Making Crop Residues a Sustainable Feedstock for Biofuel Production

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Our soil resource
Soil components

- Water: 25%
- Air: 25%
- Mineral: 45%
- Humus: 4.0%
- Organic matter: 5%
- Roots: 0.5%
- Organisms: 0.5%
C cycle in an agroecosystem

Soil organic carbon

\[ \Delta \text{SOC} = \sum (\text{Inputs} - \text{Outputs}) \]

(after Liang and McConkey, 2000)
Agriculture and soil C change

Soil carbon

Pre-cultivation steady-state

Modern agriculture

Stover harvest

Management change

\[ \Delta SOC = \text{input} - \text{output} \]
Biomass ethanol goals

- Sustainably produce ONE BILLION TONS* of feedstock annually
  - Yield increase 50% by 2030
    - Corn and small grains
    - Residue/grain ratio for soybean increase from 1.5:1 to 2.0:1
  - Machine to recover 75% stover
  - No tillage adopted universally

(*0.91 billion Mg)
What is a ONE BILLION?

- **Agricultural land (cropland plus hay and pasture land)**
  - 5 ton ac\(^{-1}\)
  - 200 x 10\(^6\) acres
    - 56% of North Central Region agricultural land
    - Iowa, Illinois, Nebraska, Minnesota, Indiana, and South Dakota (Total = 195.5 x 10\(^6\) ac)
  - Six leading corn producing states in US
Expectations for agriculture

- Provide traditional outputs for an *increasing* world population
  - Food
  - Feed
  - Fiber

- Environmental services
  - Control erosion
  - Sequester C
  - Habitat
  - Water quality

- Replenish SOC/plant nutrients

- Renewable energy feedstock
  - 998 million tons (428 million ton from crop residues)
Meeting expectations sustainably

Soil carbon

Modern agriculture

Stover harvest

Pre-cultivation steady-state

Management change

△ SOC = input - output

REAP
Meeting expectations sustainably

\[ \Delta SOC = \text{input} - \text{output} \]

- **Modern agriculture**
- **Pre-cultivation steady-state**
- **Management change**
- **Stover harvest**
- **+ No tillage?**
Meeting expectations sustainably

Soil carbon

Time

Modern agriculture

Stover harvest

Pre-cultivation steady-state

Management change

△ SOC = input - output

+ Cover crops
Green manure
Increased efficiencies
Innovative technologies

+ No tillage?
Factors limiting crop biomass removal

<table>
<thead>
<tr>
<th>Soil organic carbon</th>
<th>Water erosion</th>
<th>Wind erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous corn Moldboard plow</td>
<td>3.38</td>
<td>1.39</td>
</tr>
<tr>
<td>No or conservation tillage</td>
<td>2.34</td>
<td>0.29</td>
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<tr>
<td>Corn-soybean Moldboard plow</td>
<td>5.58</td>
<td>3.56</td>
</tr>
<tr>
<td>No or conservation tillage</td>
<td>3.52</td>
<td>0.43</td>
</tr>
</tbody>
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Wilhelm et al., Agron. J. (in press)
Increase total biomass production

- Increased efficiency
- Increased reduced C pool
Increased efficiency...  
Increased pool of reduced C

- **Agronomy**
  - Continuous green cover
  - Optimize planting patterns, cultivars, and cultural practices
- **Soil science**
  - Improve water and nutrient use efficiencies
  - Precision input application
- **Crop breeding**
  - Improve quality
  - Enhance stress tolerance
- **Physiology/morphology**
  - Canopy structure
  - Root structure and function
- **Biochemistry**
  - Modify metabolic pathways
  - Eliminated inefficiency (photorespiration)
- **Genetic engineering**
  - Convert C\textsubscript{3} species to C\textsubscript{4}
  - Use green light
  - Use all energy in photons
ARS-Renewable Energy Assessment Project (REAP)

- Management practices
- Algorithm to guide sustainable harvest
- Decision support tools
  - How much residue must be retained?
  - Quantify benefits associated with retaining crop residues
Multiple biomass
Many technologies
Conservation
Reduced expectations
Asking, and answering, the right question