Impacts of Land Conversion for Biofuel Cropping on Soil Organic Matter and Greenhouse Gas Emissions

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Questions Addressed

• How do current and previous land use interact to control soil properties and emissions?

• How can soil quality be maintained/enhanced?

• Life Cycle Analysis?
Biofuel Cropping Systems

GHG Sources:
- $\text{N}_2\text{O}$ (direct and indirect)
- Chemical Inputs
- Farm Machinery
- Soil C
- Feedstock Conversion

GHG Sinks:
- Displaced Fossil Fuel
- Soil C
- $\text{CH}_4$ Oxidation
The Energy Independence and Security Act of 2007

• 7 billion gallons ethanol out of in 180 billions consumed in 2007

• 36 billion gallons of biofuel by 2022

• Ethanol - 20% reduction in GHG compared to gasoline

• Biodiesel - 50% reduction

• Cellulosic - 60% reduction
## Global Warming Potential

<table>
<thead>
<tr>
<th>Gas</th>
<th>Atmospheric lifetime (yrs)</th>
<th>GWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>50-200</td>
<td>1</td>
</tr>
<tr>
<td>CH₄</td>
<td>12</td>
<td>21</td>
</tr>
<tr>
<td>N₂O</td>
<td>120</td>
<td>300</td>
</tr>
</tbody>
</table>
DAYCENT Ecosystem model

Primary tool for:

- Soil GHG emissions
- NO$_3$ leaching
- Crop yields
Model Testing

Ames, Iowa - Switchgrass Yields

- Observed
- DAYCENT

Biomass (Mg/ha) vs. N fertilizer (kg/ha)
Model Testing

Mean N$_2$O Emissions

gN ha$^{-1}$ d$^{-1}$

- CO short grass
- NE short grass
- MI forest
- CO dryland wheat
- NE dryland wheat
- MI corn/soy/alfalfa
- TN corn
- CO irrigated corn
- CO irrigated corn/barley
- Ontario corn

- measured
- DAYCENT
Simulated vs. Observed N$_2$O Emissions

$y = 0.9883x + 0.1488$

$R^2 = 0.8639$
Observed and DAYCENT $N_2O$ for Biofuel Cropping Systems in Pennsylvania

2005

2006

$N_2O$ gN ha$^{-1}$ d$^{-1}$

measured

simulated
CRP Conversion

- CRP soils in US currently ~ 22 Tg CO$_2$ eq. sink
- What are the impacts of converting CRP land to biofuel production?
- Selected states where most of corn for ethanol is grown in USA: Illinois, Iowa, Indiana
- Results for 10 year annual means after conversion
Iowa mean soil GHG

- CRP
- CRP to corn CT
- CRP to switchgrass

delta SOC  N2O  GHGnet

g CO₂-C eq. m⁻² yr⁻¹
Indiana mean soil GHG

g CO$_2$-C eq. m$^{-2}$ yr$^{-1}$

- CRP
- CRP to corn CT
- CRP to switchgrass

delta SOC  N2O  GHGnet

-20  0  20  40  60  80

-20
Illinois mean soil GHG

-20  0  20  40  60  80

delta SOC N2O GHGnet

g CO2-C eq. m^2 yr^{-1}

CRP
CRP to corn CT
CRP to switchgrass

delta SOC  N2O  GHGnet
mean soil GHG

g C m\(^{-2}\) yr\(^{-1}\)

- CRP
- CRP to corn CT
- CRP to switchgrass

Locations:
- iowa
- indiana
- illinois
Broaden Scope: Life Cycle Analysis

Land Use Changes:
• Existing cropland converted to ethanol
• CRP converted to ethanol
• Pasture converted to ethanol

Land Management Scenarios:
• Conventional till vs. no till
• Conventional vs. improved nitrogen fertilizers

LCA:
• Soil GHG fluxes
  • Feedstock conversion
  • Other GHG sinks/sources
Tools and Data Sources for GHG Life Cycle Analysis

• Soil GHG fluxes and crop yields - DAYCENT biogeochemical model

• GHG from farm machinery operation – IFSM

• Feedstock conversion into ethanol - West and Marland 2002


• Energy savings for co-products - Farrell et al. 2006
Components of LCA GHGnet

10 year mean after conversion to corn for ethanol - Iowa

- Soil GHGnet
- Displaced
- Feedstock
- Inputs
- Machinery

pasture
crop
crp

$g CO_2 - C eq. m^2 yr^{-1}$
The bar chart shows the carbon dioxide equivalent (g CO$_2$-C eq.) per year (yr$^{-1}$) for Illinois, Indiana, and Iowa. The bars are color-coded to represent different land uses: green for crops, red for crp (Conservation Reserve Program), and blue for pasture. The y-axis represents g CO$_2$-C eq. m$^{-2}$ yr$^{-1}$.
How can we improve?

Wind to H₂ to NH₃
UMM - WCROC

Local renewable NH₃
NRCS Photo gallery

Harvest grain and cobs
USDA Photo center

Cobs for gasification
www.CVEC.com

Manure back to soil
NRCS Photo gallery

Improved fertilizers:
Slow release
Nitrification inhibitors

Grain for ethanol
www.CVEC.com

Dry distillers grain, feed
NRCS Photo gallery
Reduction in GHGnet compared to fossil fuel GHG

10 year mean after conversion to corn for ethanol - Iowa

- Pasture
  - Conventional mgmt
  - Improved mgmt short term
  - Improved mgmt long term

- Crop
  - Conventional mgmt
  - Improved mgmt short term
  - Improved mgmt long term

- CRP
  - Conventional mgmt
  - Improved mgmt short term
  - Improved mgmt long term
Conclusions

• CRP land converted to corn ethanol is a GHG source under conventional management

• CRP land converted to switchgrass is a small soil GHG source

• Improved management can reduce N₂O emissions and maintain soil C

• Need to consider full LCA, not just impacts on soil

• Gasified corn cobs can be used to power the conversion of grain to ethanol

• Also need to account for leakage, as well as impacts on habitat, etc.