>
<td>0.001</td>
<td>0</td>
<td>0</td>
<td>0.017</td>
<td>0.022</td>
<td>1.014</td>
<td>0.019</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.707</td>
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<tr>
<td>PC9</td>
<td>0</td>
<td>0.353</td>
<td>0.496</td>
<td>0.417</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.050</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- **Final PCA Output**: For each farmer $k$: $y_{ik} = \sum_{v} u_{iv} x_{vk}$
- **Example**: $PC1 = 1.014 \times \%\text{AcresScouted} + 0.025 \times \text{UseCulturalPractices} + \ldots$ (weighted average)
- **PC1 and PC2**: Pest scouting practices
- **PC3 and PC4**: Irrigation practices
- **PC5**: Nutrient management
Cranberry Example: PC4 (irrigation uniformity testing) vs. PC3 (weather station & soil moisture monitoring)
Data Envelope Analysis (DEA)

- DEA widely used to rank or score individuals, companies, countries in a variety of contexts
- Creates index number ranking each unit relative to peers
- Too many variables reduces discriminating power
- Correlation among variables creates bias
- Discrete variables imply non-interpretable combinations
- Technically use input-oriented, constant returns to scale DEA with multiple outputs and a single dummy input of 1 for all farms, which requires all data to be positive
- Use non-negative polychoric PCA to pre-process data to reduce dimensions, remove correlation, and make data positive and continuous
- Common-weight DEA to increase discriminating power
DEA for Adoption Intensity (Theory)

- Farmer practice adoption gives PC1 and PC2
- Plot these points: Each farmer is a point
- DEA Frontier: outer envelope of points
- Distance from origin to point measures practice adoption intensity relative to frontier
- Max score = 1.0
- Min score = 0.0
Cranberry Example PC4 vs. PC3
Common-Weight DEA

Minimize \( h(d_k, \omega_i, z) = t \frac{1}{K} \sum_{k=1}^{K} d_k + (1-t)z \)

subject to \( S_k^b - \sum_{i=1}^{I} \omega_i y_{ik} = d_k, \quad d_k \geq 0, \quad z - d_k \geq 0 \quad \forall k, \quad \omega_i \geq \varepsilon \quad \forall i, \quad z \geq 0 \)

Maximize \( S_k^b(\omega_{ik}) = \sum_{i=1}^{I} \omega_{ik} y_{ik} \)

subject to: \( \sum_{i=1}^{I} \omega_{ik} y_{ik} \leq 1 \quad \forall k, \quad \omega_{ik} \geq \varepsilon \quad \forall k \)

- \( 0 \leq t \leq 1 \) weights average and max deviation in objective
- Vary \( t \) from 0 to 1 by 0.01 and solve for optimal scores, then average scores for a grower over all solutions

\[
\bar{S}_k = \frac{1}{T} \sum_{t=0}^{1} S_{kt} = \frac{1}{T} \sum_{t=0}^{1} \sum_{i=1}^{I} \omega_{it} y_{ik} = \sum_{i=1}^{I} \bar{\omega}_i y_{ik}
\]

\[
\bar{\omega}_i = \frac{1}{T} \sum_{t=0}^{1} \omega_{it}
\]
Combine Weights from PCA and DEA

- PCA is weighted average of original data
- DEA score is a weighted average of the PC’s
- Combine the weights to get score in terms of the original variables measuring grower practice adoption

\[
\overline{S}_k = \sum_{v=1}^{V} \sum_{i=1}^{I} \left( \frac{\bar{y}_{vi}}{\sigma_v} \right) x_{vk} = \sum_{v=1}^{V} w_v x_{vk}
\]

- Main Point: Can express farmer score as a weighted average of their responses, where weights are endogenous
Weed BMP Data

- Telephone survey of 400 corn, 400 soybean and 400 cotton farmers from main producing states
  - At least 250 acres of target crop
  - Surveyed during Nov-Dec 2007
  - Questions on 2007 and plans for 2008
  - Weed management with RR focus
  - Funded by Monsanto

- Published various conference papers, plus journal papers Hurley et al. 2009a, 2009b, 2009c, Frisvold et al. 2009
Weed Management Survey

- General Grower and Operation Information
- 2007 Production Practices
- Weed BMP Use
- Factors Influencing Herbicide Choices
- 2008 Production Plans
- Economic questions to derive WTP estimates
Weed Resistance Management BMPs

- Scout fields before a herbicide application
- Scout fields after a herbicide application
- Start with a clean field, using a burndown herbicide application or tillage
- Control weeds early when they are relatively small
- Control weed escapes and prevent weeds from setting seeds
- Clean equipment before moving between fields to minimize weed seed spread
- Use new commercial seed that is as free from weed seed as possible
- Use multiple herbicides with different modes of action during cropping season
- Use tillage to supplement weed control provided by herbicide applications
- Use the recommended application rate from the herbicide label
<table>
<thead>
<tr>
<th>Practice</th>
<th>Frequency of Adoption (% of Respondents)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scout fields before a herbicide application</td>
<td>1.1 1.6 10.3 31.7 55.4</td>
</tr>
<tr>
<td>Scout fields after a herbicide application</td>
<td>1.3 2.9 14.5 32.5 48.8</td>
</tr>
<tr>
<td>Start with a clean field, using a burndown herbicide application or tillage</td>
<td>9.8 5.5 12.9 15.3 56.5</td>
</tr>
<tr>
<td>Control weeds early when they are relatively small</td>
<td>0.3 1.3 10.6 36.9 50.9</td>
</tr>
<tr>
<td>Control weed escapes and prevent weeds from setting seeds</td>
<td>2.4 3.7 14.0 31.7 48.3</td>
</tr>
<tr>
<td>Clean equipment before moving between fields to minimize weed seed spread</td>
<td>34.8 26.1 18.5 10.0 10.6</td>
</tr>
<tr>
<td>Use new commercial seed that is as free from weed seed as possible</td>
<td>1.1 0.3 1.9 5.5 91.3</td>
</tr>
<tr>
<td>Use multiple herbicides with different modes of action during the season</td>
<td>18.5 20.1 33.3 14.5 13.7</td>
</tr>
<tr>
<td>Use tillage to supplement weed control provided by herbicide applications</td>
<td>37.2 23.0 24.5 7.7 7.7</td>
</tr>
<tr>
<td>Use the recommended application rate from the herbicide label</td>
<td>0.5 0.3 3.7 21.1 74.4</td>
</tr>
</tbody>
</table>
Augmented Data

- Added 3 continuous variables
- % RR target crop acres following non-RR crop
- % target crop acres treated with burndown herbicide
- % target crop acres treated with residual herbicide

<table>
<thead>
<tr>
<th>Soybean Data</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>%RRPostNonRR</td>
<td>51.0</td>
<td>43.6</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>%Burndown</td>
<td>34.7</td>
<td>43.7</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>%Residual</td>
<td>21.9</td>
<td>38.1</td>
<td>0.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Results Analyzing Each Crop Separately

- PCA: Mostly to remove correlation and convert to positive continuous variables
- Retained 11 PC’s that captured 89%, 88% and 90% of variance of original soybean, corn and cotton data
- DEA: Varied $t$ from 0 to 1 by 0.01 steps, found 20, 15 and 9 unique solutions for soybean, corn and cotton
- Calculated practice-specific weights, plus properties of the score distribution
<table>
<thead>
<tr>
<th>Practice</th>
<th>Soybean</th>
<th>Corn</th>
<th>Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scout fields before a herbicide application</td>
<td>0.0218</td>
<td>0.0002</td>
<td>0.0078</td>
</tr>
<tr>
<td>Scout fields after a herbicide application</td>
<td>0.0245</td>
<td>0.0337</td>
<td>0.0177</td>
</tr>
<tr>
<td>Start with a clean field, using a burndown herbicide application or tillage</td>
<td>0.0041</td>
<td>0.0001</td>
<td>0.0005</td>
</tr>
<tr>
<td>Control weeds early when they are relatively small</td>
<td>0.0316</td>
<td>0.0371</td>
<td>0.0496</td>
</tr>
<tr>
<td>Control weed escapes and prevent weeds from setting seeds</td>
<td>0.0002</td>
<td>0.0003</td>
<td>0.0016</td>
</tr>
<tr>
<td>Clean equipment before moving between fields to minimize weed seed spread</td>
<td>0.0184</td>
<td>0.0009</td>
<td>0.0000</td>
</tr>
<tr>
<td>Use new commercial seed that is as free from weed seed as possible</td>
<td>0.0525</td>
<td>0.0942</td>
<td>0.0632</td>
</tr>
<tr>
<td>Use multiple herbicides with different modes of action during the season</td>
<td>0.0002</td>
<td>0.0008</td>
<td>0.0004</td>
</tr>
<tr>
<td>Use tillage to supplement weed control provided by herbicide applications</td>
<td>0.0003</td>
<td>0.0000</td>
<td>0.0002</td>
</tr>
<tr>
<td>Use the recommended application rate from the herbicide label</td>
<td>0.0910</td>
<td>0.0826</td>
<td>0.1005</td>
</tr>
<tr>
<td>% RR area planted following a non-RR crop</td>
<td>0.0218</td>
<td>0.0004</td>
<td>0.0000</td>
</tr>
<tr>
<td>% planted area treated with a burndown herbicide</td>
<td>0.0003</td>
<td>0.0006</td>
<td>0.0338</td>
</tr>
<tr>
<td>% planted area treated with a residual herbicide</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0000</td>
</tr>
</tbody>
</table>
Weights and Marginal Effects

- Weights can be used to see which practices most increase grower adoption intensity scores, ceteris paribus.
- Practices coded 0, 1, 2, 3, and 4 for Never, Rarely, Sometimes, Often, Always.
  - Weight is how much grower score would increase with increasing adoption by moving up one step on the scale.
- Other practices coded as percentages.
  - Weight is how much grower score would increase with increasing adoption by 1% point.
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<td>0.0006</td>
<td>0.0338</td>
</tr>
<tr>
<td>% planted area treated with a residual herbicide</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0000</td>
</tr>
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<td>Statistic</td>
<td>Soybeans</td>
<td>Corn</td>
<td>Cotton</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------</td>
<td>-------</td>
<td>--------</td>
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<tr>
<td>Average</td>
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<td>0.889</td>
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<tr>
<td>St. Dev.</td>
<td>0.090</td>
<td>0.102</td>
<td>0.113</td>
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<tr>
<td>Minimum</td>
<td>0.504</td>
<td>0.462</td>
<td>0.412</td>
</tr>
<tr>
<td>25% Quartile</td>
<td>0.801</td>
<td>0.843</td>
<td>0.844</td>
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<tr>
<td>50% Quartile</td>
<td>0.863</td>
<td>0.927</td>
<td>0.920</td>
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<td>75% Quartile</td>
<td>0.911</td>
<td>0.964</td>
<td>0.966</td>
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</table>
Histogram of Soybean Adoption Intensity Scores
Histogram of Cotton Adoption Intensity Scores
• All three crops have group on lower tail: “Laggards”
• All three crops have group on frontier: “Leaders”
• More heterogeneity among soybean growers
• Corn and cotton “unusually” concentrated on frontier from other cases
Uses of Scores and Weights

- Measure to Manage: Scores measure BMP adoption intensity relative to peer group
- Set baseline/benchmark and targets
- Set research and outreach priorities to help laggards improve and leaders push frontier out
  - Practices and types of growers to focus on
- Track changes over time, to see how individual growers or grower populations are doing
- Compare older and newer populations to see if a group as a whole is getting better
• Redo data collection and analysis and measure improvement over time by shift in score distribution and in frontier

• Developing an Ag Sustainability program for grower groups

• Exploring using ARMS data to link adoption intensity to profit
Regression Analysis of Scores

- Use regression to explore factors driving BMP adoption
- Regress individual grower score on other variables included in the survey
- Truncated Regression: Scores must be between 0 and 1
- Farm and Farmer Characteristics: Farm Size, % Owned, Education, Experience, Livestock, Crop Diversity, State, % Deviation from Mean County Yield, County Yield CV
- Weed Management: % Custom Application, Control Costs, Value RR, PC’s of Herbicide Concerns
- Resistance: County has Resistant Weeds, % Counties in CRD with Resistance, Concerned about Resistance
<table>
<thead>
<tr>
<th>Variable</th>
<th>Soybean</th>
<th>Corn</th>
<th>Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator has college or advanced degree (Yes=1, No=0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years managing farming operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hectares of target crop plant in 2007</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% operated land owned by farmer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% herbicide applications made by custom applicator</td>
<td></td>
<td></td>
<td>0.115</td>
</tr>
<tr>
<td>Coefficient of variation for county average yield</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% farm average yield deviates from county average</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raise commercial livestock (Yes=1, No=0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herfindahl index of crop diversity</td>
<td></td>
<td>-0.0953</td>
<td></td>
</tr>
<tr>
<td>Self-reported average cost ($US/ha) to control weeds</td>
<td></td>
<td></td>
<td>0.000389</td>
</tr>
<tr>
<td>Self-reported additional value ($US/ha) from planting RR crop in 2007</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbicide resistant weeds reported in county (Yes=1, No=0)</td>
<td></td>
<td></td>
<td>0.0764</td>
</tr>
<tr>
<td>% counties in crop reporting district with herbicide resistant weeds</td>
<td></td>
<td></td>
<td>-0.00171</td>
</tr>
<tr>
<td>Herbicide resistant weeds is most important weed management concern (Yes=1, No=0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbicide Concerns PC1</td>
<td>0.0137</td>
<td></td>
<td>-0.0109</td>
</tr>
</tbody>
</table>
Results Discussion

• Soybean: Higher BMP adoption intensity if
  • Fewer counties in CRD with resistance
  • PC1: More concern about human health and environment when choosing herbicides
• Corn: Higher BMP adoption intensity if
  • Less crop diversity/More crop specialization
  • Higher costs for weed control
  • Resistance reported in county
• Cotton: Higher BMP adoption intensity if
  • More Custom Application
  • PC1: Less concern about human health and environment when choosing herbicides
Summary and Conclusions

- DEA with PC: one way to measure BMP adoption intensity for a variety of applications: IPM, IWM, sustainability, …
- Measure to manage
  - Set baseline/benchmark and targets
  - Set research and outreach priorities
  - Identify practices and grower types to focus on
  - Track changes over time for impact assessment
Caveats and Future Research

- Relative Measure, so peer group matters
  - If all farmers low adopters, still score high
- Should connect to Outcomes: practices must be “good” practices or “best management practices”
  - Science/research to guide BMPs for survey
- Income and income risk not in this measure
  - How does a higher score impact Profit? Risk?
  - Considering using ARMS data to explore
- Process still takes a long time, need to streamline it
Acknowledgments

Support for this project provided by the Arizona, Minnesota, and Wisconsin Experiment Stations, Monsanto, United Soybean Board, USDA-Specialty Crop Research Initiative and Wisconsin State Cranberry Growers Association.

Thank You For Your Attention!
Questions or Comments?
People, Profits & Planet
Triple Bottom Line

Producing crops and livestock for human use while simultaneously pursuing environmental, economic, and social goals (NRC 2010)
Sustainability is no longer “Alternative Ag” but has become Mainstream!

- Most food/ag companies and commodity & ag groups have sustainability programs and/or initiatives
  - McDonald’s, Cargill, Unilever, WalMart, Del Monte, PepsiCo/FritoLay, Sysco, …
  - National Corn Growers Association, United Soybean Board, National Association of Wheat Growers, National Potato Council, …
- Everyone’s talking about sustainability!!!