The Efficacy of Amelioration Practices for Crop Residue Removal in the Western Corn Belt

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USDOE-BETO Bioenergy’s Role in Soil Carbon Storage Workshop
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Using Management to Ameliorate Stover Removal

United States Department of Agriculture
Agricultural Research Service
A Closer Look: Stover Harvesting Practices
What are the impacts of corn stover removal on crops and soils?

- Agronomic metrics: Grain yield
- Soil sustainability metrics: Soil organic carbon (SOC), Non-CO₂ gases (N₂O)
- Soil health metrics: physical, chemical, biological properties (not presented)

How do these impacts differ between intensive production systems vs marginally productive systems?

- No-till vs tilled systems
- Continuous monocropping vs crop rotations
- Irrigated vs rainfed/dryland systems
USDA-ARS REAP Project (early 2000s to mid-2010s)

- Sun Grant Regional Partnership: USDA-ARS, NIFA, USDOE-BETO, Universities, Industry partners
- 36 field sites across US; standard design, protocols
- Led to $9M DOE-BETO Landscape Design Project (2015-2021)

1.7 to 3.2 t/ac

\[ \uparrow 5 \text{ bu/ac} \]

N=36
239 site-yr

\[ \downarrow 7\% \text{ N}_2\text{O emissions} \]

N=9
69 site-yr

2.5 t/ac
\[ \Delta \text{SOC} = 0 \]

N=11


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Does No-Till Mitigate Stover Removal Impacts?

• 2014 cross-site study
• Irrigated, no-till continuous corn
• Precipitation and SOC gradient

\[ \Delta \text{SOC}_{\text{Removed-Retained}} \ (\text{t C ac}^{-1} \text{ yr}^{-1}) = \]

-0.24  -0.41  -0.15

ARDEC  SCAL  ENREC
Retained  Removed

Stewart et al., 2019. SSSAJ 83:733–742
How Long Does It Take for Soil Changes to Occur?

**SCAL Biomass Study: 2010-now**
Irrigated, no-till continuous corn

Schmer et al. 2020, Agron J 112: 2506-2518

### 2011-2018

**AMELIORATION * STOVER EFFECT**

- +16 bu/ac (9%) w/ stover removal

<table>
<thead>
<tr>
<th>Year</th>
<th>Retained Stover Mgt</th>
<th>Removed Stover Mgt</th>
<th>Rye Amelioration</th>
<th>Manure Amelioration</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011-2017</td>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
<td><img src="image4.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

Jin et al. 2021, unpublished data

**Soil N₂O Flux (lb N ac⁻¹ yr⁻¹)**

- 2011-2017

**Soil Properties (0-12”):**

<table>
<thead>
<tr>
<th>Property</th>
<th>Stover Removal</th>
<th>Cover Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Infiltration</td>
<td>3 yr Ø</td>
<td>6 yr Ø</td>
</tr>
<tr>
<td>Water Retention</td>
<td>3 yr Ø</td>
<td>6 yr Ø</td>
</tr>
<tr>
<td>Available Water</td>
<td>3 yr Ø</td>
<td>6 yr Ø</td>
</tr>
<tr>
<td>Wet Aggregate Stability</td>
<td>3 yr (0-1&quot;)</td>
<td>6 yr (0-6&quot;) Ø</td>
</tr>
<tr>
<td>Soil Organic C</td>
<td>3 yr (0-1&quot;)</td>
<td>6 yr (0-8&quot;) Ø</td>
</tr>
</tbody>
</table>

Blanco et al. 2014, SSSAJ 78: 1368-1377; Sindelar et al. 2019, SSSAJ 83: 221-231

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Annual vs Perennial Feedstocks on Marginal Lands

9804 Bioenergy Study: 1998-now Rainfed marginal farmland

Rates of SOC Change (0-30 cm), 1998-2014

<table>
<thead>
<tr>
<th>Fertilizer N</th>
<th>NT Continuous Corn</th>
<th>Continuous Switchgrass</th>
<th>Rotational Switchgrass</th>
</tr>
</thead>
<tbody>
<tr>
<td>lb ac⁻¹ yr⁻¹</td>
<td>tons C ac⁻¹ yr⁻¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>–</td>
<td>0.40 ± 0.27</td>
<td>0.13 ± 0.04</td>
</tr>
<tr>
<td>60</td>
<td>0.09 ± 0.13</td>
<td>0.49 ± 0.04</td>
<td>0.45 ± 0.09</td>
</tr>
<tr>
<td>120</td>
<td>0.22 ± 0.13</td>
<td>0.49 ± 0.13</td>
<td>0.58 ± 0.22</td>
</tr>
<tr>
<td>120R*</td>
<td>0.31 ± 0.18</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

*R = Residue retained

Corn stover removal rate = 1.7 ton ac⁻¹ (~60%)

\( \Delta \text{SOC} > 0 \ (P < 0.05) \)

\( \Delta \text{SOC} > 0 \ (P < 0.10) \)

1998 - 2014

Ag-phase GHGs (Mg CO₂ eq ha⁻¹ yr⁻¹)

GHG Neutral
GHG Sink or Neutral
GHG Sink or Neutral

* \( P \leq 0.05 \), § \( P \leq 0.10 \)


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Stover Harvest Guidelines

- > 180 bushels/ac for adequate organic matter return and soil cover
- Target removing ≤ 2 tons/ac, alternating yrs
- Target slopes ≤ 4% to limit erosion risk
- Minimize stalk removal to limit erosion risk
Stover Harvest Guidelines – Amelioration Practices

• Recommended practices to use with stover removal
  • No-till or other reduced tillage soil management practice, PLUS
  • Winter cover crop and/or manure to replace harvested stover, AND/OR
  • Periodic soil testing (SOM, pH, N, P, K, S) to evaluate soil status

• Efficacy of amelioration management depends on initial soil status, time
  • In the cross-site irrigated studies, all sites LOST SOC despite long-term no-till use
    → No-till alone does not fully offset the impacts of removing crop residue.
    → Adding a cover crops/animal manure further offsets, but still not completely.
  • In the marginally productive farmland study, all treatments GAINED SOC
    → Poor initial soil status responded positively to all conservation management, regardless whether feedstock system was annual row-crop or perennial grass.
Many thanks to our agency, university, & industry collaborators.

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