The energy efficiency of conventional, organic, and alternative cropping systems for food and fuel production in the US Midwest

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Background

Corn grain production (million bushels)

- USA Total Production
- Food and Ethanol
- Cattle Feed
- Exports

USDA statistics
www.ers.usda.gov
Energy efficiency

The ratio between the useful output of an energy conversion machine and the input, in energy terms.

\[
\text{Energy Efficiency} = \frac{\text{Energy OUT}}{\text{Energy IN}}
\]
Objectives

• **Optimize** production cost without losing yield and profitability (best management practice).

• **Compare** energy efficiencies of common agricultural practices.

• **Compare** energy efficiencies of different end-uses of agricultural products.
Cropping systems

**Conventional Tillage (CT)** – Conventional plowing and soil preparation, herbicide and fertilizer application

**No-Till (NT)** – No plowing or soil preparation, conventional herbicide and fertilizer application

**Low Input (LI)** – 30% of chemical input with cover crops (clover)

**Organic (Org)** – Certificated organic production with cover crops (clover)
## Management over 17 years

<table>
<thead>
<tr>
<th>System</th>
<th>Soil preparation (plowing, disking)</th>
<th>Planting</th>
<th>Agro-chemicals application</th>
<th>Cultivation</th>
<th>Harvest</th>
<th>Pest control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conv. Till</td>
<td>17 10 17</td>
<td>17</td>
<td>25</td>
<td>17</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>No-Till</td>
<td>- - -</td>
<td>17</td>
<td>41</td>
<td>-</td>
<td>17</td>
<td>25</td>
</tr>
</tbody>
</table>

*Number of field operations*

Farming cost of no – till is lower despite the cost of agro-chemicals

Conventional Tillage 7.1 GJ ha\(^{-1}\) y\(^{-1}\)

No – Till 4.9 GJ ha\(^{-1}\) y\(^{-1}\)
Approach

- All harvested **grain** is used for **Food**

- All harvested **biomass** (90% total) used for **biofuel production**

Net Energy balance \((\text{GJ ha}^{-1} \text{y}^{-1})\) = Energy out – Energy in

**Energy OUT:** Energy content of harvested grain or biofuel

**Energy IN:** Energy required for management + Energy for agrochemical production
Results (grain)

Cropping systems

GJ ha\(^{-1}\) y\(^{-1}\)

<table>
<thead>
<tr>
<th>System</th>
<th>Conventional tillage</th>
<th>No-till</th>
<th>Low input</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy efficiency</td>
<td>10</td>
<td>16</td>
<td>13</td>
<td>11</td>
</tr>
</tbody>
</table>
Results (biofuel)

![Bar chart showing energy efficiency for different cropping systems.]

- **GJ ha⁻¹ y⁻¹**
- **Farming**
- **Energy production**

**Cropping systems**
- Conventional tillage
- No-till
- Low input
- Organic

Energy Efficiency:
- Conventional tillage: 7 GJ ha⁻¹ y⁻¹
- No-till: 11 GJ ha⁻¹ y⁻¹
- Low input: 9 GJ ha⁻¹ y⁻¹
- Organic: 7 GJ ha⁻¹ y⁻¹
Products End-Use and Energy Efficiency

Conversion efficiency:

- 9 kg cattle food → 1 kg of beef
- 1 kg biomass → 0.36 L Ethanol
- 1 kg soybean → 0.17 L Biodiesel

Therefore,

use of grain for cattle feed or biofuel decreases energy efficiency of agricultural production
Biofuels vs. Food

Production of grain for food is 30 – 40% more efficient than production of whole plant, as cellulosic biomass for biofuels.

However, how much of the corn produced in the U.S. is going to food?

<table>
<thead>
<tr>
<th></th>
<th>Food</th>
<th>Fuel</th>
<th>Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg x 10^6</td>
<td>% of total</td>
<td>Mg x 10^6</td>
<td>% of total</td>
</tr>
<tr>
<td>32</td>
<td>9</td>
<td>109</td>
<td>33</td>
</tr>
</tbody>
</table>

USDA statistics for 2009
www.ers.usda.gov
Use of hybrid systems:

1. Distillers' Grain (post ethanol production), used for cattle feed

OR

2. Grain used for food and stover used for ethanol production

Increases energy efficiencies of cropping systems between 20% to 50%.
Conclusions

• No-till system is the most energy efficient system (SW Michigan conditions).

• The end-use of agricultural products is very important in estimation of energy efficiency.

• Use of corn grain (biomass) for cattle feed (biofuels feedstock) is less energy efficient than use of corn grain for human food.
## Rotational Yields (grain)

<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Wheat</th>
<th>Soybean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mg ha$^{-1}$ y$^{-1}$</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CT</strong></td>
<td>2.4 (0.2)</td>
<td>0.8 (0.0)</td>
<td>0.8 (0.0)</td>
</tr>
<tr>
<td><strong>NT</strong></td>
<td>2.6 (0.1)</td>
<td>0.9 (0.0)</td>
<td>0.9 (0.0)</td>
</tr>
<tr>
<td><strong>LI</strong></td>
<td>1.9 (0.1)</td>
<td>1.1 (0.0)</td>
<td>0.8 (0.0)</td>
</tr>
<tr>
<td><strong>Org</strong></td>
<td>1.4 (0.8)</td>
<td>0.7 (0.0)</td>
<td>0.7 (0.0)</td>
</tr>
</tbody>
</table>
## Rotational Yields (biofuels)

<table>
<thead>
<tr>
<th></th>
<th>Biomass yield for cellulosic ethanol production at 90% harvest efficiency</th>
<th>Biomass yield for biodiesel production</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mg ha$^{-1}$y$^{-1}$</td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>6.2 (0.1)</td>
<td>0.8 (0.0)</td>
</tr>
<tr>
<td>NT</td>
<td>6.5 (0.1)</td>
<td>0.9 (0.0)</td>
</tr>
<tr>
<td>LI</td>
<td>6.1 (0.0)</td>
<td>0.8 (0.0)</td>
</tr>
<tr>
<td>Org</td>
<td>4.5 (0.1)</td>
<td>0.7 (0.0)</td>
</tr>
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</table>
management over 17 years of study

<table>
<thead>
<tr>
<th>System</th>
<th>Soil preparation (plowing, disking, etc.)</th>
<th>Planting</th>
<th>Fertilization*</th>
<th>Cultivation</th>
<th>Harvest</th>
<th>Pest control</th>
<th>Mowing</th>
<th>Balining</th>
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<tbody>
<tr>
<td>CT</td>
<td>17 10 17</td>
<td>17</td>
<td>25</td>
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<td>17</td>
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<td>NT</td>
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<td>3</td>
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* Fertilization including all agro-chemicals

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- No – Till 4.9 GJ ha\(^{-1}\) y\(^{-1}\)