Integrated Study of Biofuel Supply Chain Design and Land Management

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INTRODUCTION

Incentives and regulations have boosted the biofuel industry. In the United States, a 36 billion gallon goal for renewable fuel consumption by 2022 was set in Renewable Fuels Standard (RFS2) portion of the Energy Independence and Security Act (ESIA-Anderson et al., 2009).The RSF2 also places requires production of advanced biofuels that are not derived from conventional crops like corn and have a minimum level of greenhouse gas emissions. Given these strong motivations, substantial expansion of an advanced biofuel industry has been expected since the EISA act was passed. However, some have argued that the ambitious goals of RFS2 and the relatively short time frame pose challenges to the industry (An et al. 2011, Zhang, 2011). One key challenge is price competitiveness against fossil based fuels. Low cost products require producing a product with low production and logistics costs. Logistics cost is a key component of cost with estimates placing it at 35 to 60 percent of delivered feedstock cost (Fales et al. 2007; Kummar & Sokhasanj, 2007).

This study examines ways to reduce logistic costs in the design of a cellulosic biofuel supply chain. To do this we set up, a Mixed Integer Programming (MIP) model which is used to examine the consequences of alternative supply chain configurations and in turn provide insights for decision makers on selecting site, preprocessing, storage and transportation options.

OBJECTIVES

1. Determine the location in east Texas for potential herbaceous biomass growing.
2. Identify the location of biorefinery, storage, pretreat associated with the optimal switchgrass supply chain.
3. Determine the amount of herbaceous and woody biomass supplying for the biorefinery

ANALYTICAL MODEL

A mixed integer programming model was developed to search for the Pareto-optimal solutions between costs in the supply chain of biofuel supply chain in east Texas. The location of the biorefinery plant and associated feedstock draw area in Texas was also determined through applying the MIP model to high resolution spatial data.

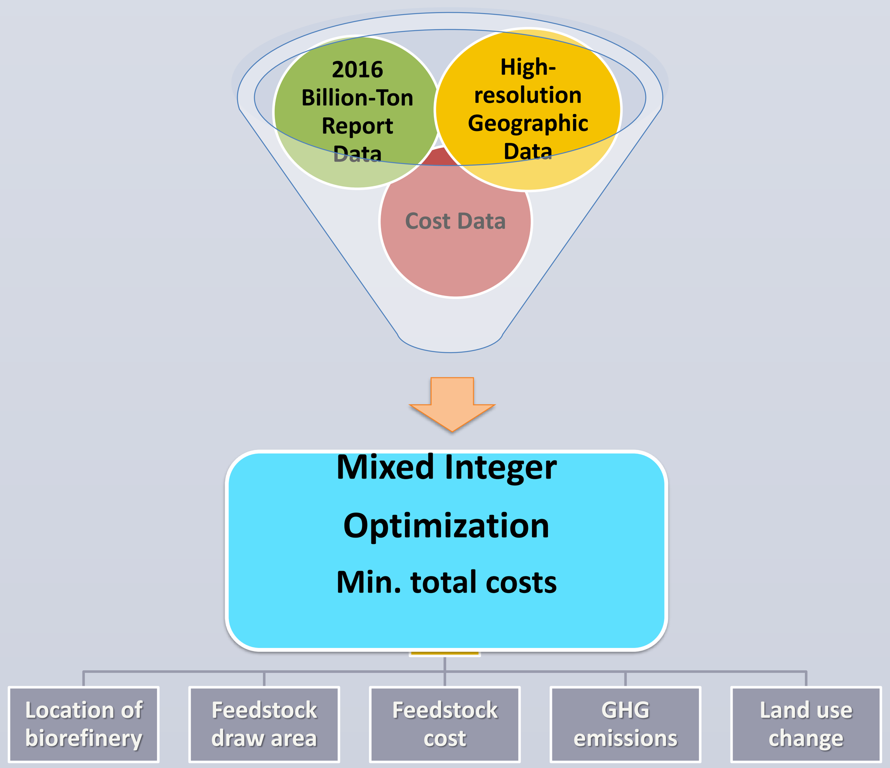

Figure 1. Model framework

MODEL ASSUMPTIONS & DATA

- Capacity of a commercial-scale and single-feedstock biorefinery is 50 million gallons of biofuel per year.
- Potential locations for the biorefineries are limited to Trinity County and Angelina county in East Texas with access to water, power, and roads, as well as sufficient storage space for preprocessing feedstocks (see Figure 2).
- Feedstock supply regions are all the available lands within 50 miles of the candidate biorefinery county (see figure 3)
- herbaceous harvested once per year during November-February
- Both woody and herbaceous biomass are used as feedstock for the biorefinery. Given that abundant woody biomass exist in east Texas, this study assume that at least 250,000 woody biomass will be supplied to the biorefinery
- Herbaceous biomass can be stored at offsite location and dry matter loss during storage up to 365 days are considered.
- Feedstock yields are obtained from KDF billion-ton and Texas Forest Service report.

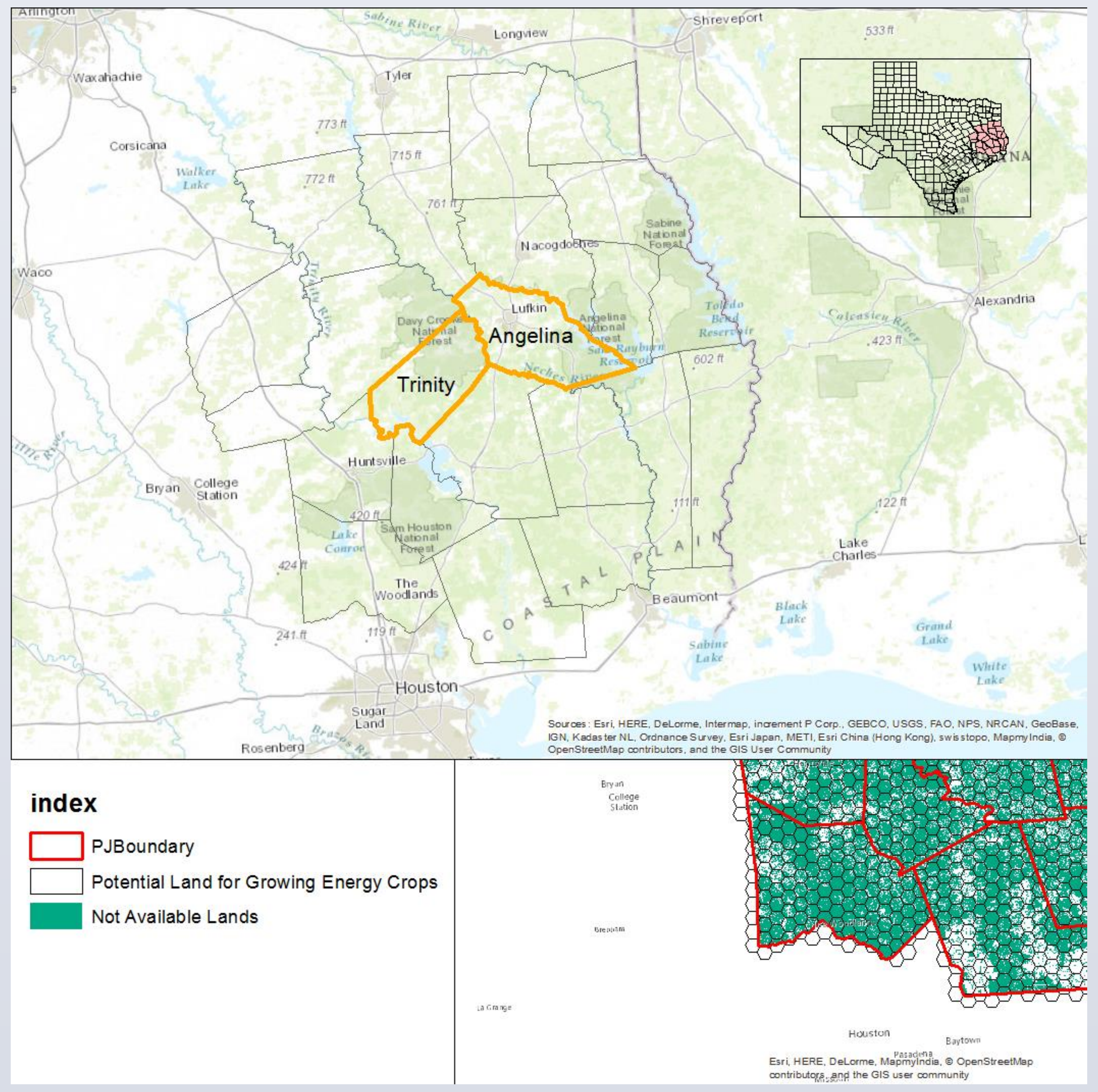

Figure 2. Study area

Table 1 summarizes the components of cost and GHG emissions in the switchgrass supply chain considered in this study.

Table 1. Cost and GHG emission from a Biofuel Supply Chain

	Economic Cost	GHG emissions	
		Direct	Indirect
Land Conversion	Opportunity Cost	Land use change	
Production	• Establishment • Annual maintenance	• N fertilizer application • Fuel usage	• Fertilizer production • Equipment production
Harvest	• Farm equipment: Fuel Labor Maintenance Ownership	• Fuel usage	• Equipment production
Storage	• Labor • Pickup fuel • Covers and Pallets	• Fuel usage • Storage emission	
Transportation	• Labor • Fuel • Truck ownership	• Truck emission	• Truck production

EMPIRICAL RESULTS

Figure 3 presents the possible outcomes from the Mixed Integer Programming optimization. The cost minimal candidate, Trinity county. Off-site storage candidate Madison county, Houston county, and Angelina county. Preprocessing candidate, Madison county.

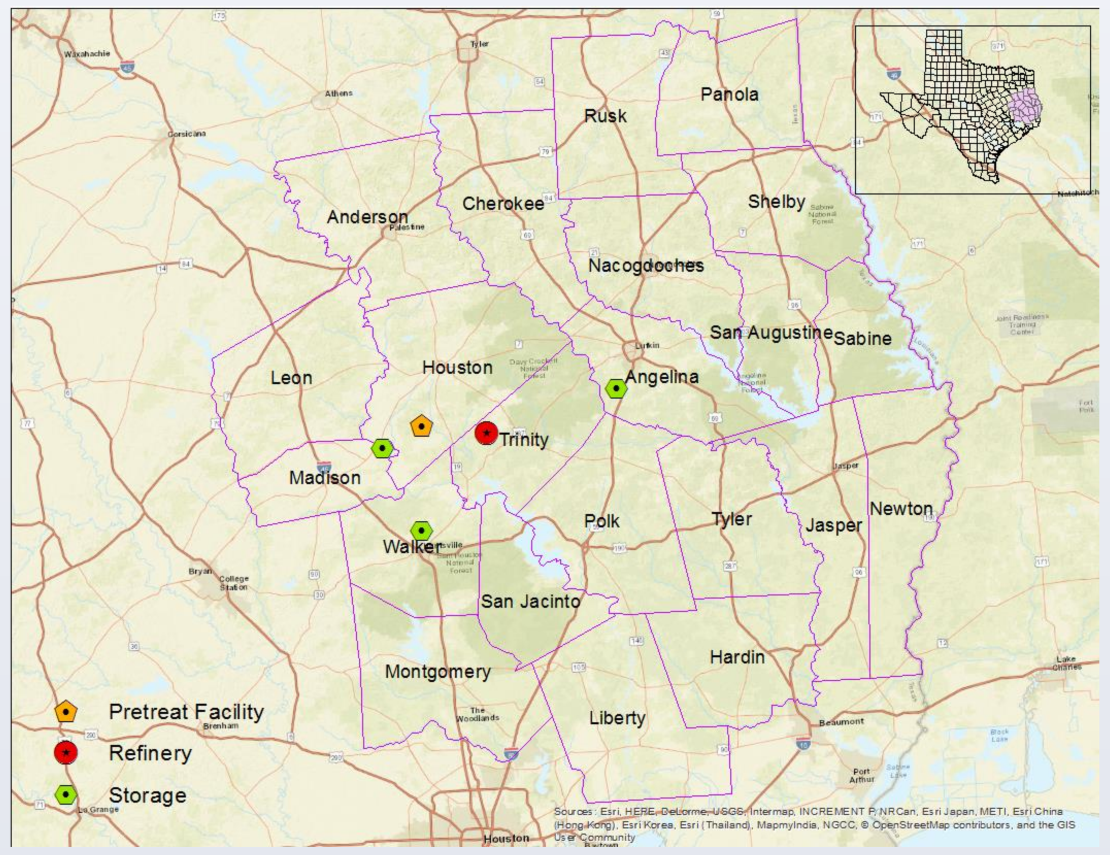

Figure 3. The Pareto-optimal curve and three candidate sites (A: cost minimal; B: GHG emission minimal; C: alternative optimal)

- The total cost of the supply chain was near $46 million
- The GHG emissions were above 81,000 CO2e ton.
- Around 160,000 acres land will have to be grown in Houston, Madison, and San Jacinto and Walker county
- 250,000 dry tons of woody biomass will be supply from Walker, San Jacinto, Angelina and Houston counties per year
- 565,000 tons of herbaceous biomass will be harvested from November-February
- 520,000 dry ton of herbaceous biomass will be stored in Madison, Walker and Angelina Counties respectively per year
- Around 57.5 million gallon of ethanol will be produced per year

Table 2 summarizes the important parameters used in this study

Table 2. Important parameters in the study

Parameters Name	Value	Source
Ethanol Conversion Rate	Woody: 71.49 (Gallon/dt) Herbaceous: 77.36 (Gallon/dt)	Ekşioğlu et al.(2009) Memisoglu(2014)
Yield	Switchgrass: 3.78 ton/ acre	Langholtz et al.(2016)
Biorefinery Capacity	5,250,000 (Gallon/month)	Assumed
Storage Capacity	500,000 (tons for eight months)	Assumed
Pretreat Facility Capacity	45,000 (tons/year)	Mani et al. (2006)
Minimum Ethanol Production	4,200,000 (Gallon/month)	Assumed
Fixed Cost of a Biorefinery	4,500,000 (dollar)	Nguyen and Prince(1996)
Fixed Cost Storage	Covered: 15,153(dollar) Uncovered: 1,500(dollar)	An et al. (2011)
Minimum Storage	60,000(ton/month)	An et al. (2011)

CONCLUSIONS

This study evaluated a biofuel supply chain in east Texas considering minimizing the costs. Our findings suggest that:

- There is sufficient amount of herbaceous and woody biomass to support the biorefinery
- Given the available land constraint and the transportation costs, most land being converted will be at the counties which surrounding Trinity county
- Although significant amount of herbaceous biomass can be grown to supply the biorefinery, and the GHGs emission through the land conversion could potentially offset the GHG reduction from using biofuel.
- Pelletizing the biomass can reduce the transportation costs; however, the increasing energy cost may unbalance the transportation cost saving.
- Choosing the type of land conversion can achieve high economic efficiency with more GHG emissions, or less GHG emissions with higher economic cost.

Further research of this topics

- Incorporate the uncertainty of crops production
- Determine the most efficient pretreat method
- Export the pelleted biomass

REFERENCE

An, Heungjo, Wilbert E. Wilhelm, and Stephen W. Searcy. "Biofuel and petroleum-based fuel supply chain research: a literature review." *Biomass and Bioenergy* 35, no. 9 (2011): 3763-3774.

Anderson, James E., Pete J. Hardigan, John M. Ginder, Timothy J. Wallington, and Richard E. Baker. *Implications of the energy independence and security act of 2007 for the US light-duty vehicle fleet*. No. 2009-01-2770. SAE Technical Paper, 2009.

Fales, Steven L., J. Richard Hess, Wallace Wilhelm, Don Erbach, William D. Provine, Kenneth P. Vogel, Todd A. Peterson, and Edward CA Runge. "Convergence of agriculture and energy: II. producing cellulosic biomass for biofuels." *Publications from USDA-ARS/UNL Faculty* (2007): 291.

Sokhansanj, Shahab, Amit Kumar, and Anthony F. Turhollow. "Development and implementation of integrated biomass supply analysis and logistics model (IBSAL)." *Biomass and Bioenergy* 30, no. 10 (2006): 838-847.

Zhang, Fengli, Dana Johnson, Mark Johnson, David Watkins, Robert Froese, and Jinjiang Wang. "Decision support system integrating GIS with simulation and optimisation for a biofuel supply chain." *Renewable Energy* 85 (2016): 740-748.

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