Biofuel and Greenhouse Gases: Yield Increases, Modeling Land Use Effects, and GHG Policy Implications

Project Update

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Overview of Presentation

- Summarize the implications of yield and fertilizer increases from the April presentation in terms of land use

- Discuss how state yield and fertilizer increases influence where corn land is released for other crop production (e.g., biomass)

- Develop land allocation model that highlights how land quality and environment influence the shares of crops (e.g., corn, biomass) and where they are produced
  - Consider different yield increase scenarios
  - Consider different nutrient scenarios

- Discuss implication for corn and biomass production and from preliminary data assessment
Fit two models for corn yield:

1. Autoregressive (AR) – future yield is a function of previous yield
2. Linear Trend (LT) – constant expected yield change over time

Identified structural breaks in yield data

Estimated the impacts of alternative corn yield scenarios on total cropland and nitrogen use
Yield Highlights

- AR model yield projections are higher than LT model but lower than 2030 yield targets for U.S.
- State level yield increase rates in important corn states may meet 2030 yield targets in AR model
Nitrogen Use Highlights

- Nitrogen model
  - N rates based on historical data using trend model
  - N use per acre has been increasing slowly in many states, if at all
  - State variation in levels and rates of increase differ
## Yield Model Details by State

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<thead>
<tr>
<th></th>
<th>IA</th>
<th>IL</th>
<th>NE</th>
<th>MN</th>
<th>IN</th>
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<th>KS</th>
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<th>MO</th>
<th>MI</th>
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<td>1.64%</td>
<td>1.63%</td>
<td>1.84%</td>
<td>1.89%</td>
<td>1.55%</td>
<td>2.89%</td>
<td>1.33%</td>
<td>1.67%</td>
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<td>1.70%</td>
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<td>2.18%</td>
<td>2.65%</td>
<td>1.77%</td>
<td>1.90%</td>
<td>2.09%</td>
<td>1.02%</td>
<td>2.36%</td>
<td>1.17%</td>
<td>2.37%</td>
<td>2.13%</td>
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<td>0.00</td>
<td>1.83</td>
<td>0.37</td>
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<td>1.04</td>
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<td><strong>2030 Nitrogen Use</strong></td>
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<td>193</td>
<td>140</td>
<td>140</td>
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<td>112</td>
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<td><strong>Initial cropland</strong></td>
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<td>11.80</td>
<td>8.85</td>
<td>7.15</td>
<td>5.46</td>
<td>4.68</td>
<td>3.86</td>
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<td>2.93</td>
<td>2.92</td>
<td>2.09</td>
<td>1.96</td>
<td>1.74</td>
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</table>
Equilibrium Corn Production
(million bushels)

Year

2005  2010  2015  2020  2025  2030  2035

Million bushels

11,000  11,500  12,000  12,500  13,000  13,500  14,000  14,500  15,000  15,500

Nitrogen Required to Grow Corn
(Thousand tons)

Year

2005 2010 2015 2020 2025 2030 2035

Thousand Tons

4,200 4,300 4,400 4,500 4,600 4,700 4,800 4,900 5,000 5,100

Land and Nitrogen Use Modeling

- State nitrogen–land use interactions
  - State corn yield growth rates coupled with N increase rates create land use tradeoffs between states
  - Not necessarily lower productivity corn land released
  - Rather, depends on profitability or on how fast yields are increasing relative to fertilizer use

- State level land use
  - Create “staircase” supply curve based on constant marginal cost for each state under different yield scenarios
  - Total land used for corn is based on the intersection of supply and demand (market equilibrium)
Land Use Determination in 2030
(1999-2009 - AR Model)

Marginal Cost (scaled)

Million Bushels

Supply
Demand

NE IA MN WI SD MI IN MO IL OH KS ND TX
Land Use Determination in 2030
(1970-2009 - LT Model)
Summary of Current Results

- Demonstrate importance of yield growth:
  - Relative to nitrogen growth and land use
  - Relative to GHG emissions from fertilizer and land use

- Limitations of current model:
  - Consideration of biomass crops, yields, and yield growth
  - Consideration of land quality, location, and environmental characteristics in land use allocation
  - Potential GHG emission reductions from yield growth from multiple crops
Phase II Progress

- Extending Phase I results and BIC cellulosic feedstock research to evaluate land use tradeoffs

- Estimate model of land allocation behavior at the county-level as a function of
  - Weather
  - Soil Characteristics
  - Yields
  - Prices
  - Agricultural policies or incentives

- Once estimated, we will be able to use model to evaluate:
  - Policy impacts
  - Alternative yield projection impacts
Each individual (county) allocates land between alternative uses

- Corn, soybeans, wheat, hay, pasture/range, woodland, and idle cropland or CRP

Exogenous factors driving decision

- Output prices
- Input prices
- Total allocable land
- Soil quality
- Climate
- Agricultural/environmental policies
Land Allocation Model

- Underlying theory
  - County will allocate land between uses to maximize profits given fixed factors, input substitutability, and constraints

- Land use data: U.S. Agricultural Census
  - Advantages:
    - Woodland, pasture/range, idle cropland, and CRP acreage
    - Not constrained to only cropland
    - County-level data
  - Disadvantage:
Land Allocation Model

- Other data:
  - Soil characteristics – County-level data from NRI
  - Climate data – Monthly precipitation and temperature
  - Prices – State-level data from NASS
  - Yields – Ag Census dataset
    - Annual data available from NASS
# Land Use Shares – Descriptive Statistics

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<tbody>
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<td>Corn (total)</td>
<td>11%</td>
<td>11%</td>
<td>10%</td>
<td>11%</td>
<td>11%</td>
<td>15%</td>
<td>4.20%</td>
</tr>
<tr>
<td>Soybean</td>
<td>10%</td>
<td>11%</td>
<td>9%</td>
<td>9%</td>
<td>10%</td>
<td>16%</td>
<td>5.50%</td>
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<tr>
<td>Wheat</td>
<td>5%</td>
<td>8%</td>
<td>6%</td>
<td>6%</td>
<td>6%</td>
<td>5%</td>
<td>-0.64%</td>
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<td>Hay</td>
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<td>Pasture</td>
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<td>39%</td>
<td>37%</td>
<td>28%</td>
<td>-8.00%</td>
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<tr>
<td>Idle</td>
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<td>3%</td>
<td>7%</td>
<td>4%</td>
<td>3%</td>
<td>5%</td>
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<tr>
<td>Woodland</td>
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<td>21%</td>
<td>21%</td>
<td>20%</td>
<td>21%</td>
<td>19%</td>
<td>-3.85%</td>
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<tr>
<td>Corn (grain)</td>
<td>10%</td>
<td>10%</td>
<td>9%</td>
<td>10%</td>
<td>10%</td>
<td>14%</td>
<td>3.38%</td>
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<tr>
<td>Pasture/range (non-cropland)</td>
<td>23%</td>
<td>24%</td>
<td>23%</td>
<td>25%</td>
<td>25%</td>
<td>18%</td>
<td>-5.18%</td>
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Phase II Progress

- Early data analysis provides intuitive results

- Ex: corn land share
  - Positively related to: own yield and soil quality
  - Negatively related to: other crop yields, CRP acreage

- Small, but significant, land use changes during the period of our analysis
Conclusions

- Phase I provided yield and nitrogen projections that can be used to project land use changes and GHG implications

- Phase II
  - Domestic land competition implications
  - County-level land allocation model that incorporates land quality, environmental characteristics, and policy impacts
Thank you!

Questions or comments?
Land Use Determination in 2030
(1970-2009 - AR Model)
Two methods of analyzing land use change

1. Production function approach
   - Phase I uses a modified production function approach requiring yield, nitrogen, and elasticities for corn and biomass
   - Analysis limited to defined cropland base

2. Land allocation approach
   - Assume land is allocated to the use that maximizes expected profits given technology, climate, and soil characteristics
   - Less data intensive and do not need to specify production and cost functions
Land Released by State (2030)

Million Acres

1970-2009 AR
1999-2009 AR
1970-2009 LT
1999-2009 LT

Illinois
Kansas
Ohio
Missouri
Texas
North Dakota
Land Released by State
1999-2009 - AR Model

Million Acres

Illinois  Kansas  Ohio  Missouri  Texas  North Dakota

2010  2015  2020  2025  2030
Land Released by State
1970-2009 - LT Model

Million Acres

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<tr>
<th>State</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
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<td></td>
<td>0.5</td>
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<td>Kansas</td>
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<td>0.5</td>
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<tr>
<td>Ohio</td>
<td>3.5</td>
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<td></td>
<td>3.5</td>
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<tr>
<td>Missouri</td>
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<td>Texas</td>
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<td>2.0</td>
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<td>North Dakota</td>
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Land Released by State
1999-2009 - LT Model

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<tr>
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<th>2010</th>
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<th>2020</th>
<th>2025</th>
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## Yield Estimates – Averaged over counties

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<td>88.45</td>
<td>101.18</td>
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Note: average over all counties; NOT weighted by size or production level