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Energy Beet Biofuel Market Development

Final Project Report

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Executive Summary

The purpose of this project is to assess the market opportunity presented by energy beet bioethanol in North Dakota. The study examines two critical stages in the market development process: evaluating farmer willingness to supply energy beet feedstock and supply chain issues. Farmer willingness to supply is evaluated using multi-modal survey techniques (in-person, internet and mail) that include demographic, contract and risk preference, and experimental questions. Results show that farmers prefer fixed contracts in the short-run and variable contracts in the long-run. Farmers also prefer unlimited acceptance of their production. Farmers are generally willing to engage in beet supply, even if there is no increase in agricultural returns. This implies that from a farmer standpoint, given good contract terms, beets could be supplied at break-even agricultural prices (at the farm-gate).

Supply chain issues are examined using integrated economic and agronomic GIS-based modelling. Results show that beet yields average 15.3 tons/ac, with break-even prices below $30 per ton in many regions of the state. They also show that a 20 million gallon ethanol plant could have positive net returns at $1.50/gallon ethanol, offering to buy beets at $30/ton. Considering integrated information, energy beet bioethanol production in the state of North Dakota is feasible. Under current market conditions, it is not particularly advisable, but as prices increase, the opportunity becomes much more attractive with multiple locations available for production.

Introduction

The Energy Independence and Security Act of 2007 (EISA) defines three classes of biofuels: conventional, advanced, and cellulosic. These classes are differentiated based on potential reduction of greenhouse gas (GHG) emissions of 20%, 50% and 60%, respectively, and the type of biomass used. Biorefiners are striving to develop new conventional and cellulosic biofuels that qualify under EISA. Several firms have commercial-scale cellulosic biofuel production facilities under construction and testing. However, advanced biofuels have received scant attention, primarily because feedstock supplies are limited. Two crops that may qualify as "advanced" biofuels under EISA are sugar beets and sugarcane. Advanced biofuel use of 21 billion gallons per year is mandated by 2022, creating a niche market opportunity.

At present, North Dakota and Minnesota account for more than 50 percent of domestic sugar beet production. Currently, all sugar beets produced in North Dakota are utilized in sugar production. There is a vision, supported by private and public entities, to build and operate 20 million gallon per year energy beet-ethanol biorefineries in North Dakota. Energy beets specifically used to produce biofuels are different than conventional sugar beets used to produce food sugar, as energy beets can contain impurities which make them poor sources of food-grade sugar. It is expected that energy beets will be grown apart from existing sugar beet production areas so that energy beet production will have no negative economic impacts on the existing sugar beet industry.

Energy beet yield trials have been conducted across North Dakota since 2009. Other areas including Alaska, California, Florida, Idaho, and the Mississippi Delta have also conducted similar energy beet yield trials. NDSU has completed an economic feasibility of ethanol produced using energy beets (see Maung and Gustafson 2011). Study findings show that it is feasible to produce sugar-based biofuel in North Dakota. The analysis was based on a 20 million gallon-per-year refinery that would require 30,000 acres of production. Biorefineries could eventually be sited in North Dakota with an annual economic impact of more than 30 million dollars per plant.

While industrial sugar derived from energy beets can be used to produce a variety of biofuels and bioproducts, the focus of this project is on energy beets and energy beet-based ethanol. Ethanol is a commodity and one of the lowest value uses for energy beets. Consequently, the use of a baseline energy beet-ethanol pathway is expected to be conservative in terms of estimates of economic returns to farmers, biorefineries, and investors. Furthermore, economic and process information from energy beet-ethanol pathways are readily understood by biofuel and bioproduct technology companies, although alternative uses for energy beet-based industrial sugar, the intermediate feedstock used to produce ethanol, may be ultimately more valuable.

To address energy beet biofuel market development to the commercial scale in North Dakota, this project aims to:

1) Estimate market supply, demand, and prices for energy beets and energy beet-based ethanol; and

2) Design the field to refinery energy beet supply chain model.

Presently, energy beets are not traded on futures markets in the United States. Consequently, growers, project developers, investors, and bankers have little market information for planning. Similarly, information on farmers' attitudes and willingness to grow and supply energy beets for biofuel production is limited. Therefore, this study elicits farmers' willingness to supply energy beets under alternative market conditions to construct a demand schedule and determine market prices for energy beets. This demand schedule represents industry's willingness and ability to purchase energy beets and is dependent on processing technology, input costs, and product prices. This study employs a multi-modal (mail, internet and in-person) survey to examine market supply, demand and prices (Dillman, 2000).

This study also addresses regional energy beet production, transportation and processing. While one dimension of spatial price variability is transportation distance, regional production variability also is a consideration. This study employs integrated economic, bio-physical and GIS-based modelling to examine beet production, transportation and processing.

Results: Market Supply and Prices

Market supply, demand and prices were examined using a multi-modal survey of agricultural producers in North Dakota. The survey resulted in 28 in-person, 38 internet and 59 mail responses from a cross-section of farmers. All of the 28 in-person surveys contained useable data. The internet survey returned 18, and the mail survey contained 23, useable responses. The mail survey was sent to 640 producers and 59 were returned – a response rate of 9.2%. The mail survey has been appended to this report in Appendix A.

The first issue that was examined using this data deals with contract mechanism design to entice farmers to sign energy beet contracts. Without a stable supply of beets, the nascent industry would not be able to get sufficient financial backing to launch. This study used a stated choice experimental survey to evaluate the effects of contract design mechanisms and farmers' risk preferences on biomass supply for ethanol production. A rank-ordered logit model was used to assess the effects of price and quantity based contract mechanisms, risk preferences, and farm characteristics, on contract preferences. The results show that, under price based contracts, farmers are likely to prefer contracts that set fixed prices when contracts are offered over the short-term. However, in the long–term, farmers prefer contracts that use a formula with a floor price. In quantity based design mechanisms, our model results illustrate that contract terms that limit biomass quantity delivery requirements become less preferable even if farmers are allowed to negotiate delivery prices. In addition, farmers' risk perception factors towards engaging in marketing organization and vertically organized supply chains play a significant role in ranking contract preferences. This academic manuscript titled "The Effects of Contract Mechanism Design and Risk Preferences on Biomass Supply for Ethanol Production" is currently under review in "Agribusiness" and a draft of this manuscript has been appended to this report in Appendix B. A summary of the survey results is also present in the tables of Appendix B.

To examine the willingness-to-supply energy beets of producers, the study employs stated choice experimental methods. With favorable contract terms, producers are willing to supply energy beets even with no price incentives. Irrespective of other contract attributes, farmers are willing to convert 10.4% of their farmland, on average, to beets without increased agricultural returns (Table 1). A 10%, 20% and 40% increase in agricultural returns results in an average willingness to convert cropland at rates of 13%, 11.9% and 14.4%, respectively. This general trend makes sense, but the dip in willingness from 10% to 20% increase is unexpected, driven by the internet survey results. The in-person survey has the lowest average willingness-to-supply results, followed by the mail survey. The internet survey has the highest willingness-to-supply, almost twice the rates observed in the in-person survey.

Table 1: Willingness-to-supply energy beets (% of area) based on rate of increased agricultural returns and survey type.

	Increased Agricultural Returns			
Response Type	**No Increase**	**10%**	**20%**	**40%**
In-Person	7.2	8.9	10.3	13.1
Internet	14.7	18.4	14.3	20.4
Mail	10.7	13.5	12.0	10.1
Grand Total	**10.4**	**13.0**	**11.9**	**14.4**

The effect of age on willingness-to-supply is mostly ambiguous from the survey data (Table 2). Younger respondents do not tend to favor energy beet development, nor do elderly farmers. Farmers in the middle of the age bracket tend to be more willing to supply energy beets.

Table 2: Willingness-to-supply energy beets (% of area) based on rate of increased agricultural returns and respondent age.

	Increased Agricultural Returns			
Age	**No Increase**	**10%**	**20%**	**40%**
<25	6.7	2.5	5.0	15.0
25-34	12.2	15.1	12.0	18.0
35-44	10.2	11.9	13.0	15.1
45-54	10.2	14.0	13.9	16.0
>55	10.0	12.5	10.5	10.4
Grand Total	**10.4**	**13.0**	**11.9**	**14.4**

The effect of education on energy beet supply is also somewhat ambiguous (Table 3). In general, highly educated producers are more willing to supply energy beets, as are those with some college. However, those with undergraduate degrees are the least likely to be willing to supply energy beets.

Table 3: Willingness-to-supply energy beets (% of area) based on rate of increased agricultural returns and respondent education.

	Increased Agricultural Returns			
Education	**No Increase**	**10%**	**20%**	**40%**
High School	11.1	11.2	10.2	13.1
Some College	11.2	13.2	13.9	18.2
Undergraduate	8.0	10.6	12.0	12.1
Graduate	15.8	22.9	10.1	17.7
Grand Total	**10.4**	**13.0**	**11.9**	**14.4**

Farm sales generally have a decreasing effect on willingness to supply energy beets (Table 4). This result makes sense as smaller farmers often have to be more adaptive to make the most out of their smaller ability to make income and seek higher margins. Larger farms have less need to try new crops as their profits are more heavily weighted to volume, rather than margin.

Table 4: Willingness-to-supply energy beets (% of area) based on rate of increased agricultural returns and respondent annual farm sales.

	Increased Agricultural Returns			
Annual Farm Sales ($)	**No Increase**	**10%**	**20%**	**40%**
<100,000	17.8	25.8	11.4	18.1
100,000-499,000	11.9	11.5	11.6	11.5
500,000-999,999	7.9	11.0	13.3	17.8
>1,000,000	9.0	12.1	11.4	13.3
Grand Total	**10.4**	**13.0**	**11.9**	**14.4**

The mail survey established farmer willingness to supply energy beets in North Dakota. Results show that farmers prefer fixed contracts in the short-run and variable contracts in the long-run. Farmers also prefer unlimited acceptance of their production. Farmers are generally willing to engage in beet supply, even if there is no increase in agricultural returns. This implies that from a farmer standpoint, given good contract terms, beets could be supplied at break-even agricultural prices (at the farm-gate).

Results: Energy Beet Supply Chain Model

Energy beet supply chains were examined using integrated economic and bio-physical GIS-based simulation modelling. To examine the transportation of beets, a variety of costs were required, in addition to the yields of beets on the North Dakota landscape. Two academic manuscripts were prepared to address this issue.

To establish site specific transportation to potential ethanol plant sites in North Dakota, an agronomic model of beet growth was created. The viability of energy beet production is assessed using integrated agronomic and economic GIS-based techniques to determine yields and break-even prices in North Dakota. The results show that beet yields vary throughout the state, averaging 15.3 tons/ac, and are highest in the East, in the Red River Valley, where soil quality is high, moisture is plentiful and heat is sufficient. Production is also viable in the central and northern regions of the state, where soil quality and moisture are less favorable than in the Red River Valley. A smaller scale ethanol plant (20 million gallons) would be able to source sufficient materials for production in many locations throughout the state for prices around $30 per ton. This paper is presented in Appendix C.

The second academic manuscript examines five potential plant sites in North Dakota: Cando, Carrington, Jamestown, Langdon and Valley City. It evaluates energy beet market development at these sites using site specific information and integrated biophysical, economic and GIS-based transportation models. The study finds that beet bioethanol could provide net benefits to farmers and ethanol producers in the state, under current market conditions, but only if the bioethanol plant site is carefully selected. More specifically, a 20,000,000 gallon ethanol plant in Valley City could have net returns of $436,049. This plant would acquire 760,000 tons of beets from around the plant site and further east toward the Red River Valley from 22,682 acres of cropland, an average distance of 15.7 miles away. The average yield of the selected cropland is 33.5 tons/ac with average net farm returns of $26.09/acre above opportunity costs. Opportunity and transportation costs can substantially change the attractiveness of croplands for beet production. The current market opportunity presented by beet bioethanol at $1.50/gal ethanol is not particularly attractive, but as ethanol prices increase, this opportunity could become attractive at a number of sites throughout the state. This paper has been appended to the report as Appendix D.

Considering integrated information, energy beet bioethanol production in the state of North Dakota is feasible. Under current market conditions, it is not particularly advisable, but as prices increase, the opportunity becomes much more attractive with multiple locations available for production.

Summary of Outputs

This study successfully funded the following outputs:

1) Survey of North Dakota farmers' willingness to supply energy beets.
    a. Includes significant Extension programming related to the opportunity.
2) "Effects of Agricultural Opportunity Costs on Energy Beet Supply to Bioethanol

Refineries"

   a. Selected paper presented at the Joint Canadian Agricultural Economics Society and Northeastern Agricultural and Resource Economics Association AGM 2015, Newport, RI.

3) "Biomass Contracts for Ethanol Production: The Role of Farmers' Risk Preferences"
   a. Selected paper presented at the American Agricultural Economics Association AGM 2015, San Francisco, CA.
4) "The Effects of Contract Mechanism Design and Risk Preferences on Biomass Supply for Ethanol Production"
   a. Academic manuscript prepared for Agribusiness.
5) "The Effects of Spatial Climate and Soil Conditions on Modeled Energy Beet Yields and Break-even Prices"
   a. Academic manuscript.
6) "Energy Beet Bioethanol Plant Site Evaluation in North Dakota"
   a. Academic manuscript.

Project Evaluation and Conclusions

The purpose of this project is to assess the market opportunity presented by energy beet bioethanol in North Dakota. The study examines two critical stages in the market development process: evaluating farmer willingness to supply energy beet feedstock and supply chain issues. Farmer willingness to supply is evaluated using multi-modal survey techniques (in-person, internet and mail) that include demographic, contract and risk preference, and experimental questions. Results show that farmers prefer fixed contracts in the short-run and variable contracts in the long-run. Farmers also prefer unlimited acceptance of their production. Farmers are generally willing to engage in beet supply, even if there is no increase in agricultural returns. This implies that, from a farmer standpoint, given good contract terms, beets could be supplied at break-even agricultural prices (at the farm-gate).

Supply chain issues are examined using integrated economic and agronomic GIS-based modelling. Results show that beet yields average 15.3 tons/ac, with break-even prices below $30 per ton in many regions of the state. They also show that a 20 million gallon ethanol plant could have positive net returns at $1.50/gallon ethanol, offering to buy beets at $30/ton. Considering integrated information, energy beet bioethanol production in the state of North Dakota is feasible. Under current market conditions, it is not particularly advisable, but as prices increase, the opportunity becomes much more attractive with multiple locations available for production.

The project encountered some problems engaging North Dakota agricultural producers in the energy beet development process, as survey results were somewhat difficult to acquire. The multi-modal survey approach was valuable as it allowed additional producers to be contacted and their opinions incorporated. The information from the survey will continue to be refined in the future. Similarly, the Extension programming stemming from this project remains available to the farmers of North Dakota to encourage them to engage in new market opportunities as prices evolve in the state.

REFERENCES

Dillman, D. A. 2000. *Mail and Internet surveys: The tailored design method*. New York, NY: John Wiley & Sons, Inc.

Maung, T. A. and C. R. Gustafson. 2011. "The Economic Feasibility of Sugar Beet Biofuel Production in Central North Dakota." Biomass and Bioenergy 35: 3737-3747.

Appendix A

Producer Willingness-to-Grow New Crops in North Dakota

Thank you for your interest in new crop opportunities in North Dakota. The following survey asks your opinion on a new crop opportunity in your area. The study gathers demographic information, some general farming attitudes and then asks you to evaluate a new crop. For each question, please mark the option or enter the information that best represents your opinions and experiences. If you would prefer to do this survey online, please enter the following link into your web browser: http://tinyurl.com/nf6hb2v.

Part A: Demographic Information

- Are you actively involved in crop planting and marketing decisions? ☐ Yes ☐ No
- Gender: ☐ Male ☐ Female
- Age: ☐ <25 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ >55
- Education: ☐ Some High School ☐ High School Diploma ☐ Some College
  ☐ Undergraduate Degree ☐ Graduate Degree

If no one at your location is actively involved in farming decisions, please stop here. Return the survey in the envelope provided. Thank you.

- Acres Planted to Crops in 2015:
  - Barley ____________________
  - Dry Edible Beans ____________________
  - Canola ____________________
  - Corn ____________________
  - Flax ____________________
  - Peas ____________________
  - Potatoes ____________________
  - Soybeans ____________________
  - Sugar beet ____________________
  - Sunflower ____________________
  - Durum Wheat ____________________
  - Winter Wheat ____________________
  - Spring Wheat ____________________
  - Oats ____________________
  - Hay (Alfalfa) ____________________
  - Other ____________________
- Irrigated Acres ____________________
- Number of Employees: Full-time____________ Part-time____________
- Do you own a row planter? ☐ Yes ☐ No
- Have you farmed for more than 10 years? ☐ Yes ☐ No
- Are you near retirement? ☐ Yes ☐ No
- Are you a member of an input cooperative? ☐ Yes ☐Previously ☐ No
- Are you a member of a processing cooperative? ☐ Yes ☐Previously ☐ No
- Are you a member of a marketing (elevator) cooperative? ☐ Yes ☐Previously ☐ No
- Annual Farm Sales: ☐ <100,000 ☐ 100,000 – 499,999 ☐ 500,000 – 999,999 ☐ >1,000,000
- In which county is your operation centered? __________________________

Part B: Attitudes	Strongly Disagree→→→Strongly Agree				
1. I am hesitant to change my crop rotation	1	2	3	4	5
2. I am more likely to grow new crops when my current crop prices are low	1	2	3	4	5
3. I prefer to use technologies I am familiar with rather than adopting new ones	1	2	3	4	5
4. I prefer to conduct business as a member of a cooperative	1	2	3	4	5
5. I prefer short term supply contracts to long term ones	1	2	3	4	5
6. Contracts should tie the price I receive for beets to the price of other crops	1	2	3	4	5
7. I need higher returns when growing new crops	1	2	3	4	5
8. I am willing to make capital investments for new on-farm enterprises	1	2	3	4	5
9. I am willing to lease equipment	1	2	3	4	5
10. I have a high tolerance for financial risk	1	2	3	4	5
11. I am willing to grow crops without insurance	1	2	3	4	5
12. I prefer to harvest myself, rather than hire it done	1	2	3	4	5
13. Labor availability during harvest is not an issue in my area	1	2	3	4	5
14. I am willing to hire extra labor to harvest my crops, if necessary	1	2	3	4	5
15. I am willing to receive limited return to support local economic development	1	2	3	4	5
16. I consider myself well educated on environmental issues	1	2	3	4	5
17. I consider my operation to be environmentally friendly	1	2	3	4	5
18. I am willing to receive limited return to provide environmental benefits to all	1	2	3	4	5
19. I require price premiums to grow environmentally friendly products	1	2	3	4	5
20. Chemical carryover is a concern for beets	1	2	3	4	5
21. Beets provide soil health benefits	1	2	3	4	5
22. Beets have a spot in my crop rotation	1	2	3	4	5

Part C1: Contracting Energy Beet Production: Pricing

Bioethanol and Energy Beets in North Dakota:

- Energy beets can be used to produce bioethanol.
- North Dakota has energy beet production advantages due to long days in summer and climate factors.
- Energy beets could qualify as 'advanced' biofuels, creating market opportunities for bioethanol producers.
- Start-up bioethanol plants likely need 10 year feedstock contracts to secure financing.
- Potential contract pricing schemes include:
  - 1) Fixed (e.g. $35/ton);
  - 2) Formula (e.g. 8X the price of nearby Chicago corn futures);
  - 3) Formula with a floor (e.g. 8X the Chicago price, but no less than $25 per ton); and
  - 4) Formula with a ceiling (e.g. 8X the Chicago price, but no more than $50 per ton).

Please rank your preferred pricing scheme for 10-year, 5-year and 1-year contracts. 1 is the most preferred option and 4 is the least preferred.

Example:

Example Contract

Contract Pricing	*Fixed*	*Formula*	*Formula w/ Floor*	*Formula w/Ceiling*
Rank (1-4)	1	2	3	4

Your Response:

10 Year Contract

Contract Pricing	Fixed	Formula	Formula w/ Floor	Formula w/Ceiling
Rank (1-4)				

5 Year Contract

Contract Pricing	Fixed	Formula	Formula w/ Floor	Formula w/Ceiling
Rank (1-4)				

1 Year Contract

Contract Pricing	Fixed	Formula	Formula w/ Floor	Formula w/Ceiling
Rank (1-4)				

Part C2: Contracting Energy Beet Production: Quantity

- Potential quantity schemes, contracted by acre, include:
  - 1) All production;
  - 2) All production with a minimum requirement that needs to be met by the farmer;
  - 3) Capped production with no acceptance of additional material; and
  - 4) Capped production with a negotiated price for any additional production.

Please rank your preferred energy beet quantity scheme for 10-year, 5-year and 1-year contracts. 1 is the most preferred option and 4 is the least preferred.

Example:

Example Contract

Contracted Amount (By Acre)	*All Production*	*All Production Minimum Required*	*Capped No Additional*	*Capped Negotiated Price*
Rank (1-4)	1	2	3	4

Your Response:

10 Year Contract

Contracted Amount (By Acre)	All Production	All Production Minimum Required	Capped No Additional	Capped Negotiated Price
Rank (1-4)				

5 Year Contract

Contracted Amount (By Acre)	All Production	All Production Minimum Required	Capped No Additional	Capped Negotiated Price
Rank (1-4)				

1 Year Contract

Contracted Amount (By Acre)	All Production	All Production Minimum Required	Capped No Additional	Capped Negotiated Price
Rank (1-4)				

Part D: Willingness to Grow Energy Beets

Beet Growing Information:

- A four year rotation is recommended.
- Chemical carryover restrictions similar to soybean and canola.
- Requires row planters and specialized harvest equipment.
- Harvest occurs during a two-week window in October.
- Crop insurance is available.

Your Options: A group is interested in building a bioethanol refinery in your community. They want to know more about farmers' willingness to grow energy beets. They need to secure 30,000 acres of dryland beets to ensure adequate supply. Please identify the quantity of your land (in % terms) you would be willing to commit to energy beet production in each of the listed scenarios.

Example:

Scenario	*E*
Change in Expected Net Returns (%)	*10*
Contract Length (Years)	*10*
Contract Pricing	*Fixed*
Contract Quantity	*All Production*
Harvest	*3rd Party*
Acres Committed (%)	***20***

In this example scenario, the producer was willing to commit 20% of their land to beets.

Please proceed to the next page for your scenarios.

Example:

Scenario	*E*
Change in Expected Net Returns (%)	*10*
Contract Length (Years)	*10*
Contract Pricing	*Fixed*
Contract Quantity	*All Production*
Harvest	*3rd Party*
Acres Committed (%)	20

In this example scenario, the producer was willing to commit 20% of their land to beets.

Your Response:

Scenario	1
Change in Expected Net Returns (%)	40
Contract Length (Years)	10
Contract Pricing	Fixed
Contract Quantity	All Production
Harvest	3rd Party
Acres Committed (%)	

Scenario	2
Change in Expected Net Returns (%)	20
Contract Length (Years)	5
Contract Pricing	Formula
Contract Quantity	Capped Negotiated Price
Harvest	Individual
Acres Committed (%)	

Scenario	3
Change in Expected Net Returns (%)	0
Contract Length (Years)	5
Contract Pricing	Formula (Floor)
Contract Quantity	Capped No Additional
Harvest	Individual
Acres Committed (%)	

Scenario	4
Change in Expected Net Returns (%)	40
Contract Length (Years)	10
Contract Pricing	Formula (Ceiling)
Contract Quantity	All Production Minimum Required
Harvest	Individual
Acres Committed (%)	

Part E1: Beet Agronomic Benefits

Did you know…?

- Beets' deep tap roots improve soil health by providing access to water and nutrients far below the soil surface.

  ☐ Yes ☐ No
- Beet tops when left on the field typically receive an 80 lb. per acre nitrogen credit.

  ☐ Yes ☐ No

Knowing this, please identify the quantity of your land (in % terms) you would be willing to commit to energy beet production in each of the listed scenarios.

Your Response:

Scenario	5
Change in Expected Net Returns (%)	10
Contract Length (Years)	5
Contract Pricing	Fixed
Contract Quantity	Capped No Additional
Harvest	Individual
Acres Committed (%)	

Scenario	6
Change in Expected Net Returns (%)	10
Contract Length (Years)	10
Contract Pricing	Formula (Ceiling)
Contract Quantity	All Production Minimum Required
Harvest	3rd Party
Acres Committed (%)	

Part E2: Higher Value Uses

Did you know…?

- Sugar can be used to produce higher value fuels and chemicals than ethanol.
  ☐ Yes ☐ No
- The development of an industrial sugar system in your community may attract a biotech company that utilizes local sugar, creating dozens of high-paying jobs.
  ☐ Yes ☐ No

Knowing this, please identify the quantity of your land (in % terms) you would be willing to commit to energy beet production in each of the listed scenarios.

Your Response:

Scenario	7
Change in Expected Net Returns (%)	0
Contract Length (Years)	Spot
Contract Pricing	Formula
Contract Quantity	All Production
Harvest	3rd Party
Acres Committed (%)	

Scenario	8
Change in Expected Net Returns (%)	20
Contract Length (Years)	1
Contract Pricing	Fixed
Contract Quantity	All Production Minimum Required
Harvest	Individual
Acres Committed (%)	

Thank you for completing this survey! We appreciate your help. Please place the survey in the postage-paid return envelope provided and mail it as soon as you are able.

If you wish to participate in the iPad draw, please return the ticket with the completed survey. Entering the draw does not affect your anonymity. In order to be eligible for the draw, the survey must be returned no later than December 18th, 2015.

If you have any questions please contact me at aaron.delaporte@ndsu.edu or 701-231-8672.

NDSU NORTH DAKOTA STATE UNIVERSITY

EBS.15-X

Appendix B

THE EFFECTS OF CONTRACT MECHANISM DESIGN AND RISK PREFERENCES ON BIOMASS SUPPLY FOR ETHANOL PRODUCTION

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The Effects of Contract Mechanism Design and Risk Preferences on Biomass Supply for Ethanol Production

Abstract

This study used a stated choice experimental survey to evaluate the effects of contract design mechanisms and farmers' risk preferences in supplying biomass for ethanol production in a vertically integrated biomass supply chain in Northern Plain of the U.S. A rank-ordered logit model was used to assess the effects of price and quantity based contract mechanisms, risk preferences, and farm characteristics on ranking of contract preferences. Our empirical results show that, under price based contract, farmers are likely to prefer contract that set fixed price when contract was offered over short-term, however, under long term, farmers prefer a contract item that set formula with a floor price most. In quantity based design mechanism, our model results illustrate that contract items that limit biomass quantity delivery requirement become less preferable even if farmers are allowed to negotiate on delivery price. In addition, farmer's risk perception factors towards engaging in marketing organization and vertically organized supply chain play a significant role in ranking contract preferences.

Keywords: *Contracts; Risk Preferences; Biomass; Ethanol; Rank Order Logit Model.*

http://onlinelibrary.wiley.com/journal/10.1002/%28ISSN%291520-6297/homepage/ForAuthors.html

1. Background

The 2007 Energy Independence and Security Act (EISA) amended and established renewable fuel standards (RFS2) with a goal to use at least 136 billion lite r of bio-based transportation fuels, annually, by 2022. This goal targets 56.8 billion liter of 'conventional' corn-starch ethanol and 79.5 billion liter of 'advanced' biofuels, including ethanol sourced from sugar cane and cellulosic feedstock, and biodiesel. The corn ethanol industry has reached the annual minimum production capacity required to meet the 'conventional' RFS2 mandate (Renewable Fuel Association, 2015). Therefore, future growth in biofuel production is likely to come from alternative 'advanced' feedstock pathways, including dedicated energy crops and high-sugar feedstocks. Indeed, high-sugar feedstocks, such as sugar beets, sugar cane and sweet sorghum, are expected to fulfill some of the feedstock requirement in the EISA advanced biofuels goal.

The conversion of these feedstocks into biofuels and their commercial viability are mainly determined by investment and feedstock costs, conversion efficiency, the price of biofuels, markets, and infrastructure for the production, harvest, storage, and delivery of these dedicated energy crops (Alexander et al 2012; Babcok 2012; Coyle, 2010; Epplin et al 2007). Regardless of these uncertainties, in 2013, the California Energy Commission (CEC) funded a $5 million project to construct and test a demonstration beet-ethanol biorefinery (CEC, 2013). Since 2009, progress has been made by private developers in North Dakota in developing a flexible biorefinery plant capable of producing energy beet based industrial sugar juice, biofuels, and possibly bioproducts, and other byproducts, in a single facility.

The energy beet, a member of the beet family (*Beta vulgaris*), is a hybrid sugar beet that has been genetically engineered to yield sugar for ethanol production (McGrath and Townsend 2015; Wamisho et al 2015). Similar to sugar beets, energy beets are most effectively grown in more Northern climates, such as those found in the U.S. States of North Dakota, Minnesota, Montana, and Michigan, and the Canadian Provinces of Alberta, Saskatchewan, Manitoba and Ontario. Long days in summer and cool temperatures in the fall create ideal growing conditions for beets. Although energy beets are specific to North America, sugar beets are used in Europe for ethanol and sugar production.

From the perspective of beet ethanol investors, in addition to ethanol and beet feedstock price uncertainty and investment costs, obtaining quality and steady supply of beet feedstock for a sufficiently long period of time may be challenging given that energy beet is bulky to transport and its sucrose content quickly deteriorate unless it transported and processed fairly quickly. In the absence of spot markets for energy beet, potential new beet ethanol refineries need to rely on long-term contracts to convince farmers to produce and deliver energy beet feedstock over time given the requirement of costly initial capital investment, and risk and uncertainty about beet feedstock cost and availability. Conversely, farmers will not adopt and sign a long term contracts unless the payoff from producing the energy beet is at least as high as the payoff from the next best use of the land. In the absence of established markets and risk management mechanisms, well-designed contracts, with price and other production incentives, may encourage farmers to engage in the production of biofuel feedstock and aid in achieving return on investment targets, while still providing incentives to meet the quantity and quality targets of the refineries (Alexander et al 2012; Epplin 2007; Epplin and Haque 2011; Babcock 2012; Larson et al 2008; Rajagopal et al 2007).

A growing literatures have evaluated contract mechanism designs, types of farmer's contract preferences and their willingness to supply dedicated energy crops for biofuel production in a vertically-integrated biomass supply chain systems. A notable studies that are based on mathematical programming and numerical simulation models (Epplin et al 2007;

Larson et al 2008; Li and Ross 2014; Okwo and Thomas 2014; Yang et al 2015), while econometrics model using stated choice experiments methods (Altman, and Sanders, 2013; Altman et al 2015; Bergtold et al 2014; Caldas et al 2014; Fewell et al 2013; Jensen et al 2007**;** Jensen et al, 2011; Qualls et al. 2012). For example, Yang et al (2015) developed a simulation based principal-agent model to analyze the determinants of landowner choice among a land-leasing contract, and a fixed-price contract and a revenue-sharing contract with the price indexed to the revenue of biofuel production for perennial energy crop production. To identify likely challenges of dedicated energy crop, Epplin et al (2007) implemented a multi-region mathematical programming model to determine the cost to produce switchgrass for both a land-lease alternative and a farmer-contract alternative. Okwo and Thomas (2014) constructed an optimization model to assess the economic potential of dedicated energy crops when profit-maximizing farmers allocate croplands of varying quality toward biomass in response to multi-year contracts in Tennessee. Li and Ross (2014) used agent based simulation approach to examine the effect of various contractual terms across market scenarios and consider the potential for contractual hold-ups problem with switchgrass production and find that a higher premium is needed to avoid the possibility of hold-up.

Although production, harvesting, storage, transportation infrastructure and logistics, and price risk management is well-developed for sugar beet growers in the Red River Valley of North Dakota and Minnesota , to avoid food-versus-fuel debate, growing and supply of energy beet is targeted agricultural producers that are not currently engaged in sugar beet production. While, few studies have analyzed the technical feasibility of beets to ethanol pathway and explored the costs of beet ethanol process technologies in U.S. (Wamisho et al. 2015; Shapouri, Maung and Gustafson 2011; Salassi et al 2006). Virtually, there is no research investigating energy beet market organization issues such as transaction costs, organizational decisions and producer willingness to supply feedstock under contracts in a vertically-integrated biomass supply chain.

The purpose of this study is to assess the effects of price and quantity mechanisms, length, risk preferences, and farm characteristics on contract preferences to supply energy beets for bioethanol production. A stated choice experiment was designed to elicit farmers' willingness to grow energy beets as a bioenergy crop under alternative contractual arrangements. A rank-ordered logit (ROL) model is used to measure the effects of contract attributes and farmers' risk perception on their ranking preference of the hypothetical menu of contracts offered by a biorefinery owner. The econometric estimation is based on a sample that consists of 43 farmers, surveyed in person and online.

The study proceeds with an overview of the survey, followed by the empirical model in sections two and three, respectively. The findings of the empirical model are then reported and discussed in section four. The last section contains the conclusions and implications of the study.

2. Energy Beet Willingness-to-Grow in North Dakota: Survey Design and Administration

Survey techniques were employed to elicit North Dakota agricultural producers' willingness-to-grow energy beets. A three-phase survey technique was employed to encourage survey participation. The survey was initially administered in person, as a paper version, following energy beet educational sessions in five North Dakota Cities: Valley City, Jamestown, Langdon, Carrington and Cando, from March 17th to March 19th, 2015. The initial paper survey elicited 28 responses. The survey was then converted to an online format and transmitted to agricultural producers. Online efforts began in April with subsequent participation efforts occurring in May of 2015. The data set has 15 additional online survey responses for a total of 43. Finally, a mail survey was sent to 640 North Dakota producers in January 2016. The sample was evenly divided among ten counties in the red river valley region of North Dakota. Farmers returned 24 surveys with usable information (a 4% response rate). After exclusion of 5 partially completed surveys, a total of 19 completed surveys were considered as useable for this study.

The survey has four distinct sections requiring farmer input. The first section collects farmer demographics and information about their farm enterprise. The second section of the survey elicits various attitudes of the producer, including perceptions of risk, willingness to adopt new technologies and crops, and general attitudes about contracts, capital investment, insurance, labor and the environment. It also contains questions about energy beet knowledge and general attitudes toward growing them.

The third section of the survey is specifically geared toward investigating farmer preferences between different types of contract design mechanisms. The section is broken down into questions surrounding energy beet product pricing and quantity supplied in the contract. Farmers were asked about their preference for fixed per unit prices for beet delivery, compared to three alternate formulas based on the price of corn (Appendix 1). They were asked to rank their preferences between: 1) Fixed; 2) Formula (10x Chicago Corn); 3) Formula with a Floor; and 4) Formula with a Ceiling. "Fixed" prices would be set throughout the life of the contract. "Formula" prices would be set at ten times the Chicago nearby futures price with a maximum price paid to the farmer (ceiling) to protect the ethanol producer, or a minimum price paid to the farmer (floor) to limit downside risk. They were also asked to rank their preferences for these types of pricing mechanisms for 1-year, 5-year and 10-year contracts to examine the effect of contract length on these preferences.

Similarly, respondents were asked to rank their preferences between four quantity requested by the plant options: 1) All Production; 2) All Production Minimum required; 3) Capped No Additional; 4) Capped Negotiated Price (Appendix 2). In “All Production”, the entire crop of energy beets, regardless of size, would be delivered. In “All Production Minimum Required”, the farmer would be responsible for finding (or paying for) product that they were unable to deliver. In “Capped No Additional”, a specific amount would be negotiated for acceptance and no more could be delivered. In “Capped Negotiated Price”, the farmer would be able to negotiate a price for any production over the specified amount. Preferences for these quantity mechanisms were also ranked for 1-year, 5-year and 10-year contracts.

The final section of the survey uses a stated choice approach to attempt to elicit energy beet willingness-to-supply by asking farmers to make a production commitment based on contract attributes. More specifically, farmers were asked to commit a percentage of their land based on a percentage increase in their net returns, a contract length, a contract pricing mechanism, a quantity accepted mechanism and a harvest method. This final section of the survey is not the focus of this paper, which deals primarily with attitudes defined in the second section and the pricing and quantity mechanisms defined in the third section of the survey.

3. Empirical Model

3.1 Rank-ordered Logit (ROL) Model

The main goal of this study is to evaluate the effects of price and quantity based contract mechanisms, length, risk preferences, and farm characteristics on contract preferences to supply energy beets for bioethanol production. The theoretical framework of the ROL is based on the work of a number of authors (Fok, Papp and Van Dijk 2012; Chapman and Staelin 1982; Hausman and Ruud 1987; Train 2008). Assume that a farmer makes energy beet production choices to maximize subjective expected utility given production technology and short-run fixed input constraints. If a farmer chooses to grow and supply energy beets under a specified contract, then it is assumed that the subjective expected utility from producing energy beets under that specified contract exceeds that of producing energy beets under alternatively-specified contracts, as well as the next-best traditional crop alternative (McFadden 1973, 1974; Roe et al 2004).

The rank ordered logit model can be derived from a random utility model as in the conditional logit (CL) model, assuming that the objective of the producer is to maximize expected discounted utility, over time, when choosing between contracts to produce and supply energy beets. Thus, the random utilities for individual producer i are a set of latent variables (U_{ij}). U_{ij} denotes:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \text{ for } \forall \text{ , } j \in J \tag{1}$$

Where $i = 1,....., N$ indexes respondents and $j = 1,....., J$ indexes the contract alternatives. The utilities consist of two parts: V_{ij} is the deterministic component of the utility, which is determined by observed individual characteristics and the attributes of the alternative. The second component ε_{ij} is the random component of the utility of alternative j for individual i and it captures the factors that affect utility, but are not included in V_{ij} .

In general, the reduced-form of the deterministic part of the utility is modeled as:

$$V_{ij} = \beta' x_i + \phi Z_j + \theta W_{ij} \tag{2}$$

Where x_i is an *m*-dimensional vector with characteristics of individual i and j is an *m*-dimensional parameter, vector specific to alternative j, Zj depicts the contract attributes - the contract length in years and the potential contract pricing/quantity schemes, and Wij denotes attributes that may vary with both respondents and contracts, where β , ϕ and θ are the row parameter vectors of interest. The model is estimated assuming that the random component is independent and identically distributed with a Type-I extreme value distribution.

Conventionally, respondents are asked to choose their most preferred out of the complete set of J alternatives. Let $y_{ij} = 1$ denote that respondent i most prefers option alternative j.The information $y_{ij} = 1$ implies that, for this respondent, the utility of alternative j is larger than all other alternatives (i.e., $U_{ij} \geq Max(U_{i1}........U_{ij})$). The probability of this event depends on the distribution of ε_{ij} (Fok et al 2012). If we assume that ε_{ij} has an independent type-I extreme value distribution, we have the setup of a multinomial logit [MNL] model (McFadden 1973, 1974). This leads to the expression for the probability that item j is most preferred by individual i:

$$P_{ij} = \Pr[y_{ij} = 1; \beta] = \Pr[U_{ij.} \geq Max\{U_{i1.}........U_{ij.}\}] \quad = \frac{\exp(V_{ij})}{\sum_{l=1}^{j} \exp(V_{il})} \tag{3}$$

Where $\beta = \{\beta_1,.........\beta_j\}$ and β_j is set equal to zero for identification. Thus, Equation 3 implies that the information on the most preferred item is enough to estimate the model parameters. However, an efficiency gain can be obtained if we ask for a ranking of alternatives. Denote the response of respondent i by the vector $y_{ij} = (y_{i1},........., y_{ij})'$ where y_{ij} now represents the rank that individual i gives to item j. We also use an equivalent notation $r_{ij} = (r_{i1},........., r_{ij})'$ where r_{ij} denotes the contract alternative that receives rank j by individual i. Note that $y_{ij} = j$ is equivalent to $y_{ij} = k$. Under this assumption, individual farmers know all utility values and can easily provide a full ranking. Following, (Beggs et al

1981; Chapman and Staelin 1982), the ROL model can be expressed given the assumptions made on individual utilities, the probability of observing ranking r_i equals:

$$\Pr[r_i;\beta] = \Pr[U_{ir_{i1}.} \succ U_{ir_{i2}.} \succ .... \succ U_{ir_{ij}.}] = \prod_{j=1}^{J-1} \frac{\exp(V_{ir_{ij}})}{\sum_{l=j}^{J} \exp(V_{ir_{lj}})} \qquad (4)$$

The ROL model can be seen as a series of multinomial logit (MNL) models. Equation 4 only implies that we can look at the ranking as if consecutive choices are made (Fok et al 2012).

The ROL model assumption that respondents are able to rank each contract according to the underlying utilities does not always hold, especially for the less preferred contracts (Chapman and Staelin 1982). This argument implies that respondents do not make a complete ranking order for observed alternatives properly - farmers are only able to rank $J-k$ contracts. If the least preferred contracts are not ranked according to the underlying utility model, the use of those ranks in the estimation will bias the parameter estimates towards zero (Chapman and Staelin 1982; Hausman and Ruud 1987).

The contract choice set J comes from the farmers' selection of the most important contract choices, and they were asked to rank k_i contract (Fok et al 2012; Hausman and Ruud 1987). Following the literature, this simply requires the assumption that all the contract that were not chosen by the stakeholder, $J-k_i$, are ranked lower than his last choice contract. If the ranks beyond k are biased, the probability of observing a particular contract ranking by individual i, given that only the k most preferred items are ranked, becomes:

$$\Pr[y_i \mid k;\beta] = \Pr[U_{ir_{i1}.} \succ U_{ir_{i2}.} \succ .... \succ U_{ir_{ij}.}] = \prod_{j=1}^{k_i} \left[\frac{\exp(V_{ir_{ij}})}{\sum_{l=j}^{J} \exp(V_{ir_{lj}})} \right] \frac{1}{(J-k_i)!} \qquad (5)$$

We assume that the least preferred $J-k$ contracts are ordered randomly. Hence, the last term in Equation 5 contains the probability of observing one particular ordering of the last $J-k$ contracts (Fok et al 2012).

The estimation of this model implies the following log-likelihood function for a sample of N independent respondents:

$$\log \widetilde{L}(\beta, p) = \sum_{i=1}^{N} \log \left\{ \sum_{k=0}^{J-1} p_k \exp \left[-\log((J-k)!) + \sum_{l=1}^{k} \left(x_i{}' \beta_{r_{il}} - \log \sum_{m=l}^{J} e^{x_i{}' \beta_{r_{im}}} \right) \right] \right\} \qquad (6)$$

As defined in Section 2, two specific independent contract attributes, price and quantity mechanisms, were presented to farmers and they were asked to rank four options for each attribute. Two independent models were run for price and quantity based contracts, each with their own attributes. Common ordinal explanatory variables for each model are: contract length (1, 5 and 10 years), demographic variables, age, education and annual farm sales. Two dummy variables indicating farmers' membership in input and process cooperatives are also explanatory variables. Finally, continuous variables include total crop acreage harvested and three factor variables extracted from factor analysis representing farmers' risk perceptions.

Farmers' preferences for contract choices are characterized by heterogeneities (Lajili, Barry, Sonka 1997; Boxall and Adamowicz 2002; Bard and Barry 2000), and these heterogeneities can be explained either in the form of observed or unobserved farm or individual characteristics. Thus, incorporating and understanding heterogeneity will provide information on the distributional effects of resource use decisions or policy impacts (Alexander et.al 2012; Bard and Barry 2000, 2001; Bergtold et.al 2012; Boxall and Adamowicz 2002). To capture heterogeneities among the respondent farmers, the stated choice survey included twenty two attitudinal questions related to farmers' perceptions of risk related to farm and financial management, willingness to adopt new technologies and crops, and general attitudes about contracts, capital investment, insurance, labor and the environment (Section 2). To reduce data dimensionality while estimating the ROL model, iterated principal factors (IPF) analysis is used to condense these attitudinal questions into latent perception factors, and the estimated factors derived from the IPF are later included as independent variables in the regression analysis. The decision to retain the number of factors in the latent classes are determined based on Eigenvalues and factor loading[1]. In this study, factor loadings greater than or equal to 0.3 (in absolute value) are used to make inference about farmers' risk perception effects on latent perception factors (Martens, Crum, and Poist 2011).

[1] Factor loadings are the weights and correlations between each variable and the facto and it indicate the relative importance of each variable to each factor.

4. Results and Discussion

4.1 Brief Overview of Sample Characteristics

The scope of this section is to provide a descriptive analysis of the data. Of the 63 farmers that completed the survey in a usable form, 17 were participated on an online survey, 27 from on person interview and 19 were based on mail survey. In the stated preference survey, each respondent was asked to rank both price and quantity contract mechanisms independently. The contract mechanism design section comprises price and quantity based contract, each of them has four alternatives (refer Section 2) and respondents then were asked to rank all four alternatives, from most (=1) to least (=4) preferred. Of the 756 farmers-cases used in the contract ranking item, 31 (or 4 %) cases from price and 58 (or 6%) from quantity based contract were not assigned any ranking by respondents. Except unranked item entries, none of the respondent in both price and quantity based contracts assigned the same or tied rank to two or more items.

Table 1 reports mean ranking of each contract types by contract length. In price based contract, the most preferred contract was “Formula with a floor price (e.g. 10X the Chicago price, but no less than $25 per ton)” with average mean ranking of 1.69 to 2.03, followed by “Fixed price (e.g. $35/ton)” that received 1.62 to 2.37. On contrary, “Formula with a ceiling price (e.g. 10X the Chicago price, but no more than $50 per ton)”, was the least preferred rank both under short and long-term contracts. We count the number of times (frequency) exactly the four ranked contracts are in the order from the most to the least preferred corresponding in the survey. Subsequently, “Formula with a floor price” received the highest frequency of being as a first choice, taking 46 %, being ranked as the most preferred followed by “Fixed price” 40 %, the remaining 9 and 5 % were shared by “Formula” and “Formula with a floor price” respectively.

(Table 1 can be here).

In quantity based contract design, “All production” is the most preferred item of contract, as it was consistently ranked first over all three contract length with mean ranking 1.39 (one year), 1.42 (five years) and 1.45 (ten years) respectively. Whereas, “No Addition (Capped production with no acceptance of additional material)” is the lowest ranked contract with mean ranking 3.49 (one year) and 3.54 (ten years) respectively. “All production” implies that the biorefinery owner is willing to buy all of the quantity of energy beets produced by the farmers.

Table 2 provides descriptive statics of farmers’ demographic and farm operation information from the survey. Individual characteristics that are affecting farmers’ decisions to supply energy beet in a vertically coordinated market are education, age, and experience. Of the respondents, 42 % have some undergraduate degree, 35% are between 45 to 54 ages, 86% have farmed for more than 10 years, and only 25 % are near to retirement. Other market coordination and organizational decisions indicator variables are farmers’ cooperative membership status. With respect to being a cooperative member, only 6% of respondents were members of the identified input processing coops compared to 38% are member of processing coops. Finally, 41 % of respondents had annual farm sale greater than $1 million and 27 % of ranging from $500,000 to $1 million, and average farm operation in the sample in 2014 production season was 3,401 acres.

(Table 2 can be here).

4.2 Factor Analysis

Farmers were asked to answer twenty-two attitudinal preference statements using a scale from 1 to 5, where 1 was “strongly disagree” and 5 was “strongly agree” with the statement. An iterated principal factors (IPF) model used to derive the latent class factors out of the 22 attitudinal questions (Table 3). The suitability of the ordinal variable data for factor analysis

(FA) was then assessed using the Kaiser–Meyer–Olkin (KMO) index; KMO is a measure of sampling adequacy and high values of the index indicate that FA is appropriate. We retain attitudinal variables to be included in each of the latent factors if the variable has a factor loading greater than 0. 3 in absolute value (Martens, Crum, and Poist 2011). The higher the load, the more relevant it is in defining the factor's dimensionality. The IPF results shows that the sampling adequacy measure (KMO) was 0.53, showing that the latent factors have an adequate fit marginally. For that matter, Kaiser (1974) considered KMO values greater than 0.5 as acceptable and 0.8 or higher as desirable. In addition, the internal consistency of the items within each factor is satisfactory, as Cronbach's alpha was 0.657. Thus, attitudinal variable was excluded if its factor loading was lower than 0.3 (in absolute value). Out of 22 attitudinal questions, only two questions, "Question 12 and 16", were left out due to loading of less than 0.3.

Based on the factors analysis, we derived three latent class factors by taking the sample average responses from attitudinal preference statements loaded. Thus, Factor 1 consists of nine risk perception attitudinal questions with factor loadings ranging from 0.39 to 0.61. Factor 1 relates to adopting and investing on new crops and environmental stewardship. The nine questions contributing to Factor 1 are Questions 2, 8, 9, 14, 17, 19, 20, 21 and 22 as depicted in Table 3. Factor 2 is composed of Questions 1, 5, 7, 10, 11, 13 and 15, and their factor loadings range from 0.39 to 0.65, and it relates to community engagement, production, and technology, Finally, Factor 3 is composed of Questions 3, 4, 6 and 18, and this factor relates to marketing organization preference and engagement in vertically integrated markets. Table 3 shows the results for the three perception latent factors extracted using factor analysis.

(Table 3 can be here).

4.3. Contract Attributes and Preference Ranking

In this and the following sections, we report the regression results from ROL models to evaluate farmers' decisions to supply biomass in a vertically integrated biomass supply chain considering a menu of contracts when farmer demographics, farm characteristics, knowledge, and importance of various information sources are included as explanatory variables. The results are presented in two parts. First, we discuss the ROL model results based on price and quantity based contract considering all ranked items. Second, we discuss the ROL regression results based on latent class rank for contract items that are classified as the most and least preferred contract items. Table 4 and 5 present the parameter estimates along with robust standard errors for the ROL models. The logit predicted marginal effects reported for the first section of the regression is presented in the appendix Table 2A; marginal effect was calculated as an average of marginal effect for continuous variables while for the dummy variables it was calculated for each of the outcomes of the ordinal variable as a discrete change. All of the ROL regressions are run for each contracting length (one, five and ten years) given that the rank order choice of each contract item with respect to contract length is mutually exclusive, i.e., respondent sees four types of contract for each contract length from which they rank them according to their preference .

Under ROL, it is implicitly assumed that each farmer is capable of performing the complete ordering task. Although, there is no ties on the ranking of the contract, ties are handled via the 'Efron' method in STATA, and unranked alternatives is coded as zero. For dummy explanatory variables, we report the coefficients and hence marginal effect for the outcomes that has highest frequency within each dummy variables categories. The coefficients of the ROL model are estimated using maximum likelihood method.

4.3.1. Price based Contract Attributes and Preference Ranking

For price based contract attributes entered as independent variable, 'formula with a ceiling price' (e.g. 10X the Chicago price, but no more than $50 per ton) is used as base alternative (or intercept case omitted) . Whereas for the quantity based contract ranking, the base alternative is 'capped production with no acceptance of additional beet material' is used a base alternative.

(Table 4 can be here).

Three of the contract attributes were positive and statistically significant, and the positive coefficients indicates that contract items high on order of magnitude are more preferred relative to the base contract item. Holding all other variables constant, relative to the base contract, farmers most likely to sign contract with 'formula with a floor prices' under long-term contract, i.e., when the energy beet price is set at ten times the Chicago nearby future corn price but with no less than $25 per ton. The results tell us that, on an all other things being equal basis, the odds of preferring or ranking 'formula with a floor prices' contract is about six times the odds of preferring 'formula with a ceiling price' if contract is offered as a long-term (five and ten years period)[2]. Albeit, farmers were most likely to sign with 'Fixed price' contract that set energy beet price at $35/ton if contract was offered as a short-term. At the same time, "Formula" (e.g. 10X the price of nearby Chicago corn futures) was the second most preferred contract item when

[2] The value of the parameter estimate is assumed to be linear in the attributes, with the coefficients expressing the direction and weight of the attributes. Holding all other variables constant, for a unit change in X_i, the odds are expected to change by a factor of $\exp(\beta_i)$, (Long and Freese 2001, p. 133.). The value of the parameter estimate is assumed to be linear in the attributes, with the coefficients expressing the direction and weight of the attributes

contract was offered over a long enough time horizon with odds of preferring twice times that of 'Formula with a ceiling price'.

Although, there could be uncertainty in beet and ethanol market and technological conditions, what is clear from this paper is that given the specific menu of contracts presented, over a long enough time horizon, farmers appear to choose "formula with a floor prices" contract most. This particular contract item may limit downside risk and pass some of the yield and price risk onto the biorefinery. At the same time, "Formula with a ceiling" was the least preferred contract as it might expose farmers to energy beets yield and price risk. Given the random utility model assumptions, all else being equal, farmers' utility is likely increases most if they sign with contract mechanisms that relate energy beet prices to Chicago corn futures price with guaranteed minimum floor prices no less than $25 per ton. Looking at previous studies, for example, Yang et al (2015) found that offering only a revenue-sharing contract will lead to the largest relative losses in the profits of the refinery compared to offering a menu consisting of the three contract types. In addition, Okwo and Thomas (2014) found that a wholesale contract, in which the farmer is guaranteed a price per unit biomass, is most effective on the highest quality of land, while a contract in which the farmer is guaranteed a price per acre is most effective on lower quality land.

Our results also provide estimates of the probability of farmers' ranking a particular contract as a most preferred contract, at bottom of Table 4. The predicted probability shows that, over one year contract length, 'fixed price' contract item was chosen as top-ranked contract with a 44% probability while 'formula with a floor price" has got a 30% probability as a first choice. In contrast, over five and ten year contract length, "Formula with a floor price" ranked as first choice with probabilities of 52 % and 50% respectively. Whereas, farmers have a probability of

6, 8 and 9 % of choosing "Formula with ceiling price" as a first choice contract over one, five and ten year period respectively, implying this contract type is the least preferred contract that farmers are willing to sign contract to supply beet biomass.

4.3.2. Quantity based Contract Attribute and Preference Ranking

With regard to quantity based contracts, all else being equal, farmers most preferred contract is "All Production" , with odds of preferring about nine times than 'capped production with no acceptance of additional energy beet materials' both over one, five and ten years contract length respectively. Likewise, contract that capped production with a negotiated price for any additional production was preferred twice more than the base contract over the short and long-term periods respectively. Finally, all production with a minimum requirement that needs to be met by the farmer is the third ranked contract relative base contract type. To this end, the empirical results under quantity based contract mechanism seem somewhat counterintuitive, as farmers are willing to supply all what they produced, therefore, may be less willing to negotiate even with going energy beets price to supplying an amount less than from what they potentially produced. This make sense in hindsight given that storage and handling of beets add significant cost to the farmers if they wish to store portion of the produced beets for future sale. In addition, although quality premiums is not in the contract clauses, farmers may have the knowledge about the shelve life of energy beet as it is the case that beet sucrose content quickly deteriorate unless it transported and processed fairly quickly.

With regard to the probability of being ranked most, again "All production" has a probability of 64, 61 and 69 % of being ranked the most preferred contract over all contract lengths considered respectively (see at the bottom of Table 4). With long-term contract, five and ten years contract length, the “negotiated” and “minimum” come second and third each with a probability of about 17% and 15% respectively. It is interesting to see that farmers consistently maintained the preference ranking of “All production”, “negotiated”, “minimum” and “no acceptance” contract items as their first, second, third and fourth choice across all contract lengths.

Finally, the probability results on price and quantity based contract show no clear biases towards each ranking as respondent did not tempt to sort them according to the order in which the contracts appeared in the survey. However, in the price based contract, respondent farmers was able to sort the least preferred items, “formula with a ceiling price “ according to the order in which it appeared in the survey. Our empirical analysis support the notion that the optimal contract likely ensures risk sharing between landowners and the biorefinery to minimize their joint risk premia (Alexander et.al 2012), which in our case probably the contract that incorporates both a floor and a ceiling price. Most importantly, Alexander et al (2012) elaborated key challenges for biorefineries as a principal agent to design a contract that provides just the right incentives for growers with different risk profiles to select a contract that is best suited for them. Their observation with regard to contract mechanism design for biomass for bioenergy production is that contracts must be well designed to ensure incentive compatibility and avoid participation constraints.

4.4. Demographics and Farm Characteristics on Contract Ranking

We turn now to explore how demographic and farm operational attributes are affecting famers' ranking of contact preferences. Independent variables in the ROL regression include, among others, (1) categorical demographic variables: age (25-34 years of age used as reference) [3], (2) education (high school diploma), (3) annual farm sale (sale less than $100,000), (4) membership to input and processing cooperatives (previously a member), and finally binary variables are : having a row planter, experience of farming for more than ten years' and if farmers are near to retirement ("No" as reference). Finally, two of the continuous variables are total acres planted to crops in year 2014 and total number of employees including full time and part-time.

The regression results for both models illustrate that, many of parameters on measured farmers attributes and farm operation information included as explanatory are statistically significant. The direction and order of magnitude of parameter estimates on demographic (except education) and farm characteristics variables for the price and quantity based contract are more or less similar (see Table 4 and 5). Differences are due mostly to the size of the coefficients. Thus, if coefficient is greater than 0 means that the respondents assigns higher value to a categorical variable depicted in the tables than to their respective base reference case. For expository reasons, we focus our discussion mainly on variables whose coefficients are significant. For example, the positive coefficient on age indicates that older farmers prefer to supply beet biomass with the most preferred contract with the odds of about twice than younger farmers when contract length are one and ten years respectively. With respect to education, the odds of having positive preferences towards signing contract with most preferred contract are about 0.6 times smaller for farmers that have undergraduate degree than with high school diploma. Likewise, the odds of having positive preferences towards signing contract with most

[3] Reference case omitted for each variable is placed in the bracket.

preferred contract type are 0.5 to 0.9 times smaller for farmers that have an annual sale greater than $1 million than sales less than $100,000.

In addition, our model investigates the potential influences of ownership to row planter on farmers' ranking ability to the most preferred contract type. Apparently, owning a row planter has a negative effect on the contract preference ranking for both price and quantity based contract respectively (Table 4 and 5). Ownership of specific farm equipment such as row planter is increasingly associated with asset fixity and contract hold-up issues. For biofuel feedstock, previous studies (Altamn et al. 2013; Qualls et al. 2012) found a strong positive correlation between willingness to supply biomass and ownership of equipment related to production and harvesting of biofuel feedstock

Having large or small farm size, number of employee , being a member in processing cooperative and whether farmer is close to retirement are all not statistically significant, and implying that these attributes do not likely to affect the ranking ability of farmers preference both under price and quantity based contract designs. However, having more than ten years of farming experience is positive and statistically significant in affecting ranking ability of quantity based contract items but in case of price based contract having experience is not likely affect ranking ability. In addition, we did not find evident as being a member of input coops to affect the ranking of quantity based of contract whilst it is negative and statistically significant on price based contract ranking.

4.5. Latent Perception Factors on Farmers' Contract Preference Ranking

Turning to latent class factor variables that are included as explanatory variables in the ROL models, among three risk and attitude perception factors included in the model, Factor 1 and 3 are statistically significant in affecting the ranking of price and quantity based contract respectively. It implies that, all else being equal, higher favorable perception of farmers' towards Factor 1 significantly affects the probability of the attribute being ranked first negatively. As such, the mean value of the nine attitudinal questions included in factor 1 category is greater than three with an average of 3.76 as shown in Table 1A in appendix. Among which, farmers showed greater concern on chemical carryover of growing beets and positive attitude towards environmental stewardship efforts.

While the parameter estimates on factor 3 is positive and statistically significant in affecting farmers' ranking ability of quantity based contract items. On the contrary, factor 3 is not likely to affect the price based contract preference ordering under one and five years of contract periods respectively, however it positively affects when the contract is offered for longer time period. In fact, factor 3 relates to farmers' preference to engage in marketing organization and signing contract in a vertically organized supply chain. That is, higher favorable perception of farmers' towards the associated Factor 3 significantly affects the probability of the attribute being ranked first, all else being equal.

4.6. Latent Class Contract Rank Order

Thus far, our analysis is based on ROL model given the assumption that respondent farmers are capable of ranking all four contract according to their preferences. In practice, farmers may sometimes not perform the ranking task according to their true preferences. Reason explain: sorting task itself too complicated or time consuming, respondent may not be able to distinguish between his less-preferred alternatives. Thus, the parameter estimates of the ROL model based on reported rankings may lead to a substantial bias (Chapman and Staelin 1982; Hausman and Ruud 1987; Fok et al. 2012).

(Table 5 can be here).

To deal with ranking inability, we created latent-class rank-ordered by taking all observed rankings but considering only the most and least preferred contract items. In effect, we are assuming that, out of the four contract items, respondents are only able to rank the most and least preferred contract items correctly according to their preferences, the remaining two items being ordered randomly. In addition, we also assumed that contract items that left unranked are considered the least preferred than the ranked alternatives as farmers may have either problems or not interested to rank the contract item. Also, when respondent farmers left contract items unranked, we are assuming that farmers are not indifferent between the unranked alternatives.

Given these assumptions, we run the latent-class rank-ordered logit model (LCROL) taking the most preferred, $P_1 = 1$, the least preferred, $P_4 = 4$ and the unranked $P_0 = 0$. The results of LCROL is reported on Table 5. Also, we conducted a likelihood ratio test to test whether some individuals are able to rank all alternatives ranking. Based on LR tests, the restricted model is preferred relative to the full model as an indication that respondents' farmers were not capable of ordering all contract according to their preferences.

The parameter estimates of LCROL models are very similar in signs and the order of magnitude falls in the range between with the parameters obtained using full rank models presented in Table 3. In few exception, even though signs are consistent, some predictors such as annual farm sale no longer exert statistically significant influences on rankings of price based contract. Albeit, being a member of processing coop has a significant effect on the ranking capability of choosing the most and least preferred contract items from quantity based contract which was not otherwise when respondent farmers allowed to strictly rank all contracts in the order of their preferences.

5. Conclusions and Implications of the Findings

This study analyzes the effects of price and quantity based contract mechanisms, farmers' demographic, farm operation and risk preferences on willingness to grow and supply biomass for ethanol production in a vertically integrated biomass supply chain. A stated choice experiment was designed to elicit farmer preferences to grow energy beets under alternative contracts in selected counties of North Dakota. Empirically, the study developed a rank-order logit model that explores how farmers' risk preference and contract attributes affect their ranking preferences of contracts from a menu of contract items to grow and supply energy beets given the technological and resource constraints. Factor analysis is used to group farmers' risk perception responses into three latent class factors. The resulting risk factors are then included as an explanatory variables in the rank-order logit regression models.

Our empirical results show that, under price based contract, farmers are likely to prefer contract that set fixed price when contract is offered for short-term, however under long term contract, farmers are mostly likely to sign contract that set energy beet price with the Chicago nearby future corn price but with a floor price no less than $25 per ton. In contrary, contract that set energy beet price with the Chicago nearby future corn price but with a ceiling price no more than $50 per ton is the least preferred contract type that farmers are willing to sign irrespective of contract lengths. In quantity based contract mechanism, our model results illustrate that contract item that limit quantity delivery requirement become less preferable even if farmers are allowed to negotiate on delivery price. In addition, results show that risk perception factor related to vertical integration and market organization, plays a significant role with respect to farmers' preferences to grow energy beets under contract. For respondent farmers, age, education, annual farm sale has remarkably significant influence on the preference of the rank ordering of price based contract items.

Although technical feasibility studies provide information about the technological and economic viability of the pathway of energy beet ethanol, such studies do not necessarily render information about farmer's willingness to engage in energy beet production and supply. As such, energy beets is a relatively new enterprise compared with conventional energy crops with no commercial history and without well-function market and supply chains, which intern poses significant organizational challenges both for potential farmers and biorefineries. Under such conditions, analysis of the impacts of potential contract attributes and farmers' risk preferences is crucial to identify potential barriers to adoption of energy beet biomass and create an efficient biomass supply chain that can help to procure biomass in a cost effective manner to support the development of advanced biofuel industries.

To sum up, this study provides insights in understanding farmers' preferences for key contract attributes and thus, the results potentially contribute to the development of new advanced biofuel feedstock production possibilities by illustrating the factors that affect farmers' decision making. Our empirical modeling approach provides insights into farmers' preferences for key contract attributes and helps to explore factors that affect farmers' decision making when they are offered a contract by biofuel refinery owners. It also helps to identify the ways that biomass production in a region may be vertically integrated with biofuel industries.

References

Alexander, C., Ivanic, R., Rosch, S., Tyner, W., Wu, S. Y., & Yoder, J. R. (2012). Contract theory and implications for perennial energy crop contracting. Energy Economics, 34(4), 970-979.

Allison, P. D., and Christakis, N. (1994). Logit models for sets of ranked items. In Vol. 24 of Sociological Methodology, ed. P. V. Marsden, 123–126. Oxford: Blackwell.

Altman, I., Bergtold, J., Sanders D.R., & Johnson, T. G. (2013). Market development of biomass industries. Agribusiness 29 (4): 486-496.

Babcock, B.A., Marette, S., & Tre´guer, D. (2010). Opportunity for profitable investments in cellulosic biofuels. Energy Policy (39) 714–719.

Bard, S. K., & Barry P. J. (2000). Developing a Scale for Assessing Risk Attitudes of Agricultural Decision Makers. International Food and Agribusiness Management Review, 3, 9-25.

Bard, S. K., and P. J., Barry. (2001). Assessing Farmers' Attitudes toward Risk Using the "Closing-in" Method. Journal of Agricultural and Resource Economics, 26(1), 248-260.

Beggs S, S.Cardell and J.A., Hausman. 1981. Assessing the potential demand for electric cars. Journal of Econometrics 16: 1–19.

Bergtold, J. S., P. A.Duffy, Hite, D., and R.L, Raper. (2012). Demographic and Management Factors Affecting the Adoption and Perceived Yield Benefit of Winter Cover Crops in the Southeast. Journal of Agricultural and Applied Economics, 44(1), 99-116.

Boxall, P. C., and W.L. Adamowicz. (2002). Understanding Heterogeneous Preferences in Random Utility Models: A Latent Class Approach. Environmental and Resource Economics, 23, 421-446.

Caldas, M.M., J. Bergtold, J. Peterson, R. Graves, D. Earnhart, S. Gong, B. Lauer, and J. Brown. (2014). Factors Affecting Farmers' Willingness to Grow Alternative Biofuel Feedstocks across Kansas. Biomass and Bioenergy. 66 (7): 223-231

Chapman, R. and R.Staelin.(1982). Exploiting rank ordered choice set data within the stochastic utility model. J. Mark. Res. 19, 288–301.

Coyle, W.T. (2010). Next-Generation Biofuels Near-Term Challenges and Implications for Agriculture. United States Department of Agriculture, Economic Research Service. http://www.ers.usda.gov/media/122837/bio0101.pdf (Accessed May 20, 2015)

Energy Independence and Security Act of 2007, Public Law 110-140. (2007). Available: http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf (Accessed, May 18, 2015).

Epplin, F., C. Clark, R. Roberts, and S. Hwang. 2007. Challenges to the Development of a Dedicated Energy Crop. American Journal of Agricultural Economics 89 (5): 1296-1302.

Epplin, F.M. and M. Haque. (2011). Policies to facilitate conversion of millions of acres to the production of biofuel feedstock. Journal of Agricultural and Applied Economics 43:385-398.

Fok, D., R.Paap and B. Van Dijk. (2012). A rank-ordered logit model with unobserved heterogeneity in ranking capabilities. J. Appl. Econ. 27, 831–846.

Hausman, J. A., and P. A. Ruud. (1987). Specifying and testing econometric models for rank-ordered data. Journal of Econometrics 34: 83–104.

Jensen, K., C. D. Clark, P. Ellis, B. English, J. Menard, M. Walsh, and De la Torre Ugarte. 2007. “Farmers willingness to grow switchgrass for energy production,” Biomass and Bioenergy 31: 773 -781.

Jensen, K. L, C. D. Clark, B. C. English, and R. J. Menard. (2011). Preferences for Marketing Arrangements by Potential Switchgrass Growers. Journal of Cooperatives 25: 16-43.

Kaiser, H.F. 1974. An index of factorial simplicity. Psychometrika 39, 31–36.

Lajili, K., P. Barry, S. Sonka, and J. (1997).Farmers’ Preferences for Crop Contracts. Journal of Agricultural and Resource Economics 22,2 (1997): 264-280.

Larson, J. B. English, and L. He. (2008). Economic Analysis of Farm-Level Supply of Biomass Feedstocks for Energy Production Under Alternative Contract Scenarios and Risk. Farm Foundation Conference, Atlanta, Georgia, February 12-13.

Long, J. S., and J. Freese. (2001). Regression Models for Categorical Dependent Variables Using Stata. 1st Ed. College Station, TX: Stata Press.

Martens, B.J., M.R. Crum, and R.F. Poist. (2011). Examining Antecedents to Supply Chain Security Effectiveness: An Exploratory Study. Journal of Business Logistics 32:153– 66.

Maung, T. and C.R.Gustafson (2011). The economic feasibility of sugar beet biofuel production in Centeral North Dakota. Biomass and Bioenergy 35: 3737-3747.

McFadden D. (1973). Conditional logit analysis of qualitative choice behavior. In Frontiers in Econometrics, Zarembka P (ed.). Academic Press: New York; 105–142.

McFadden D. 1974. The measurement of urban travel demand. Journal of Public Economics 3:303–328.

McGrath J.M and B.J.Townsend. (2015). Sugar Beet, Energy Beet, and Industrial Beet," in Industrial Crops: Breeding for BioEnergy and Bioproducts, vol. Volume 9, New York, USA, Springer, pp. 81-99.

Qualls, D. J., K. L. Jensen, C. D. Clark., B. C. English, J. A. Larson and T. S. Yen. (2012). Analysis of factors affecting willingness to produce switchgrass in the southeastern United States, Biomass and Bioenergy 39: 159 – 167.

Rajagopal, D., S.E. Sexton, D. Roland-Holst, and D. Zilberman. (2007).Challenge of Biofuel: Filling the Tank without Emptying the Stomach?” Environmental Research Letters 2:1-9.

Renewable Fuel Association.(2015). http://www.ethanolrfa.org/pages/statistics(Accessed May 26, 2015).

Roe, B., T. L.Sporleder, and B. Belleville. (2004). Hog Producer Preferences for Marketing Contract Attributes. American Journal of Agricultural Economics, 86(1), 115-123.

Train, K. E. 2008. Discrete Choice Methods with Simulation. Cambridge, UK: Cambridge University Press.

Wamisho, K., D., Ripplinger, A., De Laporte. (2015). Cost of joint Production of Industrial Sugar and Ethanol using Energy Beets in the Northern Plains of United States. Biofuels, Bioprocessing and Biorefining (Biofpr). DOI: 10.1002/bbb.1585.

Yang, X., N.D. Paulson, and M. Khanna. (2015). Optimal Mix of Vertical Integration and Contracting for Energy Crops: Effect of Risk Preferences and Land Quality. Applied Economic Perspectives and Policy. Vol. 0, no 0, pp. 1–23. doi:10.1093/aepp/ppv029.

Table

Table 1. Variable Descriptions and Summary Statistics of Farmer Willing to Grow Energy beet for Rank Order Logit Analysis

Variable	Description of Categories	Mean	St. Dev.
Age	1=<25, 2= 25-34, 3=35-44, 4=45-54, 5=>55 years	3.698	1.231
Education	1= some high school, 2=high school diploma, 3=some college, 4=undergraduate degree, 5=graduate degree	3.429	0.939
Total annual sale	annual farm sale 1=<$100,000, 2=$100,000-$499,000, 3=$500,000-$999,999, 4=>$1 million	3.032	0.960
Acreage	Total acres planted to crop in 2014	3401	2937
Employees	Total number of partime and fixed employee	1.619	2.251
Experience	1=yes farmed for more than 10 years, 2=No	1.857	0.350
Retiring	1=yes to near retirement, 2=No	1.254	0.436
Input Coops	1=yes to member to input coops, 2=previously, 3=No	2.143	0.941
Processing Coops	1=yes to member to a process coops 2=previously, 3=No	2.698	0.581
Row Planter	1=yes to own a row planter, 2=No	1.790	0.407
Factor 1	(2 ,8, 9, 14, 17, b19, b20, b21, b22)	3.764	0.538
Factor 2	(1, 5, 7, 10, 11, 13, 15)	2.878	0.333
Factor 3	(b3, b4, b6, b18)	2.873	0.5582

Note: the number in parenthesis for factor 1 to 3 denotes attitudinal questions number displayed in Table 3.column 1.

Table 2.Mean Ranking of Price and Quantity based Contracts by Contract Attribute

	Contract length				Contract length		
Price	1 Year	5 Years	10 Years	Quantity	1 Year	5 Years	10 Years
Floor	2.03	1.61	1.69	All	1.39	1.42	1.45
	(0.84)	(0.82)	(0.83)		(0.84)	(0.8)	(0.86)
Fixed	1.62	2.31	2.37	Negotiated	2.44	2.37	2.4
	(0.93)	(1.1)	(1.15)		(0.89)	(0.92)	(0.97)
Formula	2.62	2.57	2.48	Minimum	2.71	2.62	2.64
	(0.8)	(0.91)	(0.95)		(0.85)	(0.89)	(0.89)
Ceiling	3.58	3.41	3.42	No accept	3.49	3.64	3.54
	(0.83)	(0.85)	(0.81)		(0.84)	(0.64)	(0.73)

Legend: Price and quantity rank (=1, 2, 3, and 4: from most to least preferred). Price attribute (1= Ceiling, 2=Fixed, 3= floor, and 4=formula), Quantity attribute (1= all prod, 2= minimum, 3= negotiated, and 4= no-add), Contract *length (1, 5, 10 years). Standard deviation is in parentheses.*

Table 3. Factor loading for attitudinal questions: empty cells shows factor loads that are less than 0.3.

Attitudinal questions	Factor1	Factor 2	Factor 3	Uniqueness[4]
1. I am hesitant to change my crop rotation		-0.555		0.178
2. I am more likely to grow new crops when my current crop prices are low	0.584		0.366	0.353
3. I prefer to use technologies I am familiar with rather than adopting new on		-0.304	0.404	0.161
4. I prefer to conduct business as a member of a cooperative			0.387	0.257
5. I prefer short-term supply contracts than long terms ones		-0.349		0.360
6. Contracts should tie the price I receive for beets to the price of other crop			0.342	0.210
7. I need higher returns when growing new crops	0.446	-0.651		0.287
8. I am willing to make capital investments for new on-farm enterprises	0.653			0.359
9. I am willing to lease equipment	0.419	0.409		0.427
10. I have a high tolerance for financial risk		0.337		0.253
11. I am willing to grow crops without insurance	-0.354	0.432		0.181
12. I prefer to harvest myself, rather than hire it done				0.236
13. Labor availability during harvest is not an issue in my area		0.373		0.209
14. I am willing to hire extra labor to harvest my crops, if necessary	0.586	0.412		0.341
15. I am willing to receive lower returns to support local economic development		0.627	0.409	0.191
16. I consider myself well educated on environmental issues				0.280
17. I consider my operation to be environmentally friendly	0.464			0.222
18. I am willing to receive limited returns to provide environmental benefits			0.630	0.228
19. I require price premiums to grow environmentally friendly products	0.430		-0.336	0.262
20. Chemical carryover is a concern for beets	0.553			0.353
21. Beets provide soil health benefits	0.668			0.371
22. Beets have a spot in my rotation	0.566	0.388		0.288

[4] Uniqueness is the variance that is 'unique' to the variable and not shared with other variables. Notice that the greater 'uniqueness' the lower the relevance of the variable in the factor model.

Table 4. Estimates of Coefficient for ROL Model: Price and Quantity Based Contract

	Price based contract			[a]Quantity based contract		
Variable	One Year	Five Year	10 Years	One year	Five year	10 years
Fixed price	1.947***	0.903**	0.810**	2.226***	2.178***	2.009***
	(0.33)	(0.29)	(0.28)	(0.38)	(0.31)	(0.31)
Formula with a fixed price	1.111**	0.819**	0.882***	0.803***	0.904***	0.797***
	(0.34)	(0.27)	(0.25)	(0.17)	(0.17)	(0.20)
Formula with a floor price	1.600***	1.818***	1.717***	0.646***	0.763***	0.639***
	(0.35)	(0.28)	(0.26)	(0.13)	(0.16)	(0.17)
Age: >55 years	0.732***	0.322	0.817***	0.475*	0.693*	0.371
	(0.16)	(0.25)	(0.16)	(0.24)	(0.29)	(0.25)
Education: undergraduate degree	0.732***	0.385+	0.817***	-0.816*	-0.844*	-0.780**
	(0.16)	(0.20)	(0.16)	(0.35)	(0.35)	(0.29)
Annual farm sale: >$1mn	-0.664+	-0.164	-0.685*	0.142	-0.012	0.321
	(0.34)	(0.39)	(0.33)	(0.45)	(0.50)	(0.48)
Acreage	0.000	0.000	-0.000	-0.000	-0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Total employee	0.016	-0.038	0.108*	0.075	0.123	0.053
	(0.041)	(0.06)	(0.05)	(0.07)	(0.08)	(0.07)
Experience in farming:> 10 years	0.222	-0.212	0.042	0.886*	0.913+	0.825+
	(0.17)	(0.22)	(0.21)	(0.44)	(0.47)	(0.43)
Not close to retirement	-0.032	-0.080	-0.138	-0.121	-0.129	-0.068
	(0.29)	(0.25)	(0.23)	(0.37)	(0.40)	(0.39)
Member to Input coop	-0.517+	-0.595*	-0.786*	-0.434	-0.488	-0.320
	(0.30)	(0.28)	(0.32)	(0.39)	(0.39)	(0.37)
Member to Process coop	0.166	0.065	0.151	0.111	0.110	0.023
	(0.27)	(0.26)	(0.28)	(0.29)	(0.28)	(0.26)
Owns Row planter	-0.532*	-0.620**	-0.742***	-0.867*	-0.959**	-0.750*
	(0.23)	(0.21)	(0.21)	(0.35)	(0.35)	(0.32)
Factor 1	-0.467*	-0.277+	-0.343*	0.033	-0.036	0.001
	(0.19)	(0.15)	(0.16)	(0.34)	(0.34)	(0.34)
Factor 2	0.601	0.363	0.509	-0.077	-0.079	-0.108
	(0.39)	(0.37)	(0.38)	(0.33)	(0.35)	(0.30)
Factor 3	0.370	0.421	0.497*	0.885***	0.942**	0.801**
	(0.29)	(0.28)	(0.22)	(0.26)	(0.33)	(0.27)
P_0	0.196	0.215	0.219	0.156	0.165	0.169
P_1	0.336	0.344	0.334	0.507	0.488	0.476
P_2	0.276	0.284	0.286	0.226	0.232	0.232
P_3	0.236	0.237	0.240	0.150	0.160	0.165
P_4	0.153	0.131	0.137	0.125	0.128	0.135
AIC	901.3	921.3	927.1	885.3	879.8	897.5
BIC	943.5	963.5	972.7	927.5	921.9	943.2

Notes: Asterisks denote significance at the + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ levels. Standard errors in parentheses.
a: except the first three variable entry, the rest of the independent variables are similar for both price and quantity based contract. Under quantity based contract ranking, the parameter estimates

for the first three rows are for variable “All production”, “Negotiated”, and “Minimum produced” respectively.

Table 4 Parameters estimate for LROL using most and least preferred price contract items

Variable	Price based contract	[a]Quantity based contract
Fixed price	1.362***	2.064***
	(0.28)	(0.27)
Formula with a fixed price	0.611+	0.549
	(0.34)	(0.38)
Formula with a floor price	2.043***	0.123
	(0.26)	(0.31)
Age: >55 years	0.723**	0.674+
	(0.25)	(0.36)
Education: undergraduate degree	-0.675**	-1.194**
	(0.23)	(0.44)
Annual farm sale: >$1mn	-0.237	-0.047
	(0.62)	(0.59)
Acreage	0.000	-0.000
	(0.00)	(0.00)
Total employee	-0.019	0.093
	(0.07)	(0.09)
Experience in farming:> 10 years	0.230	0.941+
	(0.30)	(0.49)
Not close to retirement	0.035	-0.158
	(0.36)	(0.50)
Member to Input coop	-0.536***	-0.306
	(0.10)	(0.44)
Member to Process coop	0.255	1.364*
	(0.63)	(0.60)
Owns Row planter	-0.813***	-1.144**
	(0.24)	(0.36)
Factor 1	-0.558*	-0.153
	(0.27)	(0.49)
Factor 2	0.447	-0.0165
	(0.49)	(0.46)
Factor 3	0.587**	0.780*
	(0.22)	(0.39)
$P0$	0.217	0.156
	(0.031)	(0.022)
$P1$	0.722	0.744
	(0.013)	(0.016)
$P4$	0.258	0.227
	(0.012)	(0.015)
LR statistics	812.1	845.7
AIC	1650.3	1717.3
BIC	1701.8	1769.6

Standard errors in parentheses; $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

a: except the first three variable entry, the rest of the independent variables are similar for both price and quantity based contract. Under quantity based contract ranking, the parameter estimates for the first three rows are for variable “All production”, “Negotiated”, and “Minimum produced” respectively.

Appendix.

Table 1A. Summary statistics for attitudinal questions

Attitudinal questions	Mean	St. Dev.
I am hesitant to change my crop rotation	2.54	1.01
I am more likely to grow new crops when my current crop prices are low	3.68	0.83
I prefer to use technologies I am familiar with rather than adopting new on	2.86	1.02
I prefer to conduct business as a member of a cooperative	2.85	0.86
I prefer short-term supply contracts to long terms ones	3.39	0.84
Contracts should tie the price I receive for beets to the price of other crop	2.95	0.94
I need higher returns when growing new crops	4.06	0.73
I am willing to make capital investments for new on-farm enterprises	3.71	0.77
I am willing to lease equipment	3.40	1.16
I have a high tolerance for financial risk	3.00	0.91
I am willing to grow crops without insurance	2.40	1.05
I prefer to harvest myself, rather than hire it done	3.63	1.09
Labor availability during harvest is not an issue in my area	2.13	1.16
I am willing to hire extra labor to harvest my crops, if necessary	3.74	0.86
I am willing to receive lower returns to support local economic development	2.63	0.78
I consider myself well educated on environmental issues	3.67	0.67
I consider my operation to be environmentally friendly	4.02	0.60
I am willing to receive limited returns to provide environmental benefits	2.81	0.85
I require price premiums to grow environmentally friendly products	3.65	0.78
Chemical carryover is a concern for beets	4.03	0.90
Beets provide soil health benefits	4.18	0.77
Beets have a spot in my rotation	3.50	1.10

Note: The Likert scale for attitudinal questions on a scale from 1 = “strongly disagree” to 5 = “strongly agree”.

Table 2A. Estimates of Marginal Effect based on ROL Models

	Price based contract			Quantity based contract		
Variable	One Year	Five Year	Ten Year	One year	Five year	10 year
Fixed price	3.853**	2.669**	2.301**	4.990***	4.899**	4.412**
	(1.184)	(0.922)	(0.744)	(1.359)	(1.606)	(1.473)
Formula with a fixed price	3.818**	3.375***	3.282***	4.212**	4.397*	3.868*
	(1.474)	(1.002)	(0.872)	(1.436	(1.755)	(1.547)
Formula with a floor price	4.034**	4.668***	4.248***	4.042**	4.294*	3.693*
	(1.395)	(1.005)	(0.747)	(1.477)	(1.783)	(1.542)
Age: >55 years	1.492	1.424+	1.405*	2.587+	2.620	2.228
	(1.095)	(0.859)	(0.694)	(1.349)	(1.607)	(1.415)
Education: undergraduate degree	0.986	1.328	1.100	2.443+	2.475	2.111
	(1.158)	(0.892)	(0.751)	(1.346)	(1.621)	(1.398)
Annual farm sale: >$1mn	1.478	1.609*	1.372*	2.816*	2.710+	2.477*
	(1.021)	(0.782)	(0.689)	(1.180)	(1.415)	(1.236)
Acreage	1.184	1.430+	1.194+	2.453+	2.418	2.453+
	(1.120)	(0.850)	(0.674)	(1.343)	(1.600)	(1.343)
Total employee	1.185	1.433+	1.191+	1.185	1.433+	1.191+
	(1.121)	(0.850)	(0.675)	(1.121)	(0.850)	(0.675)
Experience in farming: > 10 years	1.376	1.251	1.228	3.210+	3.197+	2.828
	(1.212)	(0.989)	(0.772)	(1.687)	(1.919)	(1.736)
Not close to retirement:	1.161	1.372+	1.087+	2.360*	2.318+	2.071+
	(1.031)	(0.795)	(0.651)	(1.102)	(1.329)	(1.138)
Input coop: Previously	1.069	1.305	1.305	2.340	2.222	2.044
	(1.152)	(0.867)	(0.867)	(1.431)	(1.686)	(1.493)
Process coop: Previously	1.204	1.389	1.144+	2.412+	2.381	2.073
	(1.115)	(0.849)	(0.669)	(1.327)	(1.567)	(1.380)
Owns Row planter	0.765	0.943	0.943	1.767	1.658	1.529
	(0.963)	(0.701)	(0.701)	(1.337)	(1.513)	(1.373)
Factor 1	1.187	1.434+	1.193+	2.452+	2.416	2.122
	(1.121)	(0.850)	(0.675)	(1.343)	(1.599)	(1.399)
Factor 2	1.187	1.433+	1.193+	2.452+	2.416	2.122
	(1.121)	(0.850)	(0.675)	(1.343)	(1.599)	(1.399)
Factor 3	1.186	1.434+	1.193+	2.454+	2.418	2.124
	(1.121)	(0.850)	(0.675)	(1.344)	(1.600)	(1.400)

Note: Standard errors in parentheses, + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix C

THE EFFECTS OF SPATIAL CLIMATE AND SOIL CONDITIONS ON MODELED ENERGY BEET YIELDS AND BREAK-EVEN PRICES

By Aaron V. 'De Laporte' and David Ripplinger

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ABSTRACT

Volatility in agricultural prices has led farmers to pursue new cropping opportunities, including bioenergy and bioproduct industrial sugar precursors, such as energy beets. The viability of energy beet production is assessed using integrated agronomic and economic GIS-based techniques to determine yields and break-even prices in North Dakota. The results show that beet yields vary throughout the state, averaging 34.4 t/ha, and are highest in the East, in the Red River Valley, where soil quality is high, moisture is plentiful and heat is sufficient. Production is also viable in the central and northern regions of the state, where soil quality and moisture are less favourable than in the Red River Valley. A smaller scale ethanol plant (75 million liters) would be able to source sufficient materials for production in many locations throughout the state for prices around $30 per tonne.

KEYWORDS

Energy Beet; Bioenergy Feedstock Supply; Spatial Yield Estimation

1. INTRODUCTION

Volatility in agricultural markets has left agricultural producers searching for new opportunities to increase their returns, while promoting environmental sustainability and community development. The opportunity to grow ‘energy beets’ to provide industrial sugar for bioenergy and bioproduct production, from bioethanol to advanced biochemicals, could increase agricultural returns and benefit rural communities by encouraging the development of an industrial sugar industry.

The ‘energy beet’ is a hybrid sugar beet (*Beta Vulgaris*) that is optimized for sugar production, without worrying about impurities (REFERENCE). The production of energy beets is particularly attractive in more northerly areas, such as the US State of North Dakota, where sugar beet production is prevalent in the Red River Valley. Long summer days and cool fall temperatures help keep sugar content high and produce high quality beets. Sugar beets are also grown effectively in other parts of the US, Canada, Europe and across the world.

While beets have been effectively grown in many locations, their yields are uncertain outside traditional growth areas, making investments in beets particularly risky. The use of agronomic modelling techniques could estimate beet yields to reduce this risk. Beet yields have been modeled in a number of locations using various modelling techniques (Baey et al. 2014). Agronomic models have also been used to model alternate biomass crops (De Laporte et al. 2014). These kinds of agronomic models use estimates of daily temperature and solar irradiance to model plant growth and yield potential throughout the growing season. More advanced models incorporate considerations of precipitation and evapotranspiration and soil conditions to examine water limitations and soil quality.

Despite the possible benefits of beet production to agricultural returns and knowledge of modelled yields, the costs of energy beets also remain uncertain. While the production costs can be estimated using observations of nearby sugar beet production, the agricultural opportunity costs are likely to significantly factor into production decisions. If agricultural producers cannot make more money than they are currently making by choosing to substitute energy beets, they will not consider production.

As a result of the economic, yield and agronomic uncertainty faced by producers that could consider energy beet production, the purpose of this paper is to estimate the yields and the break-even farm-gate prices of energy beets in North Dakota. The paper employs an integrated agronomic and economic GIS-based model that incorporates site specific considerations of temperature, precipitation, solar irradiance and soil characteristics, along with energy beet production and opportunity costs.

The yields of biomass have been modeled in a number of contexts including a variety of bioenergy crops. Switchgrass and miscanthus availability have been modeled in a number of different contexts, including Illinois, US (Khanna et al. 2008), the Upper Midwest of the US (Jain et al. 2010), and Ontario, Canada (Kludze et al. 2013a, 2013b; De Laporte et al. 2014). The yields of beets, specifically sugar beets, have been modeled in European (Baey et al. 2014), Canadian (Pervin and Islam 2014) and Moroccan (Taky 2008) contexts. However, energy beet yields have not been assessed for the Upper Great Plains of the United States of America, particularly North Dakota. The model presented here also builds upon the beet modeling presented by Baey et al. (2014) by adding soil and moisture considerations, thereby moving beyond heat based climate potential.

2. METHOD

2.1 MODELED BIOMASS YIELDS

This study uses an adapted and extended version of one of five models presented in Baey et al. (2014). More specifically, this model extends the Pilote model from Taky (2008). The base class of models employed here use the premise of Monteith (1977), which asserts that daily plant growth can be summarized as the ability of the plant to intercept and use light to create biomass. In these kinds of models, daily biomass production equals:

$$Q(t) = 0.95 \cdot RUE \cdot PAR(t) \cdot I(t)$$

where *Q(t)* is biomass production (g/m2) on day *t*, *RUE* is the radiation use efficiency (g/MJ), *PAR(t)* is incoming photosynthetically active radiation (MJ/m2) on day *t*, and *I(t)* is the fraction of intercepted radiation at time *t*. *I(t)* is established based on the Beer-Lambert Law of light interception regarding plant growth envisioned by Monsi and Saeki (1953) and depends on the leaf area index (LAI).

In the Pilote model originally designed for sorghum and sunflower (Mailhol et al. 1996; 1997) and adapted for beets by Taky (2008), daily intercepted radiation equals:

$$I(t) = 1 - \exp(-k_B \cdot LAI(t))$$

where k_B is the Beer-Lambert law extinction coefficient. The daily leaf area index, a function of thermal time, equals:

$$LAI(t) = LAI_{max}\left(\frac{\tau(t) - \tau_e}{\tau_{max}}\right)^{\beta} exp\left[\frac{\beta}{\alpha}\left(1 - \left(\frac{\tau(t) - \tau_e}{\tau_{max}}\right)^{\alpha}\right)\right]$$

where LAI_{max} is the maximum potential value of LAI in non-limiting conditions, τ is the thermal time (°C day), τ_{max} is the thermal time (°C day) needed to reach LAI_{max}, τ_e is the thermal time of emergence (°C day), and α and β are two parameters.

Harvest considerations are incorporated into the Pilote model using an annual harvest index to portion the aboveground biomass from the root biomass after the annual yield has been calculated. Soil quality considerations are incorporated into the model using scaling techniques on biomass production based on the Crop Productivity Index (CPI). The effects of available water are considered using the method developed by Hargreaves and Allen (2003). Evapotranspiration in this model is a function of rainfall, soil moisture holding capacity and solar radiation. Growth was assumed to stop when available soil moisture fell below the holding capacity.

2.2 EMPIRICAL MODEL

Study Area

North Dakota is one of the northernmost states in the continental US. The majority of the state is in the Northern Great Plains of North America. It borders the Canadian provinces of Saskatchewan and Manitoba on the North, South Dakota on the South, Montana on the West and Minnesota on the East. The Eastern border of the state is defined by the Red River of the North. The Red River Valley contains fertile croplands and is a locus of sugar beet production in the US (Figure 1). For this study, the croplands of North Dakota were aggregated into 342,902 (600m by 600m – 36 hectare) cells. In terms of US area considerations, the unit of analysis in this study is approximately half of a quarter section.

According to the apportioned cropland data, the state as a whole has an annual daily average temperature of approximately 4.99 °C. Temperatures peak in July (20.7 °C) and reach their lowest points in January (-12.3 °C). Total annual average cumulative precipitation is 477 mm. Precipitation peaks in June (86.9 mm) and is lowest in February (11.7 mm). Average daily solar radiation exposure is 13.5 MJ/m^2. Solar radiation peaks in July (24.1 MJ/m^2) and is at its lowest point in December (3.6 MJ/ m^2).

(Figure 1)

The croplands of the state have an average crop productivity index of 0.277, ranging from 0 to 0.624 (). The most productive croplands are located in the Red River Valley in the East. The Southwestern portion of the state contains relatively fewer and less productive croplands and also generally receives less precipitation. The moisture holding capacity of the variety of soils underlying the croplands of North Dakota range from 0 to 684 mm, with an average of 228 mm. North Dakota has been segmented into 9 specific regions by the North Dakota State University Extension: Northwest; Southwest, North Central, South Central; East Central; Northeast; Southeast; North Valley; and South Valley.

Economic Model

This paper uses an annual crop production model to examine the break-even price of energy beet production, given site specific yields. The break-even price of energy beets in dollars per tonne at the farm gate is:

$$P^{BE} = \frac{(C^V + C^F + C^A)}{Q^B}$$

where Q^B is the yield of energy beets in tonnes, P^{BE} is the price received in dollars per tonne, C^V is the variable (direct) cost of production, C^F is the fixed (indirect) cost of production and C^A is the agricultural opportunity cost, which is an indirect cost.

Model Specification

The model calculates daily biomass production according to Section 2.1, then portions the produced biomass into a harvested yield. The yield is then used to calculate the farm-gate break-even price required to make energy beet production attractive in that cell. This calculation is conducted for each 342,902 (36 ha) agricultural land cells defined in North Dakota.

Daily temperatures, rainfall and solar radiation were extrapolated from NOAA climate data. Soil data from the USDA was used for moisture holding capacity and soil quality. Many of the parameters for the Pilote growth model were taken from Baey et al. (2014). LAI_{max} is 3.99, τ_{max} is 1830 °C days, τ_e is 140 °C days, α is 1.54 and β is 1.92. The Beer-Lambert law extinction coefficient, k_B, is 0.7. The radiation use efficiency (*RUE*) of energy beets is 4.12 g/MJ.

To calculate break-even prices, Q^B is determined by the model described in Section 2.1 and specified above. Energy beet total production amounts were scaled by 0.62, the highest CPI present in the dataset as a calibration measure and to reflect soil quality in energy beet production. The harvest index applied to energy beet production was 0.6 (). The fixed and variable costs of energy beet production have been estimated by North Dakota State University Extension. The results are summarized in Table 1. Agricultural opportunity costs were calculated using NDSU Crop Budgets from 2015. The rotations were used to calculate the region specific opportunity costs shown in Table 2.

(Table 1)

(Table 2)

3. RESULTS

The yield and break-even price results for this study are highlighted in Table 3. The average North Dakota yield of energy beets is 34.4 t/ha (σ=21.1). The average break-even price is $103.77/t ($\sigma$=125.9). Significant regional differences exist within North Dakota. Average yields range from 15.0 t/ha in the Southwest to 62.3 t/ha in the South Valley. Correspondingly, break-even prices range from $43.09/t in the South Valley to $188.96/t in the Southwest.

(Table 3)

The spatial distribution of energy beet yields for North Dakota is shown in Figure 2. This figure reveals the pattern described in Table 3. Beet yields are highest in the Eastern part of the state – the Red River Valley. Beet yields increase in this area from North to South, with the South Valley being the most advantageous. Beet yields decrease to the West, with the lowest yields observed in the dry and relatively poor soiled Southwestern region of the state.

(Figure 2)

The break-even prices of energy beets in North Dakota are shown in Figure 3. This figure shows that break-even prices generally follow the trends established in Figure 2, but with lower break-even prices in higher yield zones. Break-even prices are lowest in the South Valley, followed by the North Valley and the regions just west of the Red River Valley. Break-even prices are the highest in the Southwestern Region.

(Figure 3)

The ‘supply’ of energy beets shown in Figure 4 depicts the break-even price of beets that would begin to attract beet production at all levels. For example, at $30/t, 946,000 hectares of farmland would be able to break-even in beet production, as defined in Section 2.2. Similarly, at a price of $40/t, 2.5 million hectares of cropland would be able to break-even producing beets. The curve in Figure 4 shows that a more than three-quarters of North Dakota croplands would be attractive for beet production at $100/t.

(Figure 4)

4. DISCUSSION

The results of this study are expected in terms of beet production. High beet yields in the Red River Valley have driven sugar beet production for decades. Copious summer sunlight, sufficient moisture and cool fall temperatures, along with relatively excellent soil conditions, make this region ideal for beet production. The model confirms this and also confirms that beet growth is greater further east in the state. The dry and somewhat poor quality land in the Southwest is also expected to have the poorest beet yields, matching with the expected trend. Overall, the model performs as expected in general terms.

Given that the model was calibrated with data primarily from west of the valley and in the central latitudes of the state, it is possible that beet yields have been overestimated in the Red River Valley. Certain agronomic considerations, such as the root maggot, which is a major concern to beet producers in the Valley, were not considered in the model. These pressures may not exist in the early stages of beet production outside of the Valley, as the prevalence of the pest is not high. This would, correspondingly, reduce the expected yield of beets and raise the expected break-even price. The problems presented by the locality of model calibration likely extends to production at the periphery in all parts of the State. Yields could be higher in certain areas, especially if irrigated production is a consideration, or lower, depending on a number of factors, including sloped production and pesticide use.

Agricultural opportunity costs are included in the break-even price values presented in this paper. However, they are regional and represent averages for the region. Therefore, the break-even prices presented do not have the same quality of spatial information as yields. This causes underestimation, when land value is higher than average, and overestimation, when the value of the land is lower than average, of specific croplands regarding break-even prices. The break-even price values represent regional averages and expectations for the cost of energy beet production.

Energy beet production in the region is expected to include small-scale bioethanol plants and other applications of industrial sugar, such as high value chemicals. For reference, a small scale beet-ethanol plant may only produce 75 million liters of ethanol per year (Maung and Gustafson 2011). This plant would require approximately 714,000 tonnes of beets at a conversion rate of 106 l/t. This would require 21,000 hectares of land at an average yield of 34.4 t/ha. From the results in Figure 4, this amount of acreage would be easily available at a price of less than \$30/t. Additional spatial factors, such as transportation distances and beet logistics need to be considered to further estimate plant viability and siting, but potential interest in energy beet production should not be a problem, from a simple monetary standpoint.

5. CONCLUSIONS

Energy beet-based ethanol shows promise as an opportunity to increase farm revenues and spur the development of bio-based industry in the state of North Dakota given unsteady agricultural commodity prices. This study employs integrated agronomic and economic GIS-based techniques to calculate the yields and break-even prices of energy beets for bioenergy production in North Dakota to assess the initial stages of viability. It shows that beet yields vary throughout the state, averaging 34.4 t/ha, and are highest in the East, in the Red River Valley, but production is also viable in the central and northern regions of the state. A smaller scale ethanol plant (75 million liters) would be able to source sufficient materials for production in many locations throughout the state for prices around $30 per tonne.

REFERENCES

Baey, C., A. Didier, S. Lemaire, F. Maupas, P. Cournede. 2014. Parametrization of five classical plant growth models applied to sugarbeet and comparison of their predictive capacity on root yieldand total biomass. Ecological Modelling 290, 11-20.

De Laporte, A., Weersink, A., McKenney, D., 2014. A spatial model of climate change effects on yields and break-even prices of switchgrass and miscanthus in Ontario, Canada. Global Change Biology Bioenergy 6(4), 390-400.

Hargreaves, G.H., Allen, R.G., 2003. History and Evaluation of Hargreaves Evapotranspiration Equation. Journal of Irrigation and Drainage Engineering 129, 53-63.

Jain, A., Khanna, M., Erickson, M., Huang, H., 2010. An integrated biogeochemical and economic analysis of bioenergy crops in the Midwestern United States. GCB Bioenergy 2, 217-234.

Khanna, M., Dhungana, B., Clifton-Brown, J.C., 2008. Cost of producing Miscanthus and switchgrass for bioenergy in Illinois. Biomass and Bioenergy 32, 482-493.

Khanna, M., Onal, H., Dhungana, B., Wander, M., 2011. Economics of herbaceous bioenergy crops for electricity generation: Implications for greenhouse gas mitigation. Biomass and Bioenergy 35, 1474-1484.

Kludze, H., Deen, B., Weersink, A., van Acker, R., Janovic, K., De Laporte, A., 2013a. Impact of land classification on potential warm season grass biomass production in Ontario, Canada. Canadian Journal of Plant Science 93, 249–260.

Kludze, H., Deen, B., Weersink, A., van Acker, R., Janovic, K., De Laporte, A., McDonald, I., 2013b. Estimating sustainable crop residue removal rates and costs based on soil organic matter dynamics and rotational complexity. Biomass and Bioenergy 56, 607-618.

Monsi, M., Saeki, T., 1953. Über den lichtfaktor in den pflanzengesellschaften und seine bedeutung für die stoffproduktion. Japanese Journal of Botany 14, 22–52.

Monteith, J.L, 1977. Climate and the efficiency of crop production in Britain. Philosophical Transactions of the Royal Society B281, 277–294.

Table 1: Variable and fixed production costs of energy beets in North Dakota without agricultural opportunity costs.

Direct (Variable) Costs	
-Seed	150.00
-Crop Chemicals	75.00
-Fertilizer	100.00
-Crop Insurance	25.00
-Fuel & Lubrication	65.00
-Repairs	90.00
-Miscellaneous	45.00
-Operating Interest	15.00
Total Direct	565.00
Indirect (Fixed) Costs	
-Misc. Overhead	60.00
-Machinery Int. & Dep.	75.00
-Land Charge	AOC
Total Indirect	135.00
Total Cost w/o AOC	700.00

Table 2: Regional breakdown of agricultural rotations and opportunity costs in North Dakota.

Region	Rotation				Opportunity Cost ($/ha)
NW	Wheat	Lentils	Barley	Flax	$261.82
SW	Wheat	Corn	Wheat	Sunflower	$177.85
NC	Wheat	Sunflower	Barley	Flax	$298.68
SC	Wheat	Soybean	Corn	Sunflower	$224.07
EC	Corn	Soybean	Wheat	Soybean	$264.52
NE	Wheat	Soybean	Barley	Canola	$253.25
SE	Corn	Soybean	Wheat	Soybean	$331.80
NV	Corn	Soybean	Wheat	Drybeans	$329.55
SV	Corn	Soybean	Wheat	Soybean	$337.62

Table 3: Regional breakdown of mean CPI, MHC, temperature, solar radiation, annual precipitation, energy beet yields, agricultural opportunity costs and energy beet break-even prices.

Region	CPI	MHC (mm)	Temperature (°C)	Solar Radiation (MJ/m^2)	Annual Precipitation (mm)	Yield (t/ha)	AOC ($/ha)	Beet BEP ($/t)
All	0.277	228	5.0	13.5	477	34.4	269.28	103.77
NW	0.238	238	5.0	13.5	398	21.8	261.81	128.66
SW	0.207	203	6.1	14.2	417	15.0	177.84	188.96
NC	0.271	233	4.4	13.3	457	31.1	298.68	99.23
SC	0.257	222	5.5	13.8	475	26.7	224.07	133.25
EC	0.294	231	4.9	13.4	495	36.3	264.53	85.65
NE	0.257	239	3.6	13.0	503	40.9	253.23	65.23
SE	0.324	240	5.5	13.6	545	47.7	331.81	65.48
NV	0.364	231	4.1	13.0	519	55.9	329.56	52.04
SV	0.375	232	5.5	13.4	582	62.3	337.62	43.09

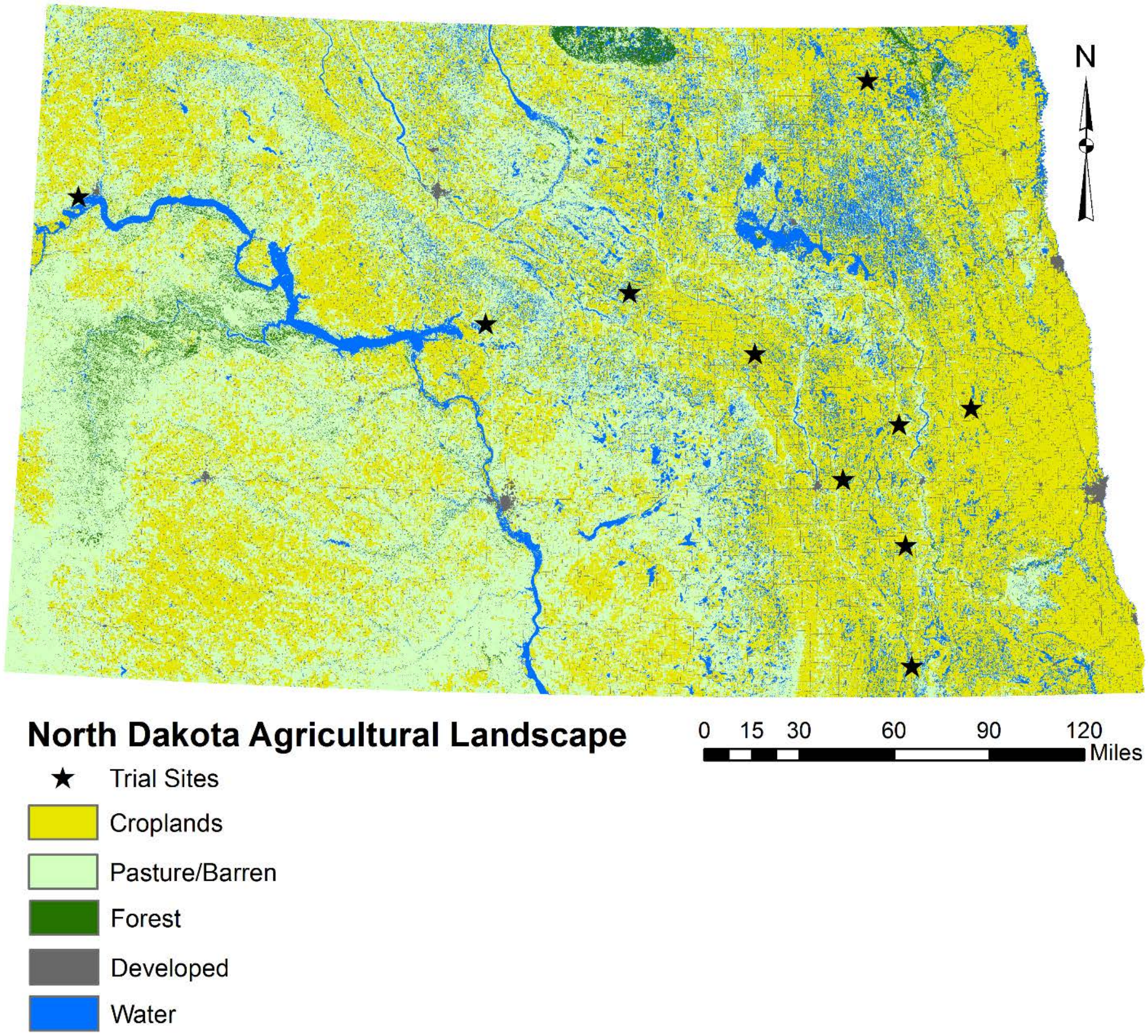

Figure 1: Land use in North Dakota highlighting agricultural lands, natural lands and developed areas.

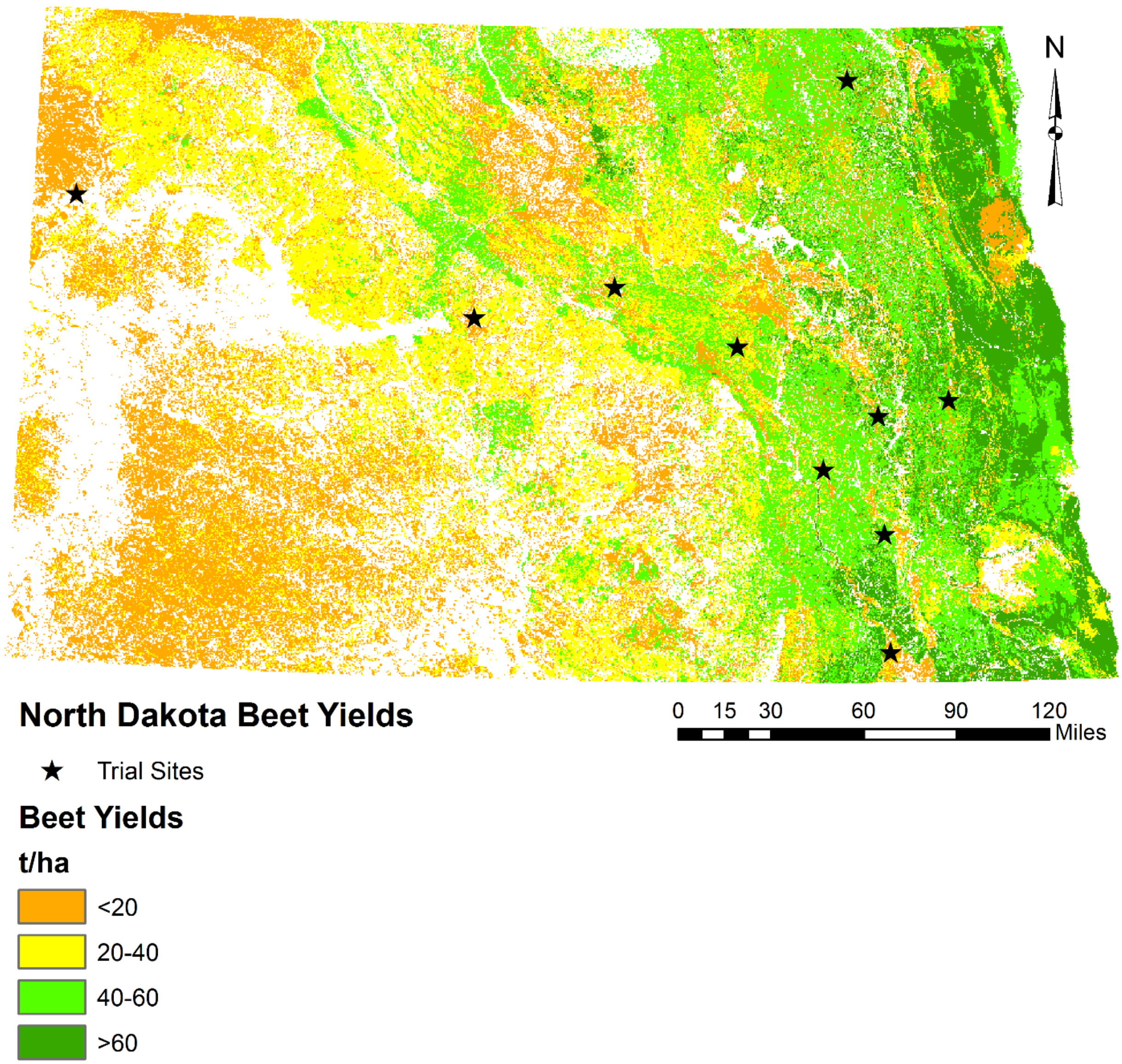

Figure 2: Energy beet yields in North Dakota considering temperature, rainfall and soil quality.

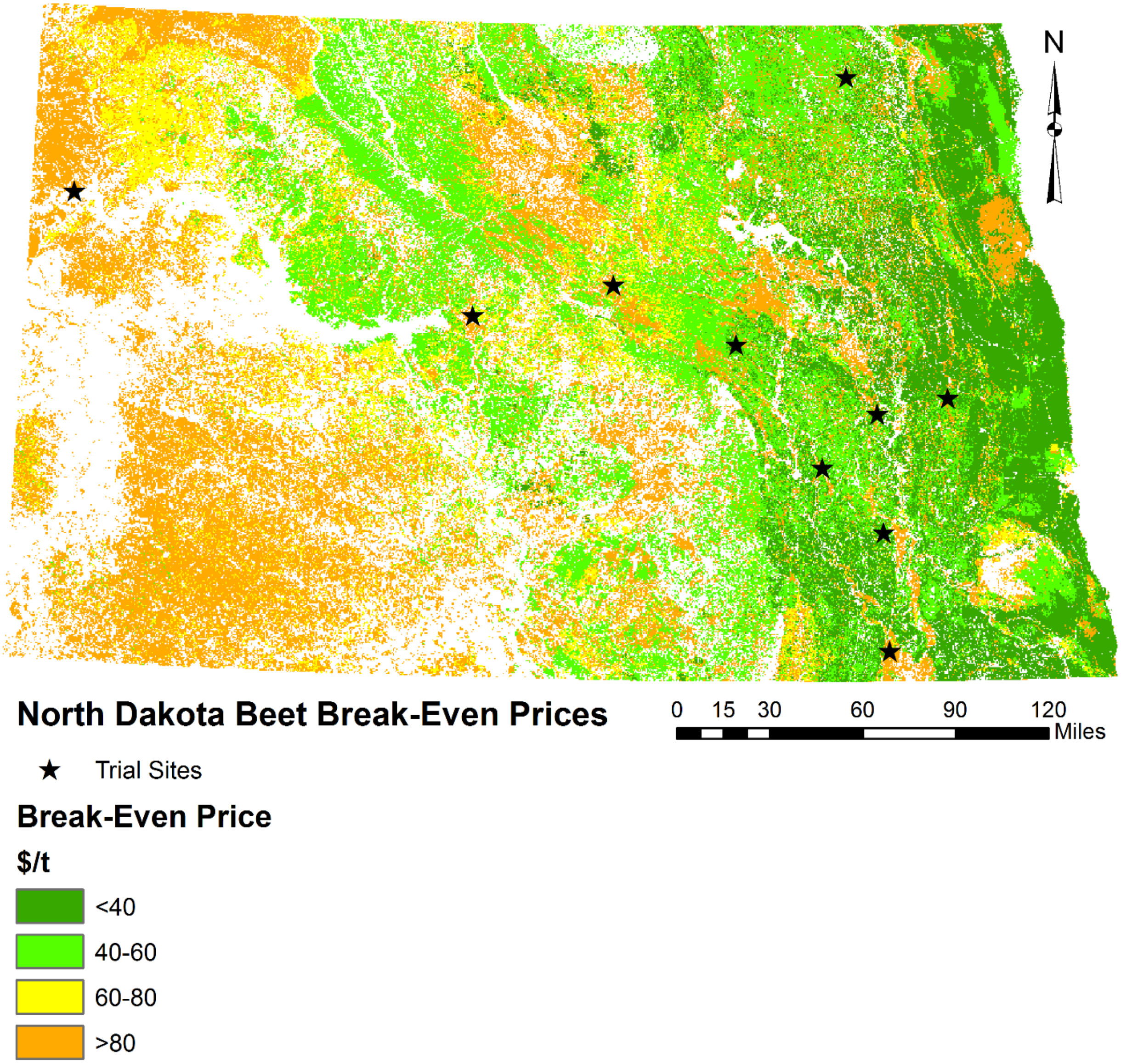

Figure 3: Energy beet break-even prices in North Dakota considering temperature, rainfall and soil quality.

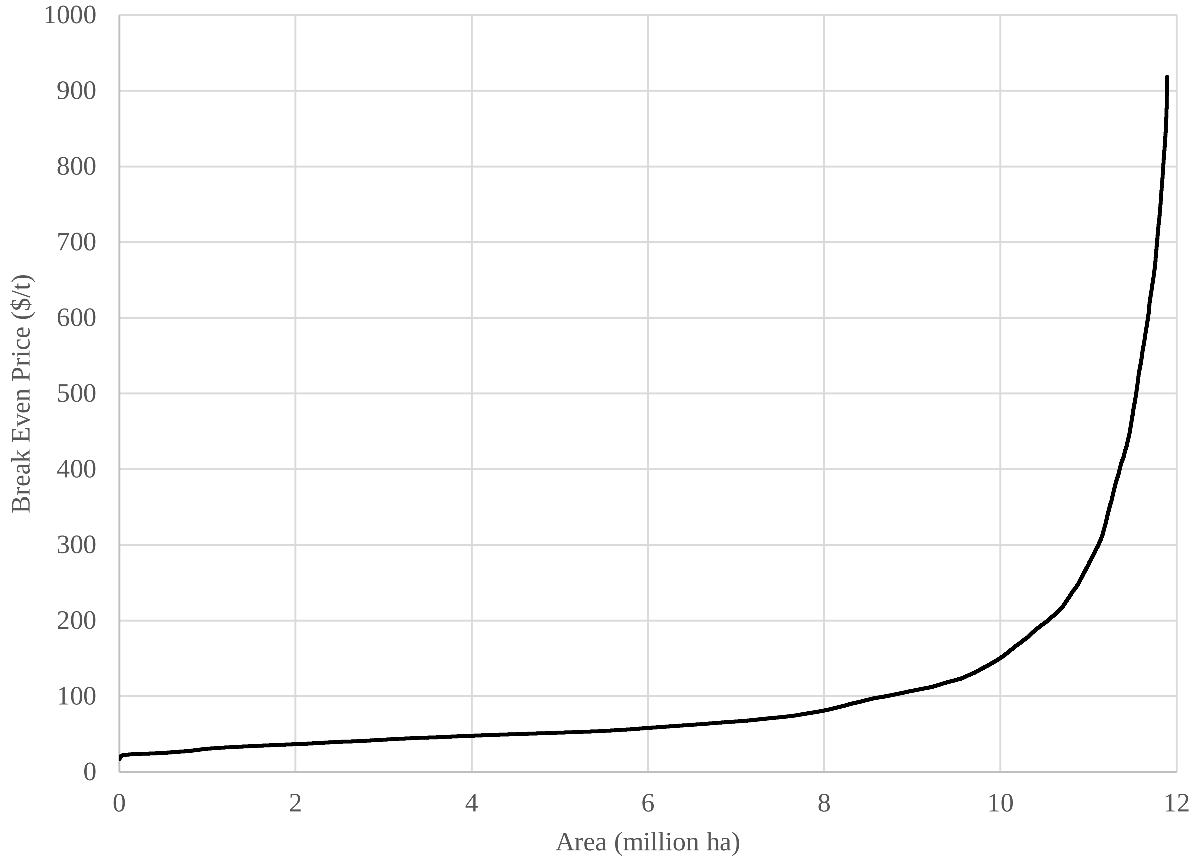

Figure 4: Potential supply of energy beets as offered prices (break-even prices) increase across North Dakota.

Appendix D

ENERGY BEET BIOETHANOL PLANT SITE EVALUATION IN NORTH DAKOTA

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ABSTRACT

Changes in crop prices have encouraged farmers to consider alternatives, such as potential advanced bioenergy feedstocks, including energy beets. This paper employs an integrated biophysical, economic and GIS-based transportation model to examine the supply of beet-bioethanol from five sites in North Dakota. The study finds that beet bioethanol could provide net benefits to farmers and ethanol producers in the state, under current market conditions, but only if the bioethanol plant site is carefully selected. More specifically, a 20,000,000 gallon ethanol plant in Valley City could have net returns of $436,049. This plant would acquire 760,000 tons of beets from around the plant site and further east toward the Red River Valley from 22,682 acres of cropland an average distance of 15.7 miles away. The average yield of the selected cropland is 33.5 tons/ac with average net farm returns of $26.09/acre above opportunity costs. Opportunity and transportation costs can substantially change the attractiveness of croplands for beet production. The current market opportunity presented by beet bioethanol at $1.50/gal ethanol is not particularly attractive, but as ethanol prices increase, this opportunity could become attractive at a number of sites throughout the state.

KEYWORDS

Energy Beets; Bioenergy Supply; Bioethanol

1. INTRODUCTION

Declines in crop prices have led farmers to consider alternatives to their current cropping practices, including the introduction of dedicated energy crops. The Energy Independence and Security Act of 2007 (EISA) sets mandates for conventional and advanced biofuel use. Certain advanced biofuels have had limited commercial scale success, in part because of limited feedstock availability. One crop that shows promise as an advanced biofuel feedstock is the sugar beet (beta vulgaris).

North Dakota and Minnesota account for more than half of domestic sugar beet production. While nearly all of the beets grown are used to make refined sugar, additional beet production in new areas of the region could provide a feedstock for advanced biofuels and enhance farmer returns. Sugar beets grown for biofuel production, so called 'energy beets', could require less demanding processing compared to refined sugar, decreasing production costs. However, as a new crop, energy beet supply chains do not exist and have not yet been rigorously designed and optimized.

Two likely energy beet supply chain alternatives exist. In one case, energy beets could be stored in-field and directly shipped to local ethanol refineries. Alternatively, beets could be shipped to a regional storage depot then moved to the refinery for later processing. Volatility in fuel prices and transportation costs may impact one supply chain more than the other.

A host of spatial factors effect supply chain costs, including yields and transportation distances. The opportunity costs of energy beet production, relative to dominant cash crops such as corn and canola, are important considerations. The environmental benefits of ethanol production from energy beets, including carbon impacts, and nutrient and soil health, are also important.

In the context of advanced biofuels, volatile energy prices, unevaluated supply chains, opportunity costs and environmental benefits, the purpose of this paper is to estimate the supply of energy beet-bioethanol in North Dakota under different price assumptions, using an integrated economic, environmental and GIS analysis, and to inform bioenergy policy in the state and nationally.

This paper employs an economic and environmental GIS-based model that maximizes the profit of potential ethanol plants situated in five North Dakota cities as determined by beet and ethanol prices with an emphasis on transportation costs. The model incorporates spatial considerations of beet yields and production costs, including agricultural opportunity costs, and transportation and logistics schedules.

2. METHOD

2.1 THEORETICAL MODEL

Bioenergy production is driven by prices in many commodity sectors. The price of agricultural commodities will negatively correlate with bioenergy crop production as the opportunity costs rise. As the price of ethanol rises, the price paid for energy beet feedstock should rise, making bioethanol production more attractive. For energy beet production to occur, the price of beets must allow net revenues to exceed opportunity costs – beets must become the best alternative for the farm. For this to be the case, the tradeoff between yields and transportation costs (through transportation distances), must be considered. In general, farms with higher beet yields and shorter transportation distances will find beet production more attractive than those with lower yields and higher distances. Site specific factors, including yields and transportation distances, production and opportunity costs, along with ethanol and feedstock prices, determine the production of energy beets in a region.

2.2 EMPIRICAL MODEL

Study Area

North Dakota is one of the northernmost states in the continental US. The majority of the state is in the Northern Great Plains of North America. It borders the Canadian provinces of Saskatchewan and Manitoba on the North, South Dakota on the South, Montana on the West and Minnesota on the East. The Eastern border of the state is defined by the Red River of the North. The Red River Valley contains fertile croplands and is a locus of sugar beet production in the US (Figure 1).

(Figure 1)

The most productive croplands are located in the Red River Valley in the East. The Southwestern portion of the state contains relatively fewer and less productive croplands and also generally receives less precipitation. As a result of the climate, in general, and the presence of sugar beet production in the Red River Valley, five sites in the East and North Central regions of the state were chosen as candidate sites for a bioethanol plant. More specifically, Cando, Carrington, Jamestown, Langdon and Valley City were chosen as they have sufficient labor, rail connections, distance from the Red River Valley and favorable growing climates for energy beet production. The proposed ethanol plant at each location could process 20,000,000 gallons of ethanol and consume 760,000 tons of beets.

North Dakota croplands were isolated from the land use layer and aggregated to 600m by 600m (~88.95 acre) parcels. Each of the relevant parcels was treated as a decision unit, resulting in 340,157 unique cropland units for analysis. Each cropland has site specific energy beet yields, transportation distances to plant sites and agricultural opportunity costs.

Economic Model

The empirical model proceeds as a two part profit maximization model. The decision to grow and transport energy beets for a static price is first considered for each of the 340,157 decision units. The beet profit optimization model, constrained by land and ethanol plant capacity, can be summarized as:

$$\max_{X_{ij}} \sum_{i=1}^{340,157} \sum_{j} \pi_{ij} X_{ij}$$

$$s.t. \sum_{j} X_{ij} \leq X_i^T, i = 1, .., 340,157$$

$$and \sum_{i=1}^{342,688} \sum_{j=Beet} X_{ij} \leq 760,000$$

where X_{ij} is the area allocated to crop *j* on location *i* and X_i^T is the total area of land at location *i*. The producer at location *i* has two crop choices (*j*) energy beets in rotation, or a traditional rotation. Given plant capacity constraints, the sum of produced energy beets must not exceed the 760,000 ton capacity. The profit function is dependent upon prices, yields, variable and fixed harvest costs, opportunity costs, and transportation costs and distances.

The ethanol plant maximizes profit choosing between energy beet and molasses inputs. The optimization can be summarized as:

$$\max_{l} \pi^E(P^E, Q^E(l), VC(l), FC) \;\; s.t. K \leq 20{,}000$$

where *l* is the type of input used to produce ethanol and *K* is the capacity constraint for ethanol. There is also a constraint that the amount of energy beets used cannot exceed the amount created in the farm level optimization. In this way, the plant must offer a sufficient price to encourage energy beet production should it choose to use this input.

Model Specification

To estimate the empirical model, spatially explicit specifications are needed for: 1) energy beet yields; 2) energy beet production costs; 3) transportation costs; 4) agricultural opportunity costs; 5) ethanol production; and 6) energy beet and ethanol prices. This section outlines the base model specification. Sensitivity analysis examines the effects of changes in these parameters later in the paper.

Energy beet yields were estimated using a daily-stepping agronomic growth model that predicts harvested yields based on site specific daily temperatures, precipitation and solar irradiance, and soil conditions (De Laporte and Ripplinger 2016). Climate variables were obtained from NOAA (2016) and soil information was obtained from the USDA (2016). These kinds of growth models (Monteith 1977) apply the principles of the Beer-Lambert Law of light absorption (Monsi and Saeki 1955). Extensions of these models include evapotranspiration (Hargreaves and Allen 2003) and soil productivity. They have been utilized in a number of contexts and conditions for a number of different crops, including beets (Baey et al. 2014), and switchgrass and miscanthus (De Laporte et al. 2014; Jain et al. 2010; Khanna et al. 2008; Khanna et al. 2011). North Dakota average regional beet yields range from 6.7 tons/acre in the Southwest to 27.8 tons/acre in the South Red River Valley, while the state average is 15.3 tons/acre.

Energy beet production and transportation costs were obtained from North Dakota State University Extension Service materials. These costs are estimated at $565 per acre. Beet transportation costs using trucking are estimated at $0.31/ton/mile.

Agricultural opportunity costs are estimated using NDSU crop budgets from 2015. Opportunity costs are initially estimated for 7 regions determined by the NDSU Extension Service, based on common 4-year crop rotations. These costs are then scaled by the Crop Productivity Index obtained from USDA soil information. Energy beets are assumed to cost one-quarter of the potential net return of the rotation as opportunity costs, as beets are grown once every four years. The total net return of regionally specific 4-year rotations ranges from $71.97 in the Southwest to $136.63 in the South Red River Valley (Table 1).

(Table 1)

The ethanol plant in this study is based on Maung and Gustafson (2011). The plant has a capacity of 20,000,000 gallons per year. The base conversion efficiency of beets to ethanol is 26.4 gallons per ton. To reach capacity, the plant requires 760,000 tons of beets. The cost of beet-ethanol production is $0.34 per gallon. High cost beet molasses ($180/ton) can be used in the plant as a substitute for raw beets at a conversion efficiency of 79.2 gallons per ton.

The production of bioethanol is very dependent on prices. Beet feedstock prices could make up more than 75% of the costs of production. Current ethanol prices are around $1.50 per gallon. For the plant to make any positive net return, beet prices must be lower than approximately $30 per ton. The base model of analysis in this case considers an ethanol price of $1.50 per gallon at the factory gate and an offered beet price of $30 per ton delivered. The farmers in this model bear the costs of transportation.

3. RESULTS

To examine energy beet-bioethanol supply, this section presents the results of four modelling scenarios: 1) Base (P^B=$30/ton; P^E=$1.50/gal); 2) Capacity (P^B=$35/ton; P^E=$1.70/gal); 3) ¼ Transportation Costs (P^B=$30/ton; P^E=$1.50/gal); and 4) 1.5 Transportation Costs (P^B=$40/ton; P^E=$1.90/gal). In these scenarios, P^B is the price offered for energy beets and P^E is the price of ethanol. The results include the areas producing beets, both spatially and quantitatively, and the average distance, yield and return of these areas (Table 2).

The baseline scenario examines the possibility of bioethanol production using approximate current market conditions. The price of ethanol was set to $1.50/gal, which is similar to the current market price. The price of beets was set at $30/ton to approximately reflect the break-even feedstock cost of the plant with current ethanol prices. The results of the base model show that bioethanol production is only potentially feasible at the Valley City site (Table 2; Figure 2). The other four sites do not produce at, or anywhere close to, capacity. At Valley City, beets are transported from 1,020 sites (22,682 acres) an average distance of 15.7 miles to the plant. The average yield is 33.5 tons/ac from the selected sites and average returns are $26.09/ac. The beets are generally gathered from nearby sites and sites stretching to the east toward higher yields in the Red River Valley. In this scenario, the ethanol plant makes $436,049 in net revenue operating at capacity.

(Figure 2)

The capacity simulation examines the possibility of bioethanol production using market conditions that would encourage participation from each site. The price of beet feedstock was set at $35/ton to push production to the plant capacity. The price of ethanol was set to $1.70/gal to make the bioethanol plant at least break-even. The results show that bioethanol production at this level is potentially feasible at every site except Cando (Table 2; Figure 3). The other four sites produce at capacity, but Valley City ($67.97/ac) remains the best site, followed by Langdon ($33.24/ac), in terms of average net farm returns. Beets are transported from between 1,020 sites (22,682 acres) at Valley City and 1,349 sites (29,998 acres) at Jamestown. Average transportation distances range from 15.7 miles at Valley City to 19.4 miles at Langdon. Average yields range from 25.3 tons/ac at Jamestown to 33.5 tons/ac at Valley City. Spatially, a similar pattern exists to the base model, where beets are gathered from nearby sites and sites stretching to the east toward the Red River Valley. In this scenario, the ethanol plant net revenue is $648,170 operating at capacity.

(Figure 3)

The ¼ transportation costs scenario examines the effect of decreased transportation costs on the simulation. The prices of beet feedstock and ethanol are the same as in the base scenario. The decrease in transportation costs makes every site viable and significantly changes the pattern of cropland selection (Table 2; Figure 4). This scenario pushes beet production into the Red River Valley and nearby high yield sites. While Valley City remains the most profitable site, Jamestown becomes preferred to Langdon. The number of sites decreases across the board from the capacity scenario as the most productive lands are chosen. This causes average transportation distances to balloon from 15.7 to 36.7 miles in the case of Valley city. Similarly, average yields increase from 33.5 to 40.4 tons/ac and average farm returns increase from \$26.09/ac to \$88.94/ac. The highest yield sites in the Red River Valley end up shipping beets to all sites. In this scenario, the ethanol plant net revenue remains \$436,049 operating at capacity.

(Figure 4)

4. DISCUSSION AND CONCLUSIONS

This paper examines the supply of energy beet-bioethanol from five potential plant sites in North Dakota and considers the effects of opportunity costs, supply chain logistics and carbon balances. The base scenario shows that Valley City is the only location that could successfully supply beet-bioethanol under current price conditions (Table 2; Figure 2). Increasing the price of beets to \$35/ton would make beet production significantly more viable at Langdon, Carrington and Jamestown, but would necessitate higher ethanol prices (Figure 3). Decreasing transportation costs by a factor of four makes each site viable and completely changes the structure of the supply chain, where beets are shipped much longer distances from the highest yield beet sites in the Red River Valley (Figure 4). This could approximate intermediate beet piling and transport using rail, disaggregating plant siting from beet production.

While Valley City was selected as the most favored site in all scenarios (Table 2), it does have some drawbacks as well. The areas of the Red River Valley that are most attractive for beet production are the most profitable in the state and some do already produce sugar beets for food-grade sugar. One of the keys to beet-bioethanol in the state involves non-interference with the food-grade sugar industry and the associated US sugar policy. Therefore, if the most attractive sites in Valley City and Langdon, to a lesser degree, interfere with existing sugar beet production, the site likely becomes non-viable for political reasons.

Increasing opportunity costs would decrease the viability of beet-bioethanol, as these costs are relatively low in times of decreased crop prices. Supply chain logistics, including intermediate piling sites, could decrease transportation costs and make potential high yield sites in the valley more attractive. Ongoing life-cycle analysis shows that beet-ethanol is likely to reduce carbon emissions compared to conventional corn-ethanol. Should this be the case, price incentives in the RFS could make advanced beet-bioethanol production much more attractive. These scenarios constitute the next steps as this research moves forward.

Energy beet-based bioethanol in the state of North Dakota could be feasible under select conditions, even under current prices. However, ethanol prices seem to be at historic lows and investments in ethanol production capacity, especially considering the risk and uncertainty associated with the supply chain, would not be highly recommended. As the price of ethanol increases, this opportunity may become much more attractive.

REFERENCES

Baey, C., A. Didier, S. Lemaire, F. Maupas, P. Cournede. 2014. Parametrization of five classical plant growth models applied to sugarbeet and comparison of their predictive capacity on root yield and total biomass. Ecological Modelling 290, 11-20.

De Laporte, A., D. Ripplinger. 2016. The effects of spatial climate and soil conditions on modeled energy beet yields and break-even prices. Working Paper, North Dakota State University Department of Agribusiness and Applied Economics.

De Laporte, A., A. Weersink, D. McKenney. 2014. A spatial model of climate change effects on yields and break-even prices of switchgrass and miscanthus in Ontario, Canada. Global Change Biology Bioenergy 6(4), 390-400.

Hargreaves, G.H., R.G. Allen. 2003. History and Evaluation of Hargreaves Evapotranspiration Equation. Journal of Irrigation and Drainage Engineering 129, 53-63.

Jain, A., M. Khanna, M. Erickson, H. Huang. 2010. An integrated biogeochemical and economic analysis of bioenergy crops in the Midwestern United States. GCB Bioenergy 2, 217-234.

Khanna, M., B. Dhungana, J.C. Clifton-Brown. 2008. Cost of producing Miscanthus and switchgrass for bioenergy in Illinois. Biomass and Bioenergy 32, 482-493.

Khanna, M., H. Onal, B. Dhungana, M. Wander. 2011. Economics of herbaceous bioenergy crops for electricity generation: Implications for greenhouse gas mitigation. Biomass and Bioenergy 35, 1474-1484.

Maung, T. A., C.R. Gustafson. 2011. The economic feasibility of sugar beet biofuel production in central North Dakota. Biomass and Bioenergy, 35, 3737-3747.

Monsi, M., T. Saeki. 1953. Über den lichtfaktor in den pflanzengesellschaften und seine bedeutung für die stoffproduktion. Japanese Journal of Botany 14, 22–52.

Monteith, J.L. 1977. Climate and the efficiency of crop production in Britain. Philosophical Transactions of the Royal Society B281, 277–294.

Table 1: Opportunity costs of North Dakota agriculture summarized by region.

Region	Rotation				Opportunity Cost ($/acre)
NW	Wheat	Lentils	Barley	Flax	$105.96
SW	Wheat	Corn	Wheat	Sunflower	$71.97
NC	Wheat	Sunflower	Barley	Flax	$120.87
SC	Wheat	Soybean	Corn	Sunflower	$90.68
EC	Corn	Soybean	Wheat	Soybean	$107.05
NE	Wheat	Soybean	Barley	Canola	$102.49
SE	Corn	Soybean	Wheat	Soybean	$134.28
NV	Corn	Soybean	Wheat	Drybeans	$133.37
SV	Corn	Soybean	Wheat	Soybean	$136.63

Table 2: Scenario results for the production of bioethanol in North Dakota showing decision units, beet quantity gown, average transported distance, average site yield and average farm return by potential plant location.

Location	Decision Units	Beets Grown (tons)	Average Distance (miles)	Average Beet Yield (tons/ac)	Average Farm Return ($/ac)
Base (PB=30; PE=1.50)					
Cando	172	108,696	7.5	28.4	18.55
Carrington	111	80,924	22.2	32.8	10.89
Jamestown	19	11,391	7.1	27.0	8.17
Langdon	362	228,123	11.5	28.3	7.47
Valley City	1,020	760,000	15.7	33.5	26.09
Capacity (PB=35; PE=1.70)					
Cando	983	564,218	15.2	25.8	18.60
Carrington	1,283	760,000	17.9	26.6	16.63
Jamestown	1,349	760,000	14.7	25.3	11.42
Langdon	1,149	760,000	19.4	29.7	33.24
Valley City	1,020	760,000	15.7	33.5	67.97
1/4 Transportation Costs (PB=30; PE=1.50)					
Cando	950	760,000	66.2	36.0	38.22
Carrington	968	760,000	54.6	35.3	43.48
Jamestown	855	760,000	69.8	40.0	60.20
Langdon	942	760,000	40.8	36.3	58.60
Valley City	847	760,000	36.7	40.4	88.94
1.5 Transportation Costs (PB=40; PE=1.90)					
Cando	1,412	760,000	13.7	24.2	29.52
Carrington	1,337	760,000	15.1	25.6	32.40
Jamestown	1,403	760,000	12.7	24.4	29.42
Langdon	1,288	760,000	13.2	26.5	46.73
Valley City	1,096	760,000	12.1	31.2	86.36

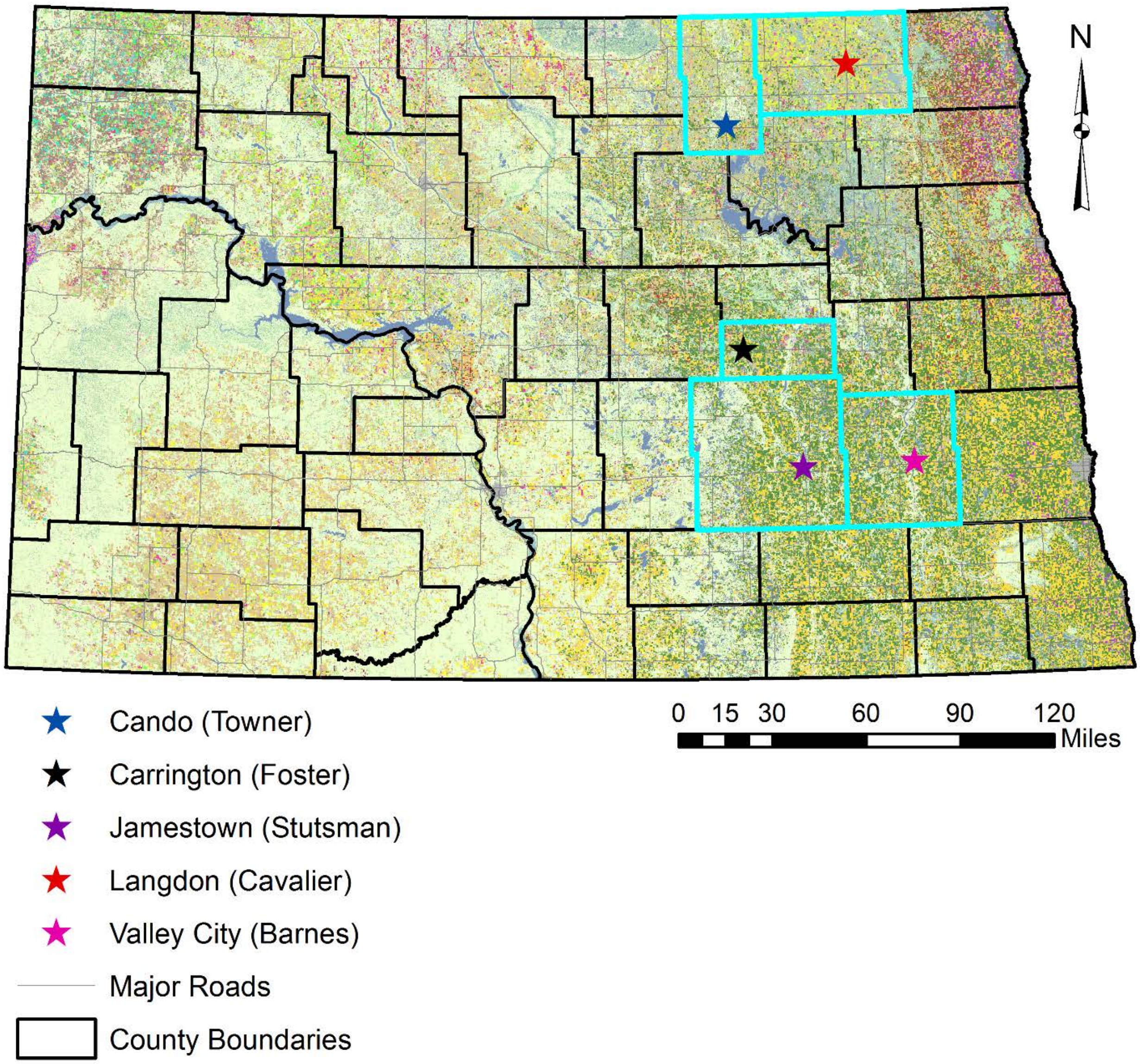

Figure 1: Land use in North Dakota highlighting agricultural lands, natural lands, developed areas and five potential bioethanol plant sites.

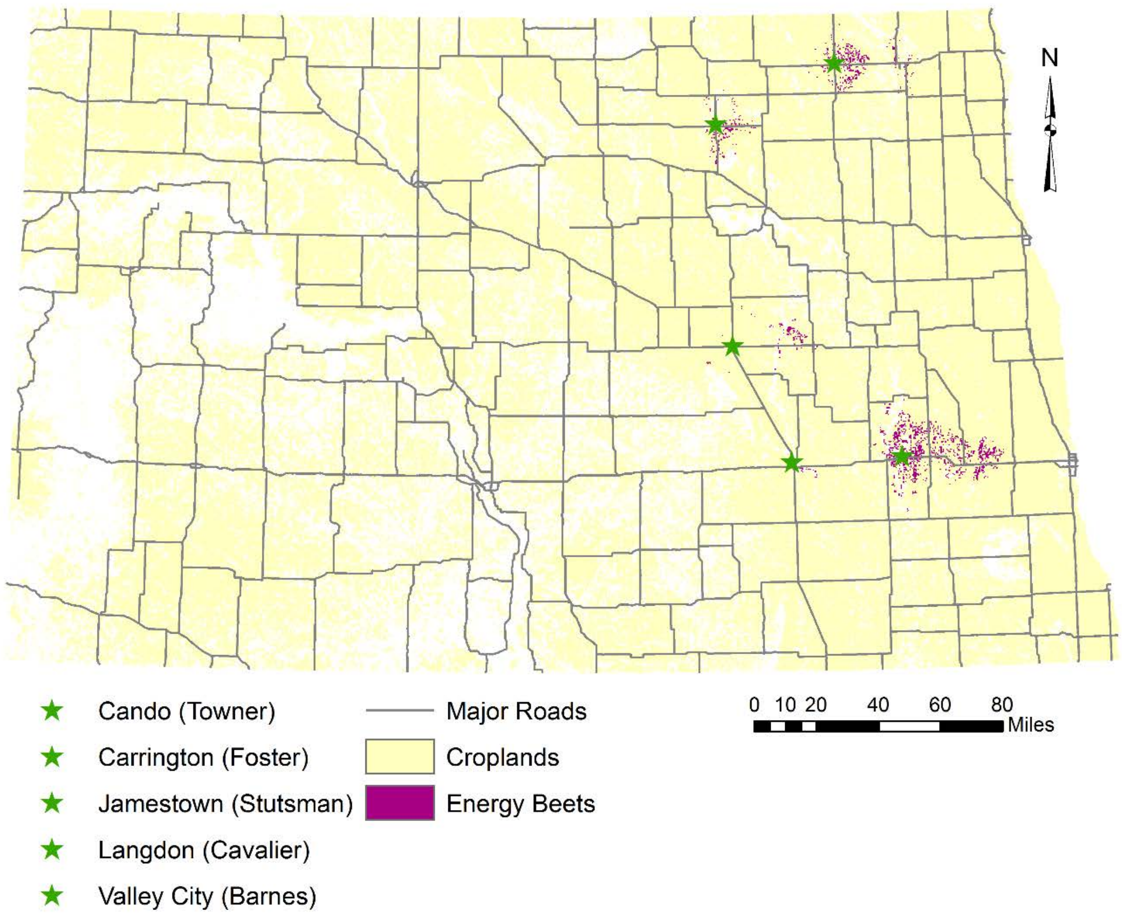

Figure 2: Croplands growing energy beets for selected North Dakota bioethanol sites in the Base Scenario (P^B=\$30/ton; P^E=\$1.50/gal)

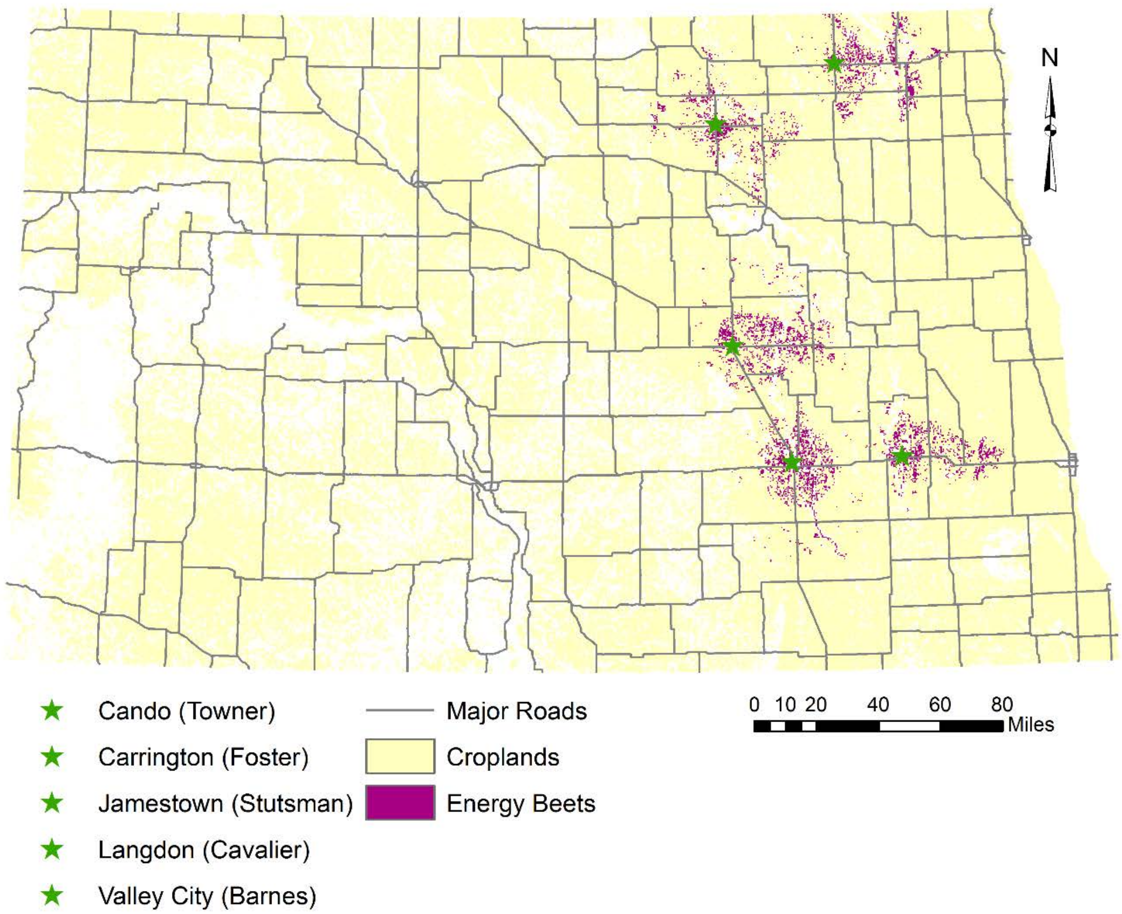

Figure 3: Croplands growing energy beets for selected North Dakota bioethanol sites in the Capacity Scenario (P^B=\$35/ton; P^E=\$1.70/gal)

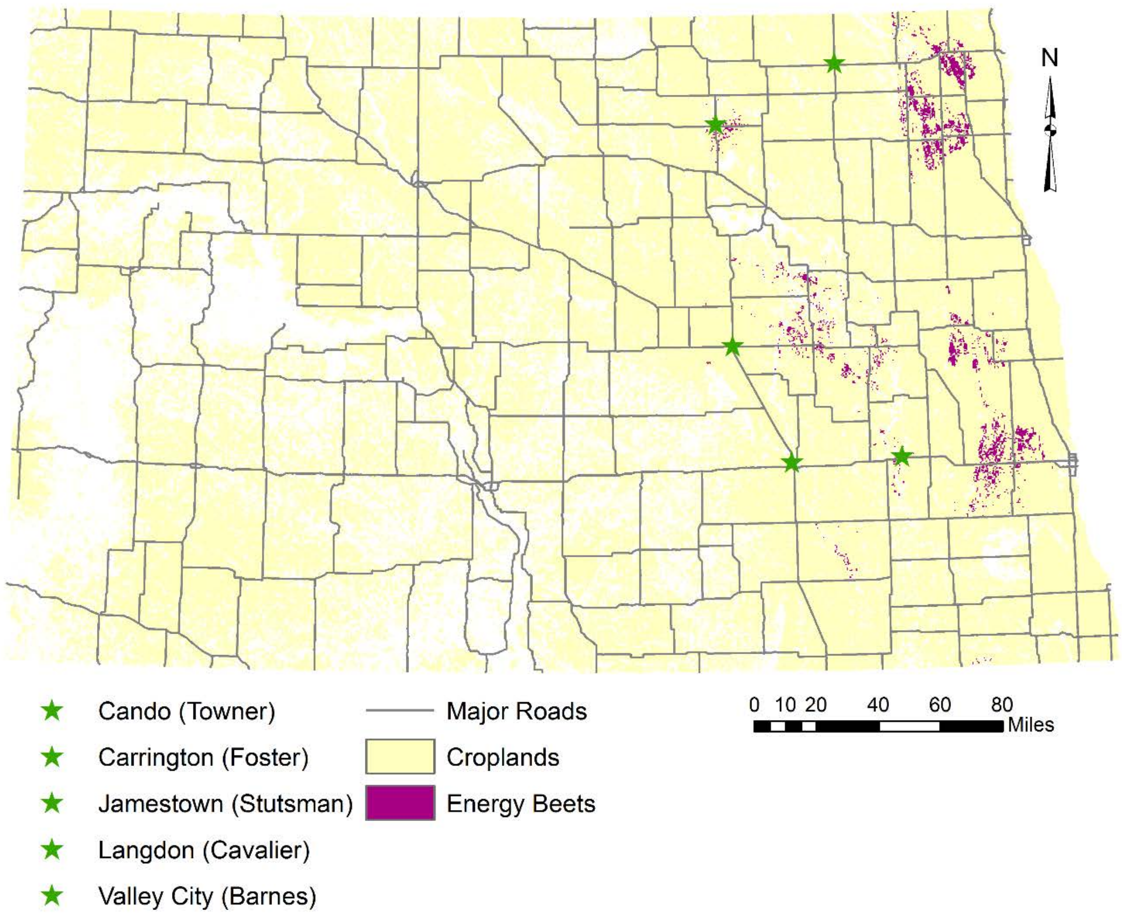

Figure 4: Croplands growing energy beets for selected North Dakota bioethanol sites in the ¼ Transportation Costs Scenario (P^B=$30/ton; P^E=$1.50/gal)