FONDAZIONE ENI ENRICO MATTEI

Can Dispersed Biomass Processing Protect the Environment and Cover the Bottom Line For Biofuel?

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1. Background

- In 2007 the U.S. Congress has passed the EISA bill to mandate production of 16 billion gallons of cellulosic biofuels by 2022

- Two bio-refinery configurations have been proposed in the literature for cellulosic biofuels production:
  - A centralized bio-refinery
  - A local biomass processing depot (LBPD)

- The profitability and the environmental impact of these two spatial bio-refinery configurations are not well understood

Background (cont')

- Tillman (2006) and Robertson (2008) show that low-inputs and high-diversity crops would be environmentally sustainable for cellulosic biofuels

- Low-inputs and highly diverse perennial crops would generate fewer nutrient runoffs, less GHGs, and are good for biodiversity

- A Centralized bio-refinery production could be a threat to diversity because only the cheapest and the most profitables crops will be attracted

Background(cont')

- E.g. Crop residus at low prices and monocropped perennial grasses like Switchgrass for high biomass prices (Egbendewe-Mondzozo et al. 2011)

- Environmental policy could provide incentives for diversified cropping systems (egbendewe-Mondzozo et al. 2012), but LBPDs also could achieve similar results

- Eranki et al. (2011) have provided some introductry works on the potential environmental benefits of the LBPDs.

1.1 Research Objectives

Principal objective: Analyse profitability and environ. impacts of a Centralized vs. an LBPD bio-refinery configurations.

Specifically,

- Evaluate biorefinery profitability based on farm level production, transport and bio-refinery processing costs
- Simulate long-term environmental impacts (soil erosion, GHG emissions, P and N runoffs, and N leaching) on local lanscape
- Evaluate potential bio-refinery conversion technology improvement on profitability and environmental impacts

1.2 Research Questions

- What are the key parameters driving profitability in each of the two spatial bio-refinery configurations?

- What are the land use change and environ. Impacts associated to each bio-refinery configuration?

- How are profitability and environ. Impacts altered by technological change in biomass conversion?

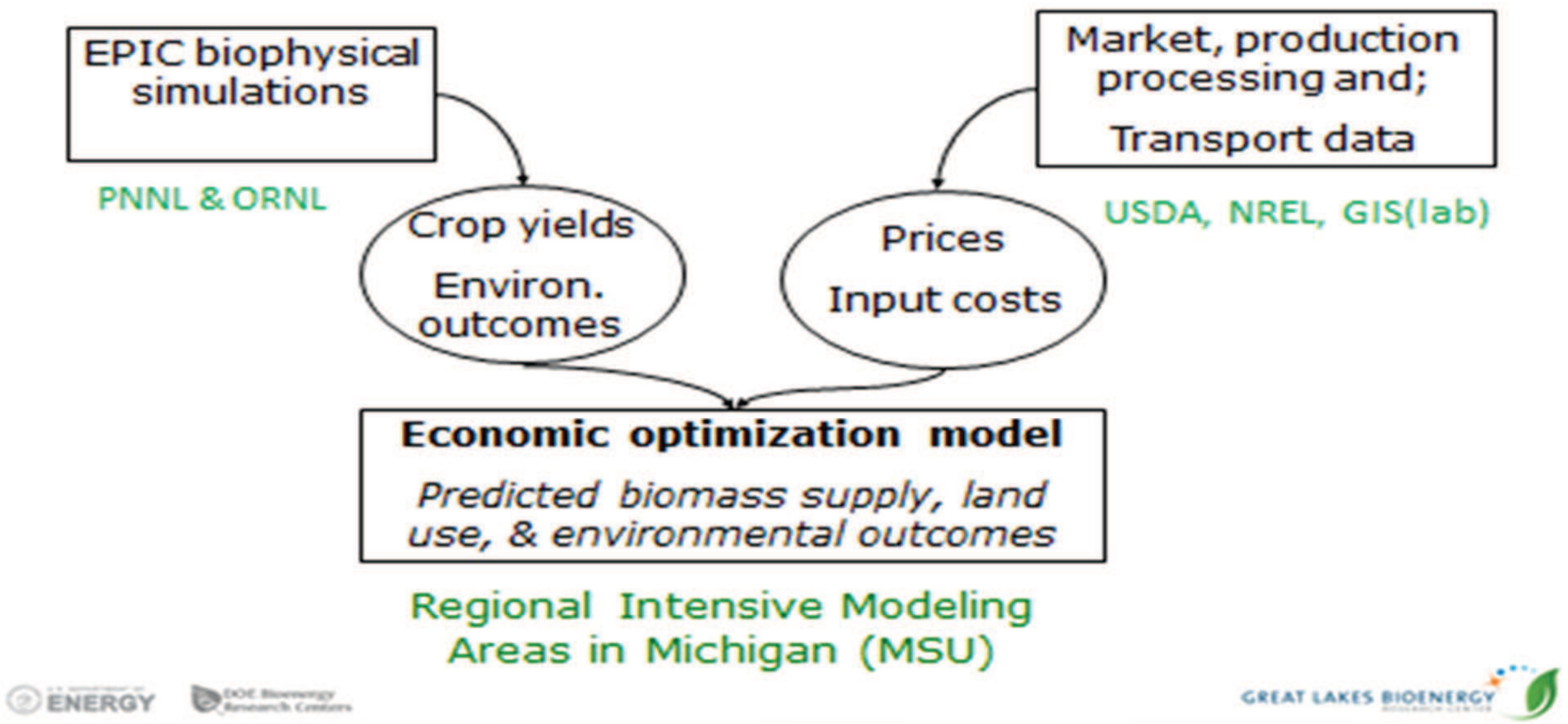
2. Materials and Methods

- We use a bioeconomic model that maximizes profits for farms and the ethanol processing facilities (Math. Programming)
- The bio-refinery capacity constraint must bind at the optimum
- The model selects among 82 cropping systems
- EPIC is used to simulated yields and environmental outcomes for each cropping system
- The region is at the southwest of Michigan with 9 counties

2.1

Bioeconomic Model Structure

Spatial bioeconomic model of crop production: Biomass supply & environmental trade-offs



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2.2 Modeling Region

2.3 Cropping Systems

Simulation of crop yield and environmental outcomes

- 82 cropping systems:
- Crops
  - 6 annuals: Corn, corn silage, soy, wheat, canola, & alfalfa
  - 7 perennial: Switchgrass, miscanthus, poplar, 4 grass & prairie mixes
- Tillage: no-till or chisel
- Fertilization: high or medium
- Residue removal: No or 50%

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3. Data and Assumptions

- There are 70 sub-watersheds in the region and 82 cropping systems are simulated on each (1986-2009) and averaged
- The model feeds in 70x82=5740 rows and 18 columns (13 crops & biomass and 5 environmental outputs) data
- Production costs are based on machine work rates, transport costs are based on GIS and Michigan road map
- Market prices for crops are exogenous from USDA-NASS and biomass conversion rates from NREL and MBI international

3.1 Biomass Conversion Assumptions

- The 8 LBPDs process from 100 to 250 tons/day of biomass. Biomass is pretreated with Ammonia technology (AFEX™)
- After the pretreatment the biomass is briquetted and shipped for to the bio-refinery processing into ethanol
- The bio-refinery will produce ethanol and electricity as outputs to be sold at the market place
- The capital investment in the LBPDs and in the bio-refinery are to be amortized in 20 years

3.2 Biomass Conversion Rates

Table 2: List of properties for the types of biomass considered in the study

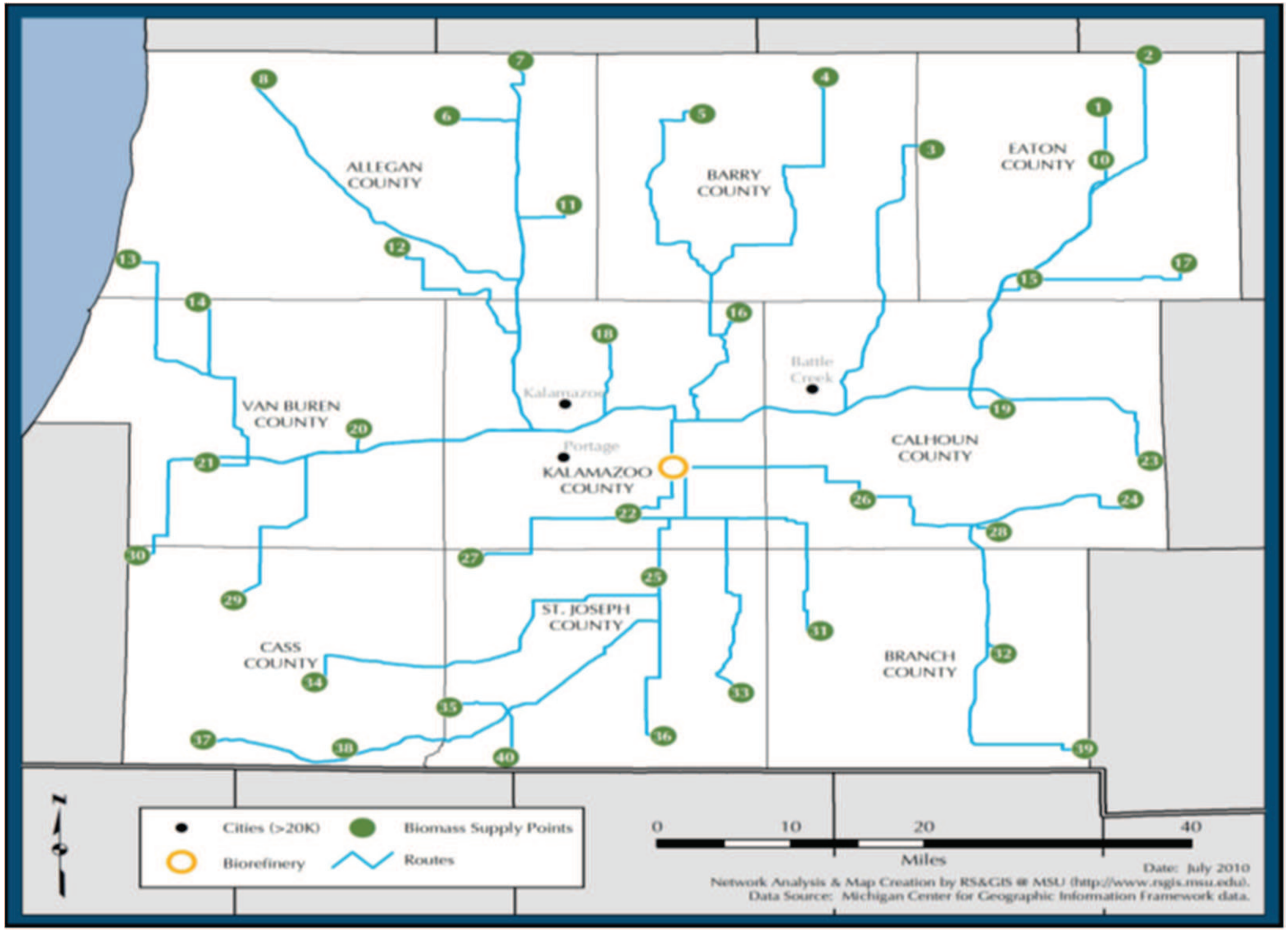
Biomass	Glucan content (g/kg)	Xylan content (g/kg)	Pretreatment severity	Ethanol yields (L/Mg)	Electricity produced [a] (kWh/Mg)	Variable costs [b] ($/Mg)
Corn stover	350	220	Low	275.80	368.98	55.33
Switchgrass	335	240	High	277.10	367.67	55.32
Miscanthus	440	190	High	267.20	455.28	55.75
Native prairies	290	170	Low	208.30	428.74	55.63
Wheat straw	380	230	Low	295.50	360.42	55.28
Grass mixes	320	200	Low	274.10	323.63	55.11
Poplar	440	150	High	189.50	608.18	56.39

3.3 Biomass Conversion Costs

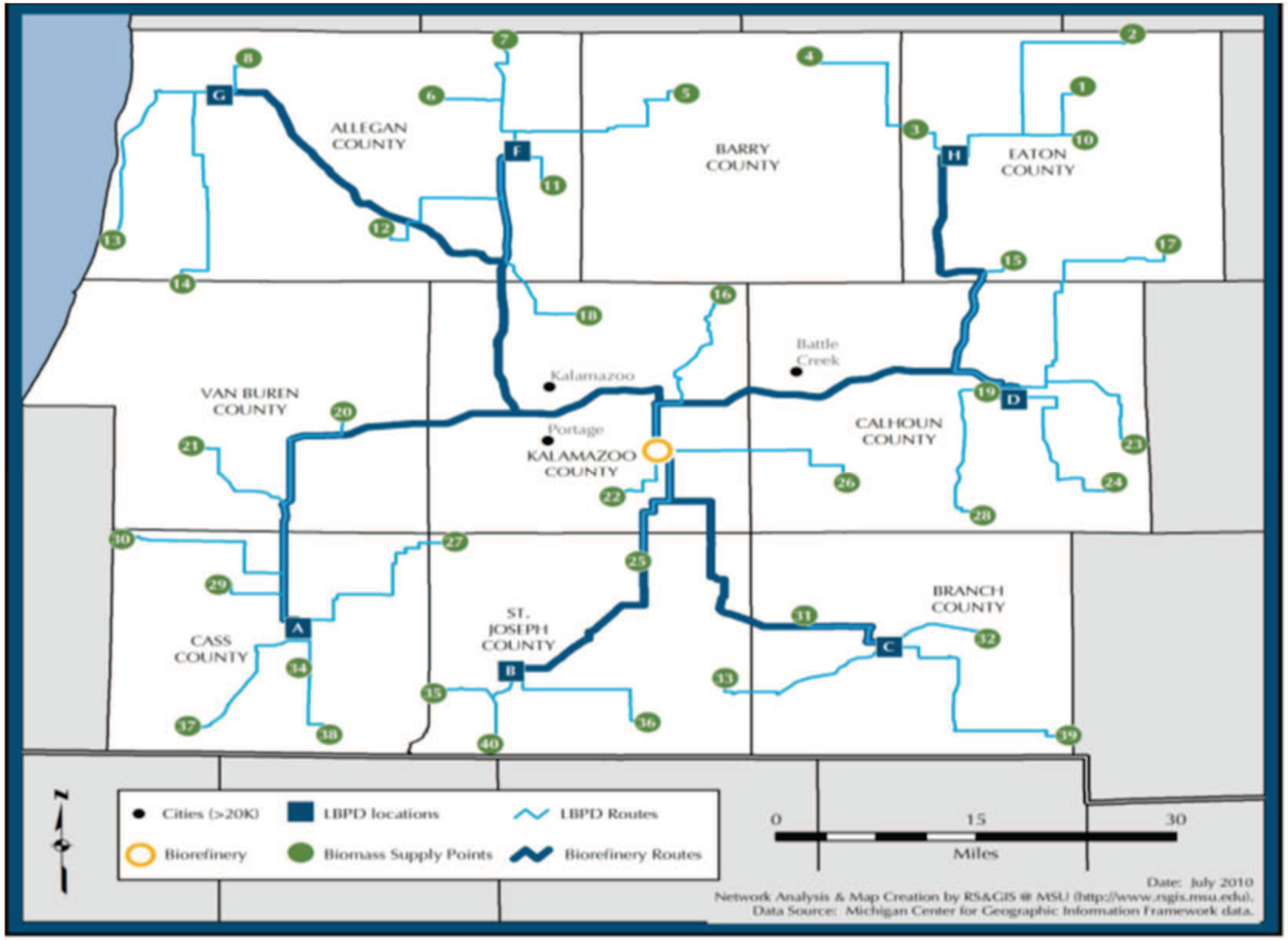
Table 3: Variable and capital costs associated with the facilities modeled

Types[a]	Size (Mg/day)	Low severity variable costs ($/Mg)	High severity variable costs ($/Mg)	Capital costs (Million $/year)
LBPD	100	42.73	49.60	0.79
LBPD	250	30.09	36.96	1.77
Pretreatment	550	30.40	37.94	1.50
Pretreatment	2000	31.70	39.24	5.25
Biorefinery[b]	2000			10.09

Centralized Configuration



Decentralized Configuration (LBPD)



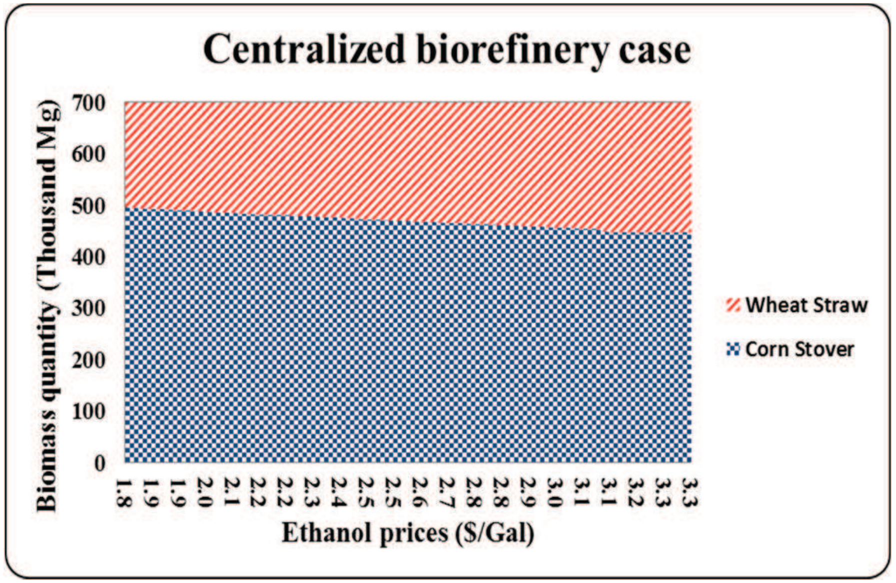
4. Model Simulation Results

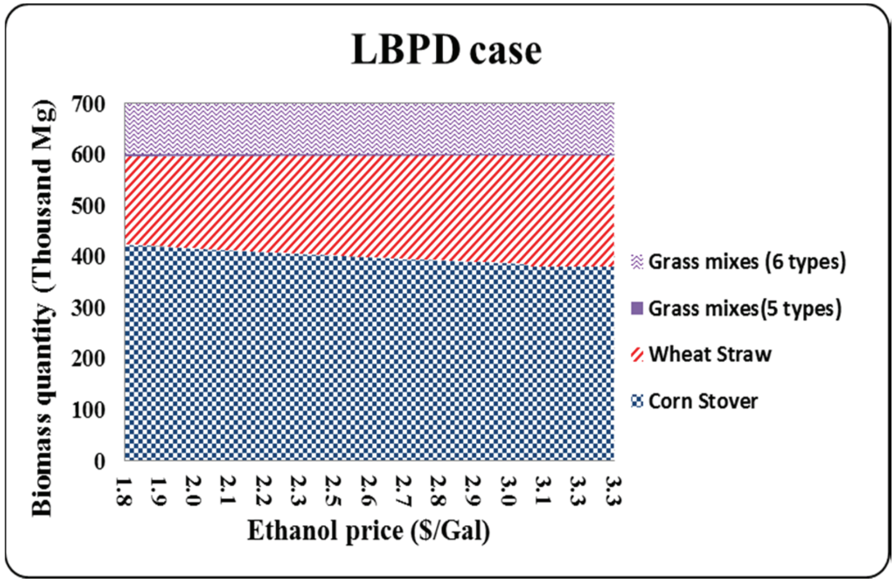
- The model is calibrated to 2007-09 average crop prices and land use. No cellulosic ethanol is produced in the baseline

- Then holding all other parameters constant, ethanol price was raised from $1.78/gal to $3.36/gal($2.66 to $5.05/gal gaz-gal-eq)

- A total of four scenarios were experimented:
  - a. Centralized refinery with current processing technology
  - b. LBPD with current processing technology
  - c. Centralized refinery with ethanol yield improvement
  - d. LBPD with ethanol yield improvement

4.1 Initial Results (biomass demand)





Only Crop residues are used in the centralized case but some perennial grasses appear in the LBPD case

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Initial Results (profitability and Land use)

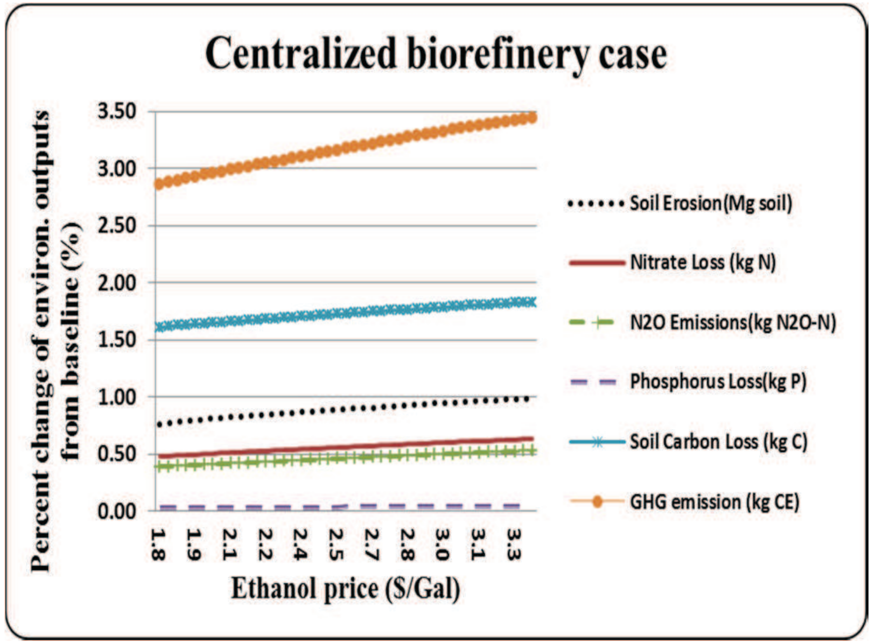
- Biomass and ethanol activities are profitable for LBPDs when ethanol price is at $2.30/gal and biomass price at $74/Mg

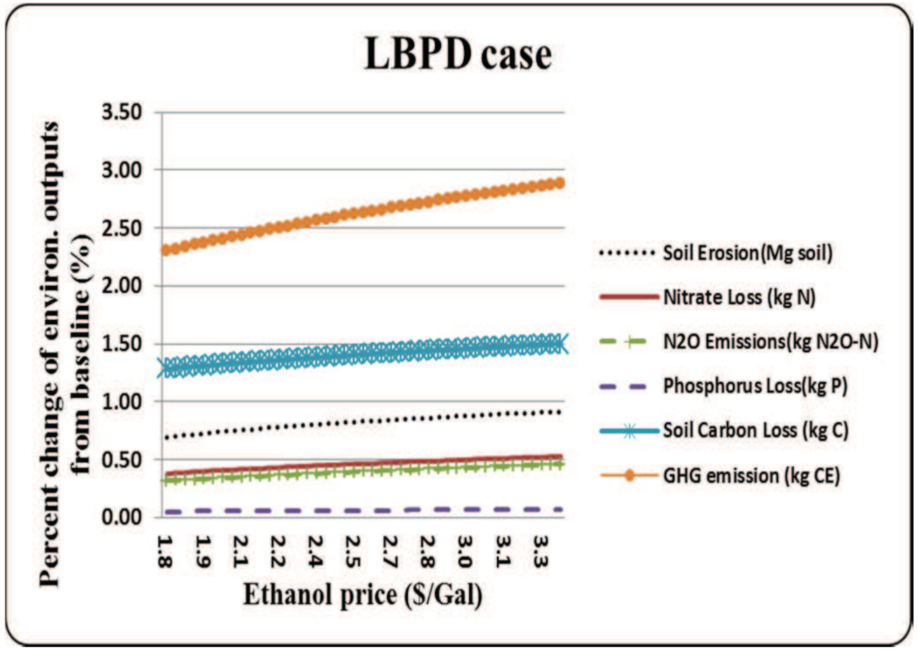
- The joint enterprise is profitable for Centralized bio-refinery when ethanol price is at $2.00 and biomass price at $44/Mg

- 2% of cropland is diverted to perennial crops production in the LBPD case

- Clearly there is a trade-off between profitability for biofuels and environmental quality

Initial Results (Environmental Outcomes)





Environmental Outcomes are higher with the centralized case than the LBPD case

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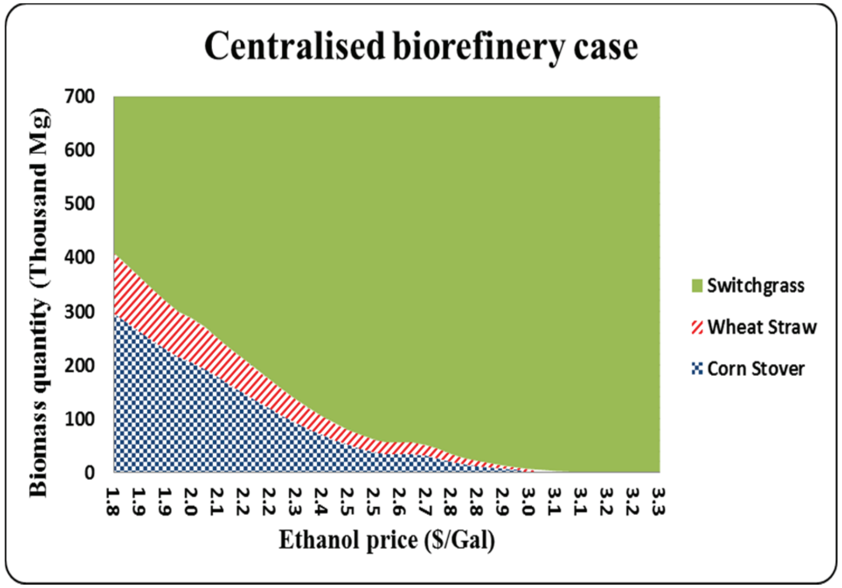
4.2 Biomass Conversion Improvement

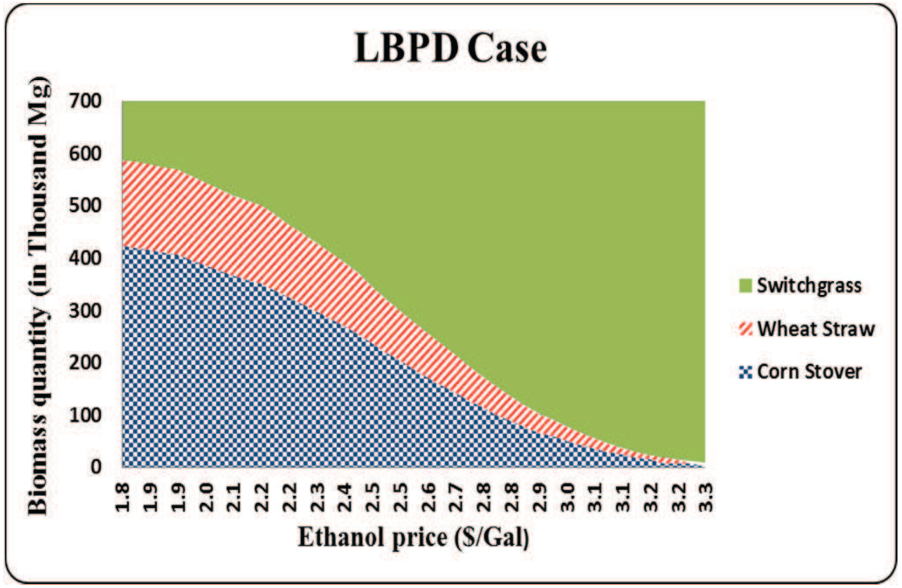
- We have looked at two technological change scenarios that reduce the conversion cost of ethanol from switchgrass

- A medium scenario: increase the ethanol yield parameter for switchgrass from 277.1 to 298.6 liters/Mg (an 8% increase)

- A more optimistic scenario: a high increase in the switchgrass ethanol yield from 277.1 to 323.1/Mg liters (a 17% increase)

Ethanol yield change scenario (Biomass demand)





17% ethanol yield increase from switchgrass triggers more demand for switchgrass

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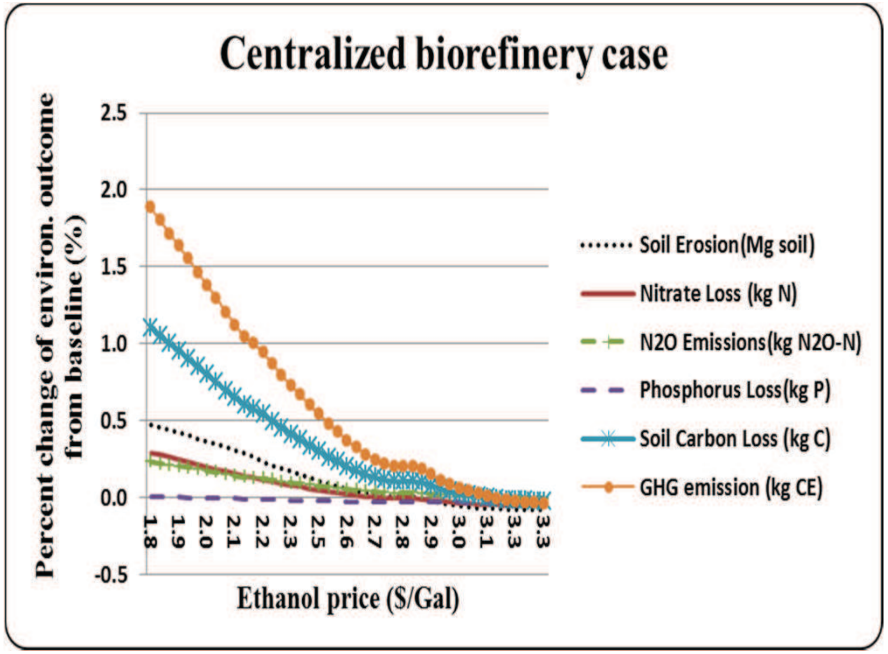
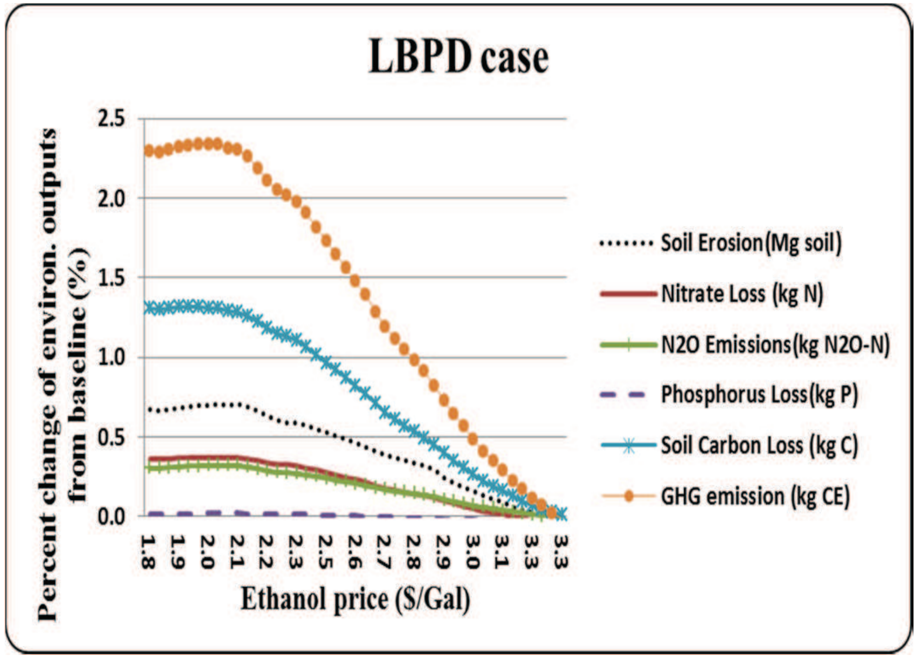
Ethanol yield change (profitability and Land use)

- Biomass and ethanol activities are profitable for LBPDs when ethanol price is at $2.20/gal and biomass price at $74/Mg
- The joint enterprise is profitable for Centralized bio-refinery when ethanol price is at $2.00 and biomass price at $60/Mg
- 10% of cropland is diverted to perennial crops production in the LBPD case because of increase production of switchgrass
- Clearly the increase in land diverted to perennial improved environmental outcomes but may put pressure on food prices

Ethanol yield change scenario (Environ. Outcomes)





17% ethanol yield increase from switchgrass triggers more reduction in environmental outcomes

5.

Conclusion and Discussion

- The study shows that spatially dispersed biomass processing can generate better environmental outcomes
- However, with current technologies, costs of production are still high to make it happen
- Improvement in conversion technologies is need to achieve greater profitability and better environmental outcomes
- To mitigate impact on food price with biofuels, improvement in both crop yields and conversion technologies are needed

- Further research in life cycle analysis will provide a complete assessment of the environmental benefits of biofuels at local landscape

- Integration of animal feed byproducts in the bio-refinery outputs may also improve profitability for biofuels

- Strategic placement of perennial grasses on marginal land instead of cropland could also improve environmental outcomes and mitigate impact on food prices

MANY THANKS

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