Land Scarcity and Life Cycle Emissions in Biofuel Production and Use

Project Update
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Research Summary

Focus: Explore implications of multiple feedstock biofuel production from a given acre of land (e.g., corn grain + corn stover)

- “A life cycle assessment of advanced biofuel production from a hectare of corn” (Kauffman, Hayes, and Brown)
  - Published in *Fuel* (2011)

- “The Feasibility of Carbon-Negative Biofuels from Biochar-Amended Corn Fields” (Kauffman, Hayes, Brown, Laird, and Dumortier)
  - Under review at *Nature Climate Change* (1st submission)
  - Presubmission enquiry invited a full review

- “The Tradeoff Between Bioenergy and Emissions with Land Constraints” (Kauffman and Hayes)
  - Under review at *Energy Policy* (2nd submission)
“A life cycle assessment of advanced biofuel production from a hectare of corn”

Outline

- Corn grain $\rightarrow$ ethanol (EPA)
- Corn stover $\rightarrow$ bio-oil, biochar via fast pyrolysis
  - Bio-oil upgraded to drop-in fuel
    - Displaces gasoline/diesel
  - Biochar applied to soil
    - Carbon sequestered
    - Fertilizer reduction
    - Possible yield improvements
Conclusions

- GHG Emissions are measured per acre
- Corn grain (ethanol) plus corn stover (bio-oil/biochar)
- Generates a 52% reduction in emissions relative to gasoline
- Sufficient to qualify as an advanced biofuel if “corn” restriction removed from EISA
"The Feasibility of Carbon-Negative Biofuels from Biochar-Amended Corn Fields"

Pathway Summary

YEAR ONE
Corn (1 ha)
Net Emissions:
–2.05 tCO₂e/ha
Feedstock Removal (Sequestration Loss)
0.13 tCO₂e/ha
Nutrient Replacement
0.08 tCO₂e/ha
Corn Stover Collection
0.08 tCO₂e/ha
Transportation
0.01 tCO₂e/ha
Pyrolysis Operations
No net emissions
Biochar + NCGs supply energy requirements
Biochar Application
0.06 tCO₂e/ha
Fertilizer Displacement
-0.05 tCO₂e/ha
Carbon Sequestration
-0.59 tCO₂e/ha

HIGHER YIELD
YEAR TWO
Corn (1 ha)
Net Emissions:
–2.05 tCO₂e/ha
ILUC emissions credit from increased yield
Bio-gasoline Distribution
0.01 tCO₂e/ha
Bio-oil Upgrading
0.29 tCO₂e/ha
Transportation
0.27 tCO₂e/ha
Gasoline Displacement
-2.41 tCO₂e/ha
Bio-gasoline
Refinery
Bio-char
“The Feasibility of Carbon-Negative Biofuels from Biochar-Amended Corn Fields”

Results

![Graph showing net emissions (g/MJ) over time horizon from 2010 to 2040. The graph compares net emissions with and without yield effect, and with carbon neutral scenarios.](image-url)


**Sensitivity Analysis**

- **Stover Removal Rate (40%, 70%)**
- **Biochar Yield (17%)**
- **Biochar-Induced Yield Growth (6%)**
- **Biochar Used for Combustion (33%)**
- **Bio-Oil to Bio-Gasoline Conversion (42%)**
- **Bio-Oil Yield (61.7%)**
- **Bio-Oil Required for Hydrogen Production (38%)**
- **Bio-Oil Hauling Distance (400km)**

**Net emissions gCO₂e/MJ**

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Hayes & Kauffman (ISU)  Scarcity and Life Cycle Emissions  April 20, 2012  8 / 15
Motivation

- Land scarcity implies a trade-off between bioenergy production and emissions reduction.
- Conventional life cycle assessments (EPA) do not capture this trade-off.

Summary of Analysis

- Comparison of switchgrass and corn (1 acre)
- Minimize emissions and maximize biofuel production on 1 acre
- Land constraint
2006 - 2010 Average Non-Irrigated Corn Yields
Estimated Switchgrass Yields (Khanna et al., 2011: 75%)
Policy Scenario 1: No External Value to Biofuel Production
“The Tradeoff Between Bioenergy and Emissions with Land Constraints”

\[ S = 0.45, \ P = 5 \]

Policy Scenario 2: External Value = $0.45, Carbon = $5/Mt
Policy Scenario 3: External Value = $0.45, Carbon = $30/Mt
Thank you!
Questions or Comments?
Optimal Regional Cropland Allocation and Crop Rotation Strategies for U.S. Biomass Supply

Project Proposal
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Economics Department

April 20, 2012
Policy Scenario 3: External Value = $0.45, Carbon = $30/Mt
Determined optimal cropland allocation of corn vs. switchgrass.
- Static (1 year) framework
- From perspective of society
- Emissions per acre

Also considered possible yield effects of biochar in a thermochemical pathway.
Motivation for Proposed Work

- Realities not yet considered
  - Switchgrass is a perennial (time to establish).
  - Farmers decisions may not coincide with society’s goals.

- Proposal summary
  - Farmer’s perspective
    - Profit-maximizing
    - Forward-looking
  - Solve for policy (or policies) that would cause farmer = society.
  - Model as a real option switching problem
    - Competitive markets
    - General equilibrium (Commodity prices endogenous)
  - Rotations to consider
    - Corn/Soybeans vs. Switchgrass
    - Continuous Corn (with pyrolysis and possibly cover crop) vs. CS or CCS.
Change in Corn Acreage by 2050

Probability of regime switching by 2050

- 0.01% - 10%
- 11% - 20%
- 21% - 30%
- 31% - 40%
- 41% - 50%
- 51% - 60%
- 61% - 70%
- 71% - 80%
- 81% - 90%
- 91% - 100%

Hayes & Kauffman (ISU)  Cropland Allocation and Rotations  April 20, 2012  6 / 8
Work Plan

1. Collect data on regional production and input costs
   - Crop choice: corn, soybeans, switchgrass, (Miscanthus?)
   - Rotation strategies

2. Develop, calibrate, and refine model

3. Conduct analysis, write up results, submit for publication
Thank you!
Questions or Comments?