2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

1.1.1.2 Sustainable Feedstock Production-Logistics Interface

May 23, 2013
Sustainability and Analysis Platform

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Idaho National Laboratory

This presentation does not contain any proprietary, confidential, or otherwise restricted information
Goal Statement

• Develop integrated biomass production system designs that:
  – Increase total productivity of the landscape
  – Decrease delivered feedstock cost
  – Increase production system environmental performance
### Project Quad Chart Overview

#### Timeline
- Project start date: 10/01/2011
- Project end date: 09/30/2017
- Percent complete: 40%

#### Barriers
- Ft-A. Feedstock Availability and Cost
- Ft-B. Sustainable Production
- Ft-D. Sustainable Harvesting

#### Budget
- Total Funding = $600,000
  - DOE share – 100%
  - Contractor share – 0%
- Funding in FY11 = $300,000
- Funding in FY12 = $300,000

#### Partners
- DOE Regional Feedstock Partnership
- USDA ARS
- USDA NRCS
- Iowa State University
- Colorado State University
- Enersol Resources
Focused on quantifying the limiting factors, so we can effectively develop the agronomic strategies.
1 - Approach

The models and databases exist,
We need a framework where models can plug together to answer our questions.
2 – Technical Progress

Key Products to Date

• National Assessment
• Sub-field Decision Framework
• Variable Rate Impact Quantification
• Effective Decision Support Tool
2 – Technical Progress: National Assessment Results
## 2 – Technical Progress: National Assessment: Results

<table>
<thead>
<tr>
<th>State</th>
<th>2011 Sustainable Residue (metric tons)</th>
<th>2030 Sustainable Residue (metric tons)</th>
<th>Percentage Increase from 2011 to 2030</th>
<th>2030 Sustainable Residue – All No Till Assumption (metric tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA</td>
<td>25,916,452</td>
<td>37,320,712</td>
<td>44%</td>
<td>49,761,379</td>
</tr>
<tr>
<td>IL</td>
<td>20,934,715</td>
<td>29,995,334</td>
<td>43%</td>
<td>44,070,875</td>
</tr>
<tr>
<td>NE</td>
<td>18,608,878</td>
<td>25,147,128</td>
<td>35%</td>
<td>31,542,110</td>
</tr>
<tr>
<td>MN</td>
<td>16,005,783</td>
<td>21,251,610</td>
<td>33%</td>
<td>27,925,458</td>
</tr>
<tr>
<td>IN</td>
<td>8,614,653</td>
<td>12,457,194</td>
<td>45%</td>
<td>18,217,545</td>
</tr>
<tr>
<td>SD</td>
<td>9,215,154</td>
<td>11,436,652</td>
<td>24%</td>
<td>12,889,524</td>
</tr>
<tr>
<td>ND</td>
<td>7,332,947</td>
<td>8,614,473</td>
<td>17%</td>
<td>10,953,330</td>
</tr>
<tr>
<td>OH</td>
<td>5,686,982</td>
<td>8,225,276</td>
<td>45%</td>
<td>10,620,349</td>
</tr>
<tr>
<td>KS</td>
<td>6,491,175</td>
<td>8,170,214</td>
<td>26%</td>
<td>13,155,859</td>
</tr>
<tr>
<td>WI</td>
<td>4,261,587</td>
<td>6,391,914</td>
<td>50%</td>
<td>11,589,503</td>
</tr>
<tr>
<td>MI</td>
<td>3,200,437</td>
<td>4,375,145</td>
<td>37%</td>
<td>7,219,949</td>
</tr>
<tr>
<td>TX</td>
<td>2,282,048</td>
<td>3,342,113</td>
<td>46%</td>
<td>7,296,466</td>
</tr>
<tr>
<td>MO</td>
<td>2,251,692</td>
<td>3,303,103</td>
<td>47%</td>
<td>6,456,004</td>
</tr>
<tr>
<td>......</td>
<td>......</td>
<td>......</td>
<td>......</td>
<td>......</td>
</tr>
<tr>
<td>US Total</td>
<td>150,897,178</td>
<td>207,905,224</td>
<td>38%</td>
<td>297,499,383</td>
</tr>
</tbody>
</table>
2 – Technical Progress: Variability at the Sub-Field Scale

Soil Characteristics

Surface Topography

Grain Yield
2 – Technical Progress: Sub-Field Scale Variability

Field 1
Implementing Sustainable Harvest: Sub-Field Scale Variability

Field 2
Implementing Sustainable Harvest: Sub-Field Scale Variability

Field 3

(a) Organic Matter in the top horizon (%)
(b) Sand Fraction in the top horizon (%)
(c) Surface Slope (%)
(d) Grain Yield (Mg ha⁻¹)
(e) Residue Removal Rate (Mg ha⁻¹)
(f) Sustainable
   SCI < 0
   Erosion > T & SCI < 0
   Erosion > T
## 2 – Technical Progress: NRCS Conservation Planning and Sub-Field Variability

<table>
<thead>
<tr>
<th>Field</th>
<th>Field Ave. Yield (Mg ha⁻¹)</th>
<th>Tillage</th>
<th>Rot. Harvest Op’s.</th>
<th>Rem. Rate (Mg ha⁻¹)</th>
<th>Comb. Eros. (Mg ha⁻¹)</th>
<th>T Value (Mg ha⁻¹)</th>
<th>SCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.85</td>
<td>Red.</td>
<td>Corn-Soy. Rake and Bale</td>
<td>2.68</td>
<td>6.53</td>
<td>11.21</td>
<td>-0.15</td>
</tr>
<tr>
<td>2</td>
<td>12.60</td>
<td>Red.</td>
<td>Cont. Corn Rake and Bale</td>
<td>6.46</td>
<td>2.14</td>
<td>11.21</td>
<td>0.33</td>
</tr>
<tr>
<td>3</td>
<td>12.40</td>
<td>Conv.</td>
<td>Cont. Corn Rake and Bale</td>
<td>5.10</td>
<td>7.54</td>
<td>11.21</td>
<td>0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field</th>
<th>Total Mg Removed</th>
<th>Mg Removed Sustainably</th>
<th>Total Field Area (ha)</th>
<th>Area Managed Sustainably</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>152</td>
<td>23%</td>
<td>57</td>
<td>21%</td>
</tr>
<tr>
<td>2</td>
<td>119</td>
<td>89%</td>
<td>19</td>
<td>83%</td>
</tr>
<tr>
<td>3</td>
<td>387</td>
<td>72%</td>
<td>77</td>
<td>62%</td>
</tr>
</tbody>
</table>
Sustainable management options

- Lower removal rates via equipment choice or interval removal schemas
- Advanced equipment development, i.e. variable rate
- Agronomic strategies
  - Tillage
  - Cover crops
  - Landscape management concepts
2 – Technical Progress: Tillage Impacts in Iowa

<table>
<thead>
<tr>
<th></th>
<th>State Average Yield (tons/acre)</th>
<th>Tonnage Weighted Average Yield (tons/acre)</th>
<th>Total Residue (tons)</th>
<th>Sustainably Harvestable as Percentage of Total Residue Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Tillage</td>
<td>0.65</td>
<td>1.01</td>
<td>16,684,931</td>
<td>15%</td>
</tr>
<tr>
<td>Reduced Tillage</td>
<td>1.19</td>
<td>1.56</td>
<td>30,218,151</td>
<td>28%</td>
</tr>
<tr>
<td>No Tillage</td>
<td>1.78</td>
<td>2.00</td>
<td>43,157,338</td>
<td>40%</td>
</tr>
<tr>
<td>Actual Tillage</td>
<td>1.16</td>
<td>1.48</td>
<td>29,190,729</td>
<td>27%</td>
</tr>
</tbody>
</table>
• Next generation removal concepts

• Modeled from existing systems with additional performance assumptions

• Assumed to dynamically adjust from 25% to 80% removal
Field 1
2 – Technical Progress: Variable Rate Removal

Field 1 Removal Rate Distribution
- Field Distribution (%)
- Cumulative (%)

Field 2 Removal Rate Distribution
- Field Distribution (%)
- Cumulative (%)

Field 3 Removal Rate Distribution
- Field Distribution (%)
- Cumulative (%)
## 2 – Technical Progress: Agronomic Strategies - Cover Crops

<table>
<thead>
<tr>
<th>Rake and Bale Removal</th>
<th>No Cover Crop</th>
<th>Rye Cover Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Annual Sustainable Residue (short tons)</strong></td>
<td><strong>Percentage of Field Managed Sustainably</strong></td>
<td><strong>Annual Soil Loss (short tons)</strong></td>
</tr>
<tr>
<td>Reduced Tillage</td>
<td>39</td>
<td>21%</td>
</tr>
</tbody>
</table>

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**Figure:**

- **(a)** Organic Matter in the top horizon (%)
- **(b)** Sand Fraction in the top horizon (%)
- **(c)** Surface Slope (%)
- **(d)** Grain Yield (Mg ha⁻¹)
- **(e)** Residue Removal Rate (Mg ha⁻¹)
- **(f)** Sustainable (SCI < 0), Erosion = T, BSDS < 0, Erosion > T
## 2 – Technical Progress:
Agronomic Strategies – Putting it all together

### No Cover Crop

<table>
<thead>
<tr>
<th></th>
<th>No Cover Crop</th>
<th>Rye Cover Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Annual Sustainable Residue (short tons)</strong></td>
<td><strong>Sustainable Stover Removal Rate (short tons/acre)</strong></td>
<td><strong>Annual Soil Loss (short tons)</strong></td>
</tr>
<tr>
<td><strong>Reduced Tillage</strong></td>
<td>293</td>
<td>2.10</td>
</tr>
<tr>
<td><strong>No Tillage</strong></td>
<td>331</td>
<td>2.36</td>
</tr>
</tbody>
</table>
2 – Technical Progress: Current Deployments

**Sustainable Agricultural Residue Removal**

- **SustainR2 Mobile App**
  - iOS version available in Apple App Store
  - URL: [http://bioenergyldt.inl.gov/mobile](http://bioenergyldt.inl.gov/mobile)

- **Map Selection Webtool**: beta testing on INL network

- **Model Integration and Data Management Core Code Libraries**
  - Downloadable from google code project LEAF (Landscape Environmental Assessment Framework)
3 – Relevance

• Developed spatially comprehensive multi-factor agricultural residue assessment for Billion Ton Update

• Deployed decision tools that reconcile NRCS conservation planning with residue removal decisions

• Identified sub-field challenges for residue removal decisions and developed a now widely accepted toolset

• Analytics guiding development of advanced engineered systems for precision residue removal

• Model effort for collaboration between DOE/USDA/Universities/ private sector partners

• Effective Decision Support Tool
4 – Critical Success Factors

Success Factors
• Engaging data collectors to provide datasets and analytics that fill current gaps
• Engaging certification focused efforts to provide analytic support that meets certification standards

Potential Challenges
• Keeping up with deployment demands
• Beginning to work with parameters that are less effectively modeled
• Ending field trial work

Advancing the State of Technology
• Using integrated environmental process modeling to make landscape design decisions
• Cloud based computing for future deployment to cut computational time orders of magnitude
• Building progressive future resource assessments that represent emerging landscape management concepts
5 – Future Work

- Integrated landscape design
- Field scale water quality
- Increased predictive capability around N cycles
- Updated national assessment considering integrated landscape management concepts
Summary

Key Products to Date
- National Assessment
- Sub-field Decision Framework
- Variable Rate Impact Quantification
- Effective Decision Support Tool

Current Deployment Pathways
- SustainR2 Mobile App
  - iOS version available in Apple App Store
  - URL: http://bioenergyldt.inl.gov/mobile
- Map Selection Webtool
- Model Integration and Data Management Core Code Libraries
  - Downloadable from google code project LEAF (Landscape Environmental Assessment Framework)
Questions


• D. Karlen and D. Muth, "Landscape Management for Sustainable Supplies of Bioenergy Feedstock and Enhanced Soil Quality," In-Press, Agrocencia


2 – Technical Progress: The Sub-Field Integrated Framework

Data Sources
- Geoprocessed Sub-Field Yield Data: SQLite
- Geoprocessed LiDAR Topography Data: SQLite
- Local SSURGO Soils: SQLite
- RUSLE2 Climates: SQLite
- CLIGEN: SQL
- WINDGEN: SQL
- NRCS skel Management:XML

GIS Toolkit

User

Soil Data Module

Establish Management Practices

LiDAR Shapefile

Yield Shapefile

Results

RUSLE2

SCI

Iterative Spatial Loop 1

Iterative Spatial Loop 2

Climate Data Module

Management Data Module
Implementing Sustainable Harvest: Variable Rate Removal

Field 2
Implementing Sustainable Harvest: Variable Rate Removal
## Agronomic Strategies: Large Scale Impacts

### Boone County, Iowa

<table>
<thead>
<tr>
<th>Scenario</th>
<th>No Residue Harvest</th>
<th>Sustainable Removal Potential</th>
<th>Sustainable Removal Potential with Rye Cover Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual Soil Loss (short tons)</td>
<td>Total Annual Sustainable Residue (short tons)</td>
<td>Average Sustainable Removal Rate (short tons / acre)</td>
</tr>
<tr>
<td>2011 Scenario</td>
<td>512,972</td>
<td>358,616</td>
<td>2.20</td>
</tr>
<tr>
<td>2030 Scenario</td>
<td>382,013</td>
<td>615,351</td>
<td>3.78</td>
</tr>
</tbody>
</table>
Extended Integrated Modeling Framework
Results

Impact of Residue Removal on SOC

- No Removal
- Annual Removal
- Bi-annual Removal
- Tri-annual Removal

Boone County SOC Potential

Average Annual Residue Removed

NRH Mg/ha:
- 0.00 - 2.00
- 2.01 - 4.00
- 4.01 - 6.00
- 6.01 - 8.00
- 8.01 - 10.00
- 10.01 - 12.00
- 12.01 - 14.00
- 14.01 - 16.00
- 16.01 - 18.00

Sustainable Mg/ha:
- 0.00 - 2.00
- 2.01 - 4.00
- 4.01 - 6.00
- 6.01 - 8.00
- 8.01 - 10.00
- 10.01 - 12.00
- 12.01 - 14.00
- 14.01 - 16.00
- 16.01 - 18.00
Case Study: 20 Year SOC Impacts

![Bar graph showing change in soil organic carbon (top 20 cm) (Mg/ha) for various locations with and without sustainable removal.](image-url)
Case Study: 20 Year SOC Impacts
Residue Removal Decision Toolset: Current Deployments

• SustainR2 Mobile App
  • iOS version available in Apple App Store
  • URL: http://bioenergyldt.inl.gov/mobile

• Map Selection Webtool: beta testing on INL network

• Model Integration and Data Management Core Code Libraries
  • Downloadable from google code project LEAF (Landscape Environmental Assessment Framework)
In the Field Now

- **Commercial Users**
  - Monsanto
  - DuPont/Pioneer
  - Poet
  - Antares/FDC Enterprises
  - Larksen

- **NRCS Test Plan**
  - Targeting 1-3K use cases this fall
  - Will validate results with NRCS field offices

Testing and/or commercial scale locations
Agronomic Strategies: Integrated Cropping Systems

<table>
<thead>
<tr>
<th>Perennial Switchgrass</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/1 Year 1</td>
</tr>
<tr>
<td>Chisel Plow</td>
</tr>
<tr>
<td>4/15 Year 2</td>
</tr>
<tr>
<td>Field Cultivation</td>
</tr>
<tr>
<td>4/15 Year 2</td>
</tr>
<tr>
<td>Plant Switchgrass</td>
</tr>
<tr>
<td>12/15 Year 3-8</td>
</tr>
<tr>
<td>Harvest Switchgrass</td>
</tr>
</tbody>
</table>

Sustainability Factors:
- Sustainable
- SCI < 0
- SCI < 0 & Erosion > T
- Erosion > T

CG/SB  SWG
Agronomic Strategies: Integrated Cropping Systems

<table>
<thead>
<tr>
<th>Rake and Bale Removal</th>
<th>Reduced Tillage</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual Sustainable Residue (metric tons)</td>
<td>Percentage of Field Managed Sustainably</td>
<td>Annual Soil Loss (metric tons)</td>
</tr>
<tr>
<td>Scenario 1 (Corn/Soy)</td>
<td>36</td>
<td>21%</td>
<td>316</td>
</tr>
<tr>
<td>Scenario 2 (Corn/Rye/Soy)</td>
<td>140</td>
<td>83%</td>
<td>182</td>
</tr>
</tbody>
</table>

Impacts of row crop production management decisions across the whole field.
### Agronomic Strategies: Integrated Cropping Systems

#### Rake and Bale Removal

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Annual Sustainable Residue (metric tons)</th>
<th>Percentage of Field Managed Sustainably</th>
<th>Annual Soil Loss (metric tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 5 (Switch)</td>
<td>86</td>
<td>100%</td>
<td>11</td>
</tr>
<tr>
<td>Scenario 6 (Corn/Soy in Switch area)</td>
<td>10</td>
<td>18%</td>
<td>172</td>
</tr>
<tr>
<td>Scenario 7 (Corn/Rye/Soy in Switch area)</td>
<td>33</td>
<td>61%</td>
<td>79</td>
</tr>
</tbody>
</table>

Impacts from management decisions in the “at-risk” areas of the field.
### Agronomic Strategies: Integrated Cropping Systems

#### Rake and Bale Removal

<table>
<thead>
<tr>
<th>Scenario 3</th>
<th>Scenario 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Corn/Soy &amp; Switch)</td>
<td>(Corn/Rye/Soy &amp; Switch)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Reduced Tillage</th>
<th></th>
<th></th>
</tr>
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<td>Annual Soil Loss (metric tons)</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>113</td>
<td>48%</td>
<td>155</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>193</td>
<td>96%</td>
<td>114</td>
</tr>
</tbody>
</table>

**Impacts from landscape management approach to production decisions.**
### Agronomic Strategies: Integrated Cropping Systems

<table>
<thead>
<tr>
<th>Rake and Bale Removal</th>
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