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Evaluation of Breakeven Farm-gate Switchgrass Prices in South Central North Dakota

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ABSTRACT

Switchgrass, a warm-season perennial grass, native to the region, has received considerable interest for its potential role as a dedicated feedstock for cellulosic-based bio-fuels. This research examined the farm-gate price needed for switchgrass to provide per-acre net returns equal to those obtained from traditional crops in south central North Dakota.

Future production costs for switchgrass and net returns from traditional crops were estimated for three soil productivity classes and also were developed to reflect the historical revenue and cost patterns associated with producers who are typically more or less profitable (i.e., average net return per acre) than regional averages. Prices were calculated using an annualized equivalent analysis of switchgrass production costs and net returns from traditional crops from 2008 through 2017.

Switchgrass production costs ranged from just over $40 per ton on marginal soils to $34.80 per ton on highly productive soils. Breakeven switchgrass prices across the three soil productivity classes ranged from $47 per ton in the low productivity soils to $76 per ton in the most productive soils. Production costs for low-profit producers were estimated at $47 per ton, compared to the regional average of $37.50 per ton. Switchgrass production costs for the remaining profitability groups ranged from about $33.50 per ton to about $36.75 per ton. The breakeven farm-gate price for switchgrass ranged from $56 per ton for the two lowest profitability groups to over $94 per ton for the most profitable producers.

A key economic criterion influencing the breakeven price for switchgrass will be the foregone net revenue from displaced traditional crops. On marginal soils, just under one-third of the breakeven price was derived from the level of foregone net returns from traditional crops; whereas, over 80 percent of the breakeven price was derived from the level of foregone net returns from traditional crops on the most productive soils. As net returns from traditional crops decreased the more that breakeven switchgrass prices approached production costs for switchgrass. Under current conditions of high input costs, escalating transportation costs, and given the increases in net returns from traditional crops, switchgrass, as a feedstock to a cellulosic ethanol plant, will be more expensive than previously estimated.

Key Words: switchgrass, production costs, farm-gate price, North Dakota, soil productivity

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INTRODUCTION

The U.S. has seen a resurgence of concern over energy use and energy supply entering into the 21st century. The use of fossil fuels, in particular, has been at the forefront of national debate on energy policy. The focus on petroleum in recent years has developed out of the recognition of a growing reliance on imports, raising questions about energy security, escalating prices for crude oil and petroleum products, and heightened concerns over the long-term environmental effects of emissions from fossil fuels. These and other circumstances led to the Energy Policy Act of 2005, which established a renewable fuel requirement for the U.S. Subsequent legislation, such as the Energy Independence and Security Act of 2007, strengthened the role of renewable fuels in the U.S. by creating a new renewable fuel standard for the next 15 years.

A key provision of current U.S. energy policy is to increase domestic ethanol production over the next decade. The renewable fuel standard sets forth a timeline for the production or introduction into the marketplace of ethanol and other liquid renewable fuels. The standard outlines a supply schedule over the next 15 years, and the desired composition of renewable fuels from different processes. While some of the future increase in ethanol production will come from an expansion of starch or grain-based ethanol, substantial limitations exist on the capacity of the agricultural sector to provide ethanol production targets using only corn or other starch-based grains. For example, the entire domestic crop of corn in 2005, if converted to ethanol, would have only offset around 9 percent of 2005 net crude oil imports to the U.S. (Epplin et al. 2007). Policymakers recognized that grain or starch-based ethanol cannot meet the future level of renewable fuel targets in the U.S., so current domestic energy policies have placed substantial emphasis on developing cellulosic biomass as a feedstock for renewable fuel production.

The conversion of cellulosic biomass to ethanol is not yet commercially viable; however, considerable research and development is currently underway to commercialize the technologies to convert cellulose and/or lignin into transportation fuels (Kotrba 2008). Despite the lack of commercial technologies to produce ethanol from cellulosic feedstocks, scientists and policymakers have begun to look for feedstock candidates that would provide abundant and low-cost sources for cellulosic ethanol production in the U.S. Crop residues (e.g., corn stover, wheat straw), dedicated energy crops (e.g., perennial grasses), and wood

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products are among the leading feedstocks touted as viable candidates for cellulosic or lignocellulosic ethanol production.

Switchgrass, a warm-season perennial grass native to the region, has received considerable interest for its potential role as a dedicated feedstock for cellulosic-based bio-fuels. However, enthusiasm for switchgrass has developed without an understanding of producer revenues from switchgrass and willingness of producers to raise switchgrass. In an effort to aid policymakers and industry leaders in moving forward on the viability of dedicated energy crops in the upper Great Plains, potential supply and cost of acquiring those feedstocks must be evaluated. While many factors will ultimately influence farmers' willingness to supply herbaceous energy crops for bio-fuel production, a key factor is going to be how those crops compare economically to traditional crops. Although research is beginning to reveal price scenarios under which switchgrass is competitive with traditional crops in some regions of the Upper Midwest, equivalent information is lacking for North Dakota producers. Further, research into the competitiveness of switchgrass has yet to account for recent increases in commodity and input prices. This research examines the farm-gate price needed for switchgrass to provide net returns similar to those obtained from traditional crops in south central North Dakota.

OBJECTIVES

The purpose of this report is to calculate prices required for switchgrass to be economically feasible as a cash crop in south central North Dakota. Specific objectives include

1) generate estimates of the cost of producing switchgrass,

2) generate estimates of farm-gate prices needed for switchgrass to generate net returns comparable to those from future crop production in the study region, and

3) evaluate economic competitiveness of switchgrass over a range of soil productivity and farm profitability scenarios.

PREVIOUS RESEARCH

Economic competitiveness of switchgrass production, costs of switchgrass production, and other economic issues tied to producing switchgrass have been addressed to varying degrees. Most of the economic literature is not specific to North Dakota, nor does it represent recent cost increases in crop production or the demand and supply shifts within the commodity markets that have resulted in price increases for most crops. Further, economic assessments have focused on cost of production and have mostly failed to include the concept of competitive net returns between switchgrass and other crop enterprises.

McLaughlin et al. (2002) examined the competitiveness of switchgrass within the U.S. agricultural sector. The analysis tool was POLYSIS, an agricultural sector model, developed by the U.S. Department of Energy, U.S. Department of Agriculture, and the University of Tennessee to evaluate bioenergy crop production in the U.S. The U.S. agricultural sector was segregated at the agricultural statistics district level, which resulted in 305 different production regions. Market values and input costs were reflective of conditions found in the year 2000. Although regional prices and yields were used within POLYSIS, only national yields and prices were reported in the study results. At a farm-gate price of just under $40 per ton ($39.92) with an average yield of 4.19 tons per acre, switchgrass production was estimated to occur on 6.8 million acres in the U.S. Acreage of switchgrass production decreased considerably to 1.2 million acres with a farm-gate price of $27.50 per ton and an average yield of 4.95 tons per acre. Increasing the farm-gate price to $47.50 per ton while decreasing average yields to 4 tons per acre increased switchgrass acreage nationally to 8.6 million acres. In all of the price scenarios, over 50 percent of switchgrass acreage came from lands raising traditional crops, with the remaining acreage coming from CRP, pasture, or idle lands.

Haque et al. (2008) evaluated the cost to produce a ton of cellulosic biomass feedstock from switchgrass, bermudagrass, flaccidgrass, and lovegrass over four nitrogen fertilization levels and two harvest systems. A total of 32 combinations of grass species, fertilization rates, and harvest systems were evaluated based on agronomic conditions near Stillwater, Oklahoma. Grass stands were established in 2002. Enterprise budgets were developed for both establishment and annual production. The authors found that switchgrass yields were higher than the other grasses across all fertilization levels for the single fall harvest. However, switchgrass yields were not consistently higher than the other grasses in the double harvest system and, in some combinations, yields in the double harvest system were greater than yields with the single harvest system. Across all of the trial combinations, switchgrass with a 60 pound per acre application of nitrogen and a single fall harvest system produced the lowest per ton cost ($36 per ton). Costs per ton for the other switchgrass combinations ranged from $39 to $47 per ton. Costs included land rental charges, amortization of establishment costs and annual operating (fertilization, spraying, baling) expenses. The analysis did not include an estimate of the prices required for switchgrass or other grasses to generate net returns that would compete with traditional crops raised in the region.

Fumasi et al. (2008) consulted agronomists, producers, and ethanol industry representatives to identify the most feasible types of cellulosic ethanol crops in an area around Beaumont, Texas. The most suitable biomass crops identified in the study were hybrid sorghum hay, hybrid sorghum green chop, high-biomass sorghum green chop, and billeted, hybrid sugarcane. Enterprise budgets for the biomass crops and traditional crops were developed for 2007. Price forecasting and inflation adjustments were used to project revenues and expenses for 2008 through 2012. Target levels of net returns per acre were used to set contract prices for each of the enterprises for the 2008-2012 period. Contract prices were estimated to range from about $23 to $27 per ton (dry matter basis) for the sorghum crops and vary from $27 to $32 for the sugarcane crop. From a grower's perspective, sugarcane would be a preferred choice due to lower yield risk and less sensitivity to rising variable costs. However, due to conceptual understanding of the operation of a bio-refinery, the authors suggest that all four crops are likely to be required to deliver acceptable biomass feedstocks throughout the growing season. Fumasi et al. (2008) did not discuss pre-treatment, storage issues, or the reason why feedstocks would need to be harvested throughout the year. Putting biomass feedstocks into an ethanol yield basis and accounting for transportation costs, hybrid sorghum hay and sugarcane would cost a bio-refinery about $1 per gallon of ethanol, whereas green chop and high biomass sorghum would cost a bio-refinery $0.74 and $0.62 per gallon, respectively.

Perrin et al. (2008) tracked production expenses for switchgrass on ten farms in three Midwestern states over a 5-year period starting in 2000 and 2001. Results indicated that annualized yields ranged from 1.1 ton per acre to 4 tons per acre. Most farmers experienced increasing yields through the first four years of the study, but yields decreased at many sites in the fifth growing season due largely to weather-related factors. Annualized production costs averaged about $60 per ton, but ranged from $38 per ton to $97 per ton. When extrapolating costs and yields to a 10-year period (typically considered a minimum time frame that a switchgrass stand would remain commercially viable), average costs were estimated to be $54 per ton. It was estimated that the farm-gate production cost of cellulosic ethanol from switchgrass would equate to about $0.55 to $0.62 per gallon of ethanol. However, Perrin et al. (2008) did not account for the farm-gate price needed for switchgrass, over the study period, to compete with traditional crops for the same level of return from the land resource.

In addition to tracking production costs and yields over a 5-year period, Perrin et al. (2008) made cost comparisons of previous research that examined switchgrass production expenses. Several adjustments were performed on previous cost estimates to allow comparisons to account for different methods and assumptions. Adjusted for 2003 prices, the cost of switchgrass production ranged from $27 per ton by Epplin (1996) for the Oklahoma plains, to $66 per ton by Hallam et al. (2001), to $87 per ton by Duffy and Nanhou (2002) for cropland in Iowa. However, the comparisons were again limited to production costs and did not contain economic analyses of the competitiveness of switchgrass with traditional crops.

Epplin et al. (2007) discussed two possible systems or economic models that would achieve conversion of 50 to 100 million acres of land to the production of switchgrass. In the first system, the biorefinery enters into a long-term lease on land where they are responsible for production, harvest, storage, and transportation of switchgrass. The authors deemed this arrangement similar to CRP leases. The second option is for the biorefinery to contract with individual producers to produce and harvest switchgrass with the biorefinery responsible for transportation and storage. The costs of acquiring switchgrass for a biorefinery in each system were estimated. A mathematical programming model, using input prices associated with 2006/2007, was used to generate estimates of the costs for a biorefinery to produce, harvest, store, and transport switchgrass. Costs for producing switchgrass in the contract approach was based on a competitive bid process to raise switchgrass on a predetermined range of acres. The contracts were structured to favor small acreage allotments. Bids were conducted in 2005.

Epplin et al. (2007) estimated that production and transportation costs per ton of switchgrass could range from nearly $49 to over $65, based on using an eight-month and two-month harvest regime. Field costs, which included amortization of establishment costs, maintenance, and fertilizer expenses, were estimated at $9.23 and $8.35 per ton for the eight-month harvest and two-month harvest regime, respectively. The total cost per ton for the bids ranged from $36 for the two lowest bidders to $54.70 for the average cost of the bids accepted. The contract process only sought to accept bids totaling 92 acres, which resulted in the University accepting small acreage contracts. Epplin et al. (2007) did not comment on whether the land represented in the bids was cropland, hayland, or land that otherwise would not be competing with traditional crop production.

In a larger context, Epplin et al. (2007) did not discuss the implication of removing 50-100 million acres of land from current agricultural uses, and the potential price effect that might have on commodity markets. Epplin et al. (2007) did discuss the issue that biorefineries might need to develop a feedstock buffer, as a result of potential supply disruptions stemming from weather or other related issues (e.g., fire, disease).

Khanna and Dhungana (2007) examined the costs of corn stover, switchgrass, and miscanthus for use as bioenergy feedstocks. The authors developed crop budgets, based on 2003 input prices and crop yields, which estimated net returns for raising switchgrass and miscanthus. Included in the analysis for switchgrass and miscanthus was the opportunity cost of the land, defined to be the average net returns from raising a corn/soybean crop rotation. The breakeven delivered cost of switchgrass (assuming a 25-mile one-way transport) was equal to $89 per dry ton under the low opportunity cost scenario but increased to over $148 per dry ton under a high opportunity cost scenario. The low opportunity cost scenario was based on the soybean price of $5.10 per bushel and corn price of $2.00 per bushel. The high opportunity cost used $7.00 per bushel for soybeans and $3.50 per bushel for corn. The breakeven costs for switchgrass did not include land rent, overhead, building repairs and depreciation, and operator labor. Of the three feedstocks evaluated, switchgrass was considerably more expensive, delivered to a biorefinery, than either miscanthus or corn stover in both opportunity cost scenarios.

Vadas et al. (2008) compared cropping systems of continuous corn, alfalfa-corn rotations, and continuous switchgrass in Wisconsin. Budgeting tools were used to estimate production costs for all cropping systems. Crop prices were fixed within the model and three price levels were used that reflected the range of crop prices observed in the study region from 2005 through 2006. For switchgrass, market prices at the plant were based on roughly $30, $60, and $90 per ton. Switchgrass prices were largely based on feedstock input prices (prices the plant could pay) discussed by Wallace et al. (2005). Numerous assumptions were made regarding various aspects of the cropping systems, including the estimated costs for the producer to deliver the various feedstocks to an ethanol plant 50 miles from the field and assuming 4-year crop rotations. The authors recognized the agronomic inconsistences with a four-year period for corn versus switchgrass, but wanted to keep the three main systems directly comparable. Given price and cost assumptions relevant to 2005 through 2006, farm profit was estimated for each system over the low, medium, and high product prices for both a normal and high yield scenario.

Vadas et al. (2008) indicated that under the low-price scenario, the alfalfa-corn rotation produced the least level of economic loss with either the normal or high yield scenarios. Under the same assumptions, switchgrass was the least profitable of the combinations. With high prices, the continuous corn cropping system with use of stover as an ethanol feedstock was the most profitable with both normal and high yield assumptions, while switchgrass production was the least profitable in both yield scenarios. Net energy balances, as well as other energy consuming and producing measures, were included in the study. Switchgrass was the most efficient producer of net energy among the alternatives evaluated, yet among the cropping systems evaluated it was estimated to produce the least amount of ethanol per land unit.

Popp (2007) examined the cost of producing switchgrass in Arkansas based on 2006 input costs. Switchgrass stands were modeled to be commercially viable for 12 years, based on expert opinion of agronomic conditions present in the state. Expected yields were 3 tons per acre for the second year of production and 5 tons per acre for years 3 through 12. Storage expenses were included in production costs and included bale stacking at field edge and covering of bales with tarps. Production costs were estimated to vary from $36.80 per ton in year 2 to $26.73 per ton in year 3. Including amortized establishment costs the expected cost over a 12-year period was estimated to be $24.66 per ton. However, the prorated cost of $24.66 per ton did not include input cost increases observed in 2007 and 2008. Popp (2007) did not specifically calculate the net returns from conventional crops as an opportunity cost of production. Rather, a flat rate of $100 per acre was used to provide a proxy for returns to land. A land charge of $100 per acre raised the production cost by $17.85 per ton. Concluding comments by the author acknowledged that relative profitability between switchgrass and conventional crops remained a likely important consideration for producers. Other issues included value of soil improvements, carbon sequestration credits, storage risks, production risk (e.g., fire, excessive rain during harvest), weed control, and the relative merits of other biomass crops only requiring annual commitments (e.g., sweet sorghum).

Busby et al. (2007) estimated production costs for switchgrass, eastern gammagrass, and giant miscanthus in Mississippi and Oklahoma based on input costs from 2003 through 2005. Data from test plots in Mississippi revealed that yield per acre for Giant Miscanthus exceeded switchgrass and gammagrass in either the single harvest or double harvest (i.e., two times in one production season) systems. By comparison, switchgrass produced the greatest tonnage per acre of the three grasses in Oklahoma in both the single and double harvest systems. Assuming establishment costs were amortized over a 10-year period, switchgrass production expenses in Mississippi were estimated to be $26.40 per ton for the double harvest versus $29.41 per ton for the single harvest. Under the same stand life, miscanthus production expenses were estimated to range from $27.64 per ton to $29.55 for the single and double harvest systems, respectively. Expenses for gammagrass were considerably higher than switchgrass or miscanthus. In Oklahoma, switchgrass production expenses were estimated to be $20.19 per ton for the double harvest versus $14.13 per ton for the single harvest. Miscanthus production expenses in Oklahoma were estimated to range from $33.23 per ton to $36.70 for the single and double harvest systems, respectively. Expenses for gammagrass were greater than those for switchgrass, but less than expenses for miscanthus. Although not explicitly stated, production costs appeared to reflect farm-level expenses. Expenses did not include opportunity costs for foregone net returns from conventional crops.

APPROACH

The general objective of this study was to address some basic economic questions pertaining to switchgrass production in North Dakota. Determining the price(s) at which switchgrass becomes competitive with traditional crops is an important first step in evaluating the viability of dedicated herbaceous energy crops. The current paucity of agronomic data on herbaceous energy crops in North Dakota provided substantial limitations in this study. Those limitations, along with study methods, are discussed in the following sections.

Two separate analyses of the farm-level economics of switchgrass production were conducted. The first analysis examines the breakeven switchgrass price that would be needed for the crop to be competitive with future net returns from traditional crops based on producer profitability groups. This approach forecasts producer net returns for traditional crops based on trends in historical production expenses and crop yields, incorporates future crop price projections, and adjusts forecasted budgets to reflect the historical revenue and cost patterns associated with producers who are typically more or less profitable (i.e., average net return per acre) than regional averages. The second analysis focuses on evaluating future net returns from traditional crops and switchgrass across three soil productivity classes by using a budget generator to produce costs and returns assuming average producer profitability.

Data limitations prevent combining the basic analytical approach found in the first analysis with the focus on differentiating budgets based on soil productivity measures associated with the second analysis. As a result, each approach provides a somewhat different perspective on the economic competitiveness of switchgrass and provides a slightly different focus for evaluating breakeven switchgrass prices.

Geographic scope of the analysis was limited to a three-county area in south central North Dakota (Figure 1). The counties of Logan, Kidder, and Stutsman were selected to correspond with the agronomic conditions present at the Central Grasslands Research Extension Center (CGREC) in Streeter, North Dakota. The CGREC had five years of data on switchgrass yields. The CGREC has recently expanded its research program on herbaceous energy crops to include other grasses, alternative harvest regimes, and field trials at additional locations elsewhere in the state. However, results from those projects are not yet sufficient for economic analysis (Nyren et al. 2007).

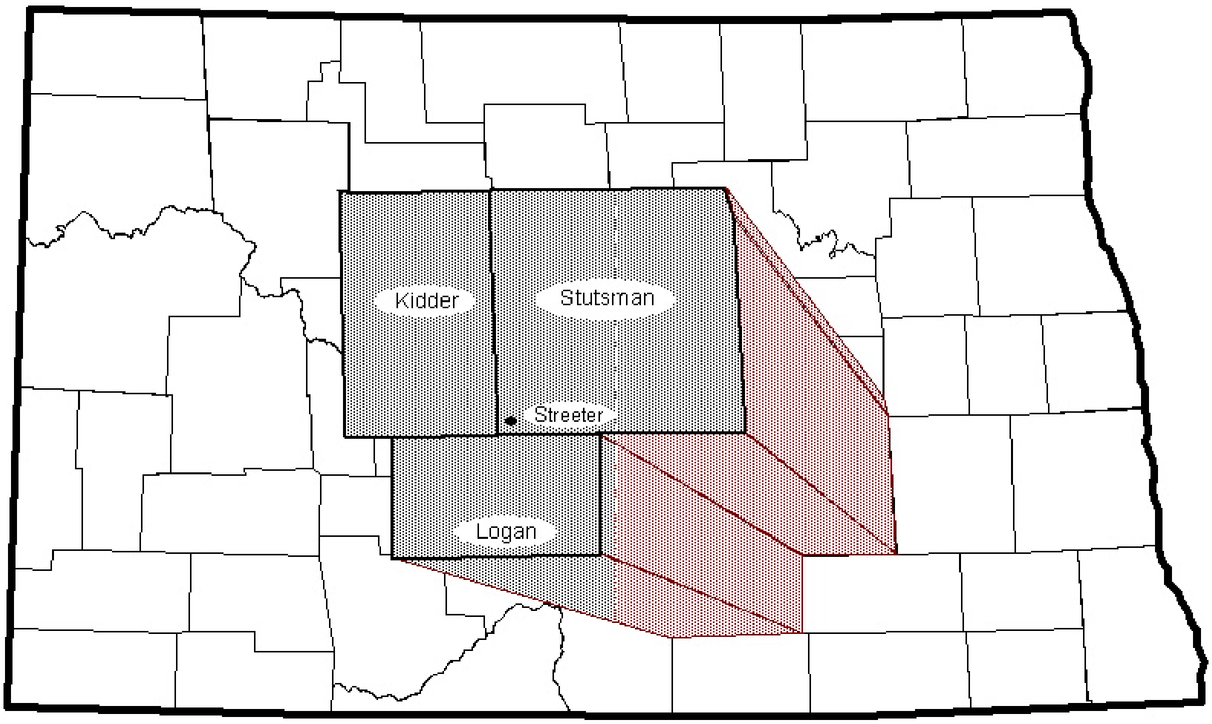

Figure 1. Study Region, South Central North Dakota

A basic premise for the study was that switchgrass would need to be at least as profitable as the mix of crops currently grown in the study region to be seriously considered by producers as a cash crop. Recognizing that producers are not likely to compare the profitability of switchgrass to that of a single crop, since most producers raise several crops each year, a composite acre was developed. The composite acre therefore represents an annual mix of crops raised in the region, but may not necessarily represent the mix or the proportion of crops raised by all producers. Crops which averaged at least 5 percent of overall annual planted acreage in the study region were included in the composite acre (Table 1). The most popular crops in the study region from 2002 through 2006, based on planted acreage, were soybeans, spring wheat, alfalfa, corn, sunflowers, and barley.

Table 1. Composite Acre, Study Region, 2002 through 2006

Crop	Average Annual Planted Acreage	Percentage of Total Planted Acreage in Study Region	Final Percentage of Composite Acre[c]
Soybeans	343,867	24.0	32.2
Spring Wheat	288,667	20.2	27.0
Alfalfa[a]	177,333	12.4	16.6
Corn[b]	111,333	7.8	10.4
Sunflowers, oil	74,833	5.2	7.0
Barley	72,833	5.1	6.8

[a] Represents harvested acres.
[b] Represents total planted acreage, including corn used for silage and irrigated acreage. However, composite acre treated all acreage as dryland corn for grain.
[c] Acreage of minor crops reallocated proportionally among the most popular crops.
Source: North Dakota Agricultural Statistics Service (various years).

Breakeven Prices by Producer Profitability Groups

The breakeven switchgrass price required to provide net returns comparable to those from traditional crops was evaluated based on the differences in cost, revenue, and net returns associated with a range of producer profitability characteristics. This approach forecasts producer net returns for traditional crops based on trends in actual production expenses, past crop yields, and future price projections. Those forecasted net returns for traditional crops were then differentiated to reflect different levels of profitability. Breakeven switchgrass prices were then estimated based on forecasted net returns on traditional crops for five different producer profitability groups.

Budgets for Traditional Crops

The FINBIN database of farm production records contained 14 years of annual data (1993 through 2006) on crops raised in the study region (Center for Farm Financial Management 2008). The FINBIN database contains financial information from producers who are enrolled in the North Dakota Farm and Ranch Business Management Education system. An advantage of the database is that all information collected and disseminated is based on actual farmer records, as opposed to estimated production expenses from a budget generator or model farm analysis. A potential disadvantage is the inability to differentiate financial records associated with soil productivity factors.

Production budgets obtained from FINBIN included yields, crop prices, government payments, miscellaneous income, direct expenses, and overhead charges. The budgets represented operations on owned land and cash rented land. Operations on share-rented land were not included.

Some adjustments to production expenses were performed on the budgets. Land expenses are not likely to change based on the crop raised. In other words, if a farmer makes a land payment, that payment does not change if the land is used to raise wheat versus soybeans. Likewise, real estate taxes are assumed to be independent of the crop raised. Cash rents were similarly assumed to remain unaffected by choice of crops raised; however, it is recognized that higher net returns are likely to be capitalized into cash rents over longer periods. In recent years, some row crops, soybeans in particular, have been financially more attractive to raise than small grains in the study region. Also, corn acreage has been increasing in the region for the same reasons. The potential for cash rents to increase as a result of these higher value crops was not addressed in this study. Therefore, assuming land expenses would not vary between switchgrass and traditional crops, land costs were not included in production expenses.

To arrive at production expenses that excluded land charges, cash rent expenses were removed from direct or variable expenses. Similarly, land taxes were removed from overhead expenses on budgets for owned land. To remove interest associated with land payments, overhead interest was removed from budgets that represented a combination of owned and rented land. However, since overhead interest would also include interest on machinery purchases, among other items, overhead interest from only rented land budgets was added back to overhead expenses. The amount of interest on purchases other than land was assumed to be similar between the owned and rented land budgets. Thus, overhead interest was retained in the fixed expenses, but more closely matched only interest for machinery and other non-land purchases.

An analysis of time trends was conducted for each crop in the composite acre for yields, direct expenses, and overhead expenses (Table 2). Yield trends over the period were only statistically significant for barley and wheat. Trends in direct expenses from 1993 through 2006, expressed in nominal dollars, were statistically significant and increasing in all crops except alfalfa. Trends in overhead expenses, also expressed in nominal dollars, were statistically significant in all crops except alfalfa and sunflowers (Table 2). Overhead expenses per acre have been decreasing for soybeans, while overhead expenses have been increasing for wheat and corn. In the cases when time trends were not statistically significant, a 10-year average was used to develop the composite-acre budgets.

Gross revenue in the FINBIN crop budgets include product income (yield times price), plus other product revenue, miscellaneous revenue, and government payments. Other product revenue is primarily composed of aftermath grazing or sales of crop residue (e.g., straw). Miscellaneous revenues primarily represent crop insurance indemnities. To account for the additional sources of revenue in the forecasted budgets, other revenue and miscellaneous revenue were estimated as a percentage of product income. Since other product revenue was only available in the FINBIN budgets back to 2002, a five-year average (2002 through 2006) of those percentages was applied to product income in the projected budgets (Table 3). Data on miscellaneous revenues; however, were available from 1993 through 2006. A 14-year average of those percentages was applied to future product income in the projected budgets. Government payments, on a per-acre basis, were assumed to be similar in the future as they have been in recent years. As a result, government payments in the projected budgets were an average of payments received from 2002 through 2006 (Table 3).

Table 2. Time Trends for Yields, Direct Expenses, Overhead Expenses, and Net Returns, by Crop, Kidder, Logan, and Stutsman Counties, North Dakota, 1993 through 2006

Crop/Component	Intercept	Year Coefficient	Standard Error	R^2
Wheat				
Yield	-2592.24	1.3141	0.4786	0.4066
Direct Expenses	-5409.04	2.7415	0.5157	0.7019
Overhead Expenses	-1071.19	0.5473	0.1097	0.6743
Soybeans				
Yield	-826.83	0.4279	0.2982	0.1464
Direct Expenses	-2442.92	1.2647	0.4708	0.3755
Overhead Expenses	1272.90	-0.6204	0.1933	0.4617
Corn				
Yield	-3486.59	1.7885	1.6300	0.0911
Direct Expenses	-7920.14	4.0218	0.7384	0.7120
Overhead Expenses	-820.60	0.4276	0.1873	0.3027
Barley				
Yield	-2096.60	1.0777	0.4330	0.3405
Direct Expenses	-4636.62	2.3518	0.3919	0.7500
Overhead Expenses	-1730.84	0.8776	0.0999	0.8653
Sunflowers				
Yield	-381.48	0.1975	0.1560	0.1178
Direct Expenses	-5396.05	2.7386	0.5641	0.6625
Overhead Expenses	-150.35	0.0894	0.1349	0.0352
Alfalfa				
Yield	70.51	-0.0342	0.0299	0.0983
Direct Expenses	-1043.66	0.5361	0.3900	0.1360
Overhead Expenses	-663.25	0.3430	0.1941	0.2064

Table 3. Parameters for Other Revenues for Forecasted Crop Budgets in the Profitability Analysis, 2008 through 2017

Crop	Additional Crop Revenues: Other Revenue	Miscellaneous Revenue	Government Payments
	------- % of product revenue -------		--- $/acre ---
Wheat	0.04	4.61	11.24
Soybeans	0.00	4.83	11.61
Corn	0.94	12.64	12.31
Barley	0.08	5.48	11.00
Sunflowers	0.01	5.97	11.43
Alfalfa	0.81	4.05	8.18

Projected future national crop prices from 2008 through 2016 were obtained from the Food and Agriculture Policy Research Institute (FAPRI) (2008) and Taylor and Koo (2008). Forecasted prices were adjusted to reflect the historic relationship between national prices and actual prices received by producers in North Dakota based on methods developed by Taylor et al. (2004). Forecasted state-level prices were further adjusted to reflect anticipated prices received by producers within the study region.

Budgets for 2008 through 2017 were developed for each crop using time trends of past expenses and yields, and future projections of crop prices. When a statistically significant time trend was present, the trend equation was used to forecast values for the budgets. When a statistically significant time trend was not present, a 10-year average value was used. The end result was separate budgets from 2008 through 2017 for each crop in the composite acre.

An adjustment on the projected budgets for the producer profitability analysis was conducted to account for the substantial increase in input prices that occurred from 2006 (last year FINBIN data were available) to 2008 (first year of ten-year analysis period). The analysis used historic data to develop trends in production expenses, which were subsequently used to project cost increases in crop budgets from 2008 through 2017. However, using past trends in the rate of change in variable and fixed expenses would not account for the rapid two-year increase in production expenses witnessed from 2006 to 2008. As a result, to make the forecasted budgets for 2008 through 2017 more reflective of the input price changes observed in the two growing seasons prior to the spring of 2008, a one-time adjustment of 35 percent was applied to the 2006 level of variable and fixed expenses for the 2008 budgets. Therefore, production costs in the 2008 budgets were adjusted upward to reflect a more realistic representation of the production costs associated with 2008 conditions than would be the case if expenses were based only on the trend procedure. From 2009 through 2017, annual changes in production expenses were assumed to follow the historic rate of change (trend) from 1993 through 2006.

Budgets for Switchgrass

Data on switchgrass yields and production inputs were obtained from CGREC. From the data, establishment-year and production-year budgets were developed (Appendix A). Switchgrass is similar in context to alfalfa where the crop is planted the first year with annual harvest starting sometime in the second year. The type and amount of inputs and type and frequency of field operations for switchgrass establishment and annual production were based on operations performed during the field trials at CGREC.

Machinery costs for both the establishment budget and annual production budget were based on custom work rates (Aakre 2007). However, since the net returns from the crop budgets obtained from FINBIN were net of operator labor (i.e., charges for operator labor were not included in expenses), labor expenses for field operations were estimated from Lazarus (2007) and subtracted from the custom work rates. Thus, removing labor expense from the custom rates allows for net returns from the switchgrass budgets to more closely reflect the same expenses found in the FINBIN budgets.

The establishment budget was developed based on parameters that assume 100 percent probability of obtaining a satisfactory stand. In reality, not all attempts to establish perennial grass in the study region result in an acceptable stand. To account for reseeding expenses, the probability of having to reseed was multiplied by the cost of the planting operation plus the cost of seed. It was assumed that if reseeding was required, the only additional costs would be seed and those associated with a planting operation. Estimated reseeding expenses were added to the direct expenses of the establishment budget. Average yields were assumed to not be affected by reseeding, as reseeding efforts were expected to be performed within sufficient time for new seed to germinate and establish prior to fall freeze up.

The establishment and production budgets included an estimated government payment. The average government payment that was received from traditional crops in 2006 was estimated from FINBIN data and included in the establishment budget. The average government payment, weighted by crop acreage from 2002 through 2006, was estimated from FINBIN data and included in the production budget. Again, government payments, on a per-acre basis, were assumed to be similar in the future as they have been in recent years and eligibility of receiving government payments would not be affected by raising switchgrass.

The establishment budget also included the foregone net return (i.e., opportunity costs) from raising a crop on the switchgrass acreage. While a cover crop was included in the establishment budget for switchgrass, revenues from the cover crop were not considered as a substitute for replacing the opportunity cost of raising a traditional crop. Current knowledge of establishing switchgrass precludes harvesting switchgrass at the end of the establishment year or raising a second crop (e.g., double cropping with wheat or soybeans) on the same acreage. So, by putting land into switchgrass, a producer foregoes the opportunity to collect the net revenue that they would have collected had the land been used to raise another crop. Average net return, excluding charges for land, for the composite acre in 2007 was estimated and included as an expense in the establishment budget. Net costs (negative net returns) of establishing switchgrass were amortized over 10-years at 5 percent interest and included as an expense in the production budget.

Breakeven Prices by Soil Productivity Classes

The second analysis focuses on evaluating switchgrass prices based on soil productivity criteria. The premise for this analysis is that switchgrass might have a competitive advantage over traditional crops when raised on low productivity soils. The concept of using marginal or low productivity soils to produce dedicated herbaceous energy crops is analogous to the land targeting goals that occurred with the Conservation Reserve Program in the late 1980s and early 1990s (Bangsund et al. 2004). The marginal crop lands in question generally are considered to be poor candidates for traditional crops and perceived to be in better use when returned to perennial grasses (analogous to CRP lands being returned to grass). Further, by targeting marginal soils, herbaceous energy crops are not as likely to compete for use on more productive soils, and thereby mostly avoiding direct competition with the most economical of the traditional crops grown on more productive soils.

While limiting the economic comparison of switchgrass to traditional crops on marginal or low productivity lands is straightforward, the availability of trial data and observed yields for such comparisons is currently limited. FINBIN data does not allow for public reporting based on soil productivity factors making it impossible to determine net returns for traditional crops on only marginal soils. Also, field trial data for switchgrass yields based on a range of soil productivity factors for the region were unavailable. Since production records for traditional crops and field trial data for switchgrass were not available with respect to marginal soils, budget generators and soil data were used to estimate crop revenues, production expenses, and net returns on marginal soils, holding all other parameters constant (e.g., managerial skill, producer profitability).

Soil Productivity Groups

Soil data for the study region were obtained from the National Cooperative Soil Survey (Natural Resources Conservation Service 1995, 2004; Soil Conservation Service 1986). Information for detailed soil map units, which can represent a soil series, a soil phase, or a soil complex, generally fall into eight different land capability classifications. Those classifications, along with land capability subclasses (when available), were used to determine soils that represent cropland. Land capability classifications place soils into categories based on the suitability of the soil to raise conventional crops. The most suitable soils for crop production included the first three classes (Class I, II, III). Class IV soils have a more mixed use consisting of hayland, pasture, or limited-use cropland. Class V, VI, and VII soils are primarily limited to pasture or rangeland. Class VIII soils have limitations that prevent their use for commercial crop, hay, or forage production.

Soil map units in the study area that were classified as class I, II, III soils were included as cropland. Class IV soils described as cropland or hayland were included, while class IV soils classified as pasture or range were excluded from the analysis. All class V, VI, VII, and VIII soils were excluded. Information on acreage and yield potential were available for the soil map units. Yield potential, in the soil data, represents an expected yield under normal growing conditions with a 'high level of management.' Yield potentials therefore directly reflect the inherent site-specific factors affecting crop productivity. Yield potentials were available for spring wheat, barley, oats, flax, sunflowers, and alfalfa hay, and represent a relative measure of productivity given a fixed level of technology. Thus, yield potentials listed in the soil data are not necessarily going to equal historic yields or match future yield expectations, but can be used to sort soils based on a common productivity criterion.

For illustrative purposes, a weighted average value for expected yields by crop for the study region was compared to an average of actual crop yields from 2004 through 2006 (Table 4). Recent yields for small grains appear to exceed the yield expectations from the soil data, while yields for alfalfa would appear to fall short of yield expectations.

Table 4. Expected Yields for Selected Crops Based on Soil Survey Data and Actual Yields Obtained by Producers, Kidder, Logan, and Stutsman Counties, North Dakota

Crop	Units /acre	Yield Expectation[a]	Average Yield 2004 - 2006[b]
Spring Wheat	bu	25.4	33.1
Barley	bu	41.3	56.2
Sunflowers	lbs	1,277.8	1,241.6
Alfalfa Hay	tons	2.10	1.76

[a] Yield based on soil data, weighted by acreage of soil types. Soil data did not contain yield expectations for corn or soybeans.

[b] North Dakota Agricultural Statistics Service (various years).

Unfortunately, objective measures, in an economic context, of what constitutes a marginal or low productivity soil or an expected yield from a marginal soil were not found in soil or economic literature. Objective measures of expected yields for highly productive soils were also absent from economic literature. Despite objective measures, the term 'marginal' is typically associated with low productivity soils in any particular area. By any reasonable definition, marginal soils would be less productive than average productivity soils. Therefore, average crop yields were used as a reference for defining marginal soils. Similarly, soils with yields consistently better than average would constitute the most productive soils within a given region.

However, delineating how much less/more than average any particular soil would need to be for it to be considered marginal or highly productive remains subjective. Soils producing spring wheat yields within five bushels (roughly +/- 15 percent of the mean) of the regional average were considered to be of average productivity. Once the range of yields for average productivity soils was determined, all soils with expected yields that were below the lower range of average productivity soils would constitute marginal soils. The same would hold for high productivity soils having yields that exceed the upper bound of yields for average soils. This approach is still subjective because there is a lack of data to determine the statistically acceptable range of yields for average productivity lands.

Wheat yields in the study region averaged 33 bushels per planted acre from 2004 through 2006 (NDASS various years). Using this study's definition, along with the regional average wheat yield, soils with average productivity would be capable of producing wheat yields that ranged from 27 to 38 bushels per acre. Unfortunately, actual distribution of wheat yields in the study region was not available to test the above hypothesis, although yields observed from FINBIN data would confirm that yields higher than the NDASS average were achieved by numerous producers in the region. Anecdotally, the range used for average productivity soils seems reasonable. Assuming the range of wheat yields for defining average productivity is acceptable, then soils that produce average wheat yields less than 27 bushels per acre could be classified as marginal. Likewise, soils producing average wheat yields exceeding 38 bushels per acre would represent highly productive soils.

The range of actual yields (i.e., 27 bushels/acre and 38 bushels/acre) were then used to estimate the equivalent lower and upper range of expected yields (i.e., based on soil data). The weighted average expected yield for spring wheat in the region was 25.2 bushels per acre across all soil types. By maintaining the ratio of average actual yields to the average expected yield, lower and upper bounds of expected yields were estimated for average productivity lands (Table 5). Therefore, all land with an expected yield for spring wheat of less than 21.4 bushels per acre would be considered marginal. Similarly, all soils with an expected yield for spring wheat greater than 28.2 bushels per acre would be classified as highly productive land.

The weighted average for all soils having an expected yield less than 21.4 bushels per acre was 15.8 bushels per acre. An expected yield of 15.8 bushels per acre would translate into an actual yield of 20.8 bushels per acre (Table 5). Thus, a typical wheat yield on marginal soils in the region would be around 21 bushels per acre. Of course, during any year there will be considerable yield variation among marginal soils. Using the same procedures, the typical wheat yield on highly productive soils would be around 44 bushels per acre.

The yield potential for spring wheat was the criterion for judging the productivity of soils in the region. Expected yields for sunflower, barley, and alfalfa hay were also estimated from the group of marginal soils and the group of highly productive soils (Table 5). Estimated actual yields of sunflower, barley, and alfalfa on the two groups of soils were then estimated using the same technique used with wheat yields. Expected yields for corn and soybeans were not available from the soil data so expected sunflower yields were used as a proxy to estimate actual yields for corn and soybeans on marginal and highly productive soils (Table 5).

Switchgrass yields were also adjusted to reflect the relative productivity difference between the soil(s) used in the CGREC trials and those representative of low and high productivity soils in the region (Table 5). The expected yield for alfalfa, found in the soil data, was used as a proxy for estimating switchgrass yields on marginal soils. The yield potential for alfalfa on the CGREC plots used for the switchgrass trials was 2.3 tons per acre. The regional average yield potential for alfalfa was estimated at 2.09 tons per acre. The land used for the switchgrass trial was slightly more productive than the regional average with respect to alfalfa. Therefore, a regional average yield for switchgrass was estimated at 3.01 tons per acre, which reflects the difference between productivity of the soil in the trial plots to that of the region as a whole.

Switchgrass plots yielded about 3.31 tons per acre (Nyren 2008). The soils in the switchgrass trials have an alfalfa yield potential of 2.3 tons per acre. The regional average alfalfa yield potential was estimated at 2.09 tons per acre. Thus, regional switchgrass yields could average lower than those observed on CGREC trial plots, if the link between alfalfa potential and switchgrass potential is accurate. Regional switchgrass yields, across all cropland, were estimated to average about 3 tons per acre. Applying the ratio of expected yield for alfalfa on marginal lands to the expected yield for alfalfa on average productivity lands (1.86 tons/2.09 tons) to the regional estimate of switchgrass yield (3.01 tons per acre) produced an estimated yield of 2.67 tons per acre of switchgrass on marginal lands (Table 5). Similarly, using the same procedures, the most productive soils in the region could be expected to produce an average switchgrass yield of 3.5 tons per acre.

Table 5. Estimated Yields on Marginal, Average, and High Productivity Soils, Kidder, Logan, and Stutsman Counties, North Dakota, 2004 Through 2006

		Marginal			Average			High		
Crop	Category	Lower	Avg[a]	Upper	Lower	Avg[a,b]	Upper	Lower	Avg[a]	Upper
Wheat	Yield Potential (Soil Data)	8.0	15.8	21.4	21.4	25.2	28.2	28.2	32.8	40.0
	Estimated Actual Yields[c]	na	20.8	22.1	28.1	33.1	38.1	38.1	43.8	na
Barley	Yield Potential (Soil Data)	13.0	25.7	34.0	34.0	40.7	47.0	47.0	54.0	65.0
	Estimated Actual Yields[c]	na	35.5	na	na	56.2	na	na	74.5	na
Sunflowers	Yield Potential (Soil Data)	400.0	790.8	1,050.0	1,050.0	1,262.0	1,500.0	1,500.0	1,659.0	2,000.0
	Estimated Actual Yields[c]	na	778.0	na	na	1,241.6	na	na	1,632.2	na
Alfalfa	Yield Potential (Soil Data)	na	1.86	na	na	2.09	na	na	2.44	na
	Estimated Actual Yields[c]	na	1.57	na	na	1.76	na	na	2.06	na
Soybeans	Estimated Actual Yields[c,d]	na	19.0	na	na	30.3	na	na	39.8	na
Corn	Estimated Actual Yields[c,d]	na	55.5	na	na	89.6	na	na	116.5	na
Switchgrass	Estimated Actual Yields[c,e]	na	2.67	na	na	3.01	na	na	3.51	na

na = not available or not applicable.

[a] Weighted by acreage of each soil type.

[b] Yield potential for each crop represents weighted average for study region.

[c] Actual yields for average productivity soils represent average yields for entire region from 2004 through 2006 (NDASS 2005-2007). Estimated actual yields for marginal and high productivity soils were estimated from ratio of expected yields on marginal soils to expected yields on average soils multiplied by county average yield.

[d] Corn and soybean yields on marginal and high productivity soils estimated by adjusted county average yield by ratios for sunflower yields.

[e] Central Grasslands Research Extension Center trial research data adjusted based on soil productivity factors for alfalfa.

Budget Parameters

In the soil productivity analysis, estimated 2008 crop and switchgrass enterprise budgets were developed using the NDSU Extension Crop Budget Generator and based on production assumptions associated with NDSU Farm Management Planning Guides (Swenson and Haugen 2007). The NDSU projected budgets are generated using a set of assumptions on farm debt, machinery complement, production practices, field operations, and input prices. Those general assumptions were held constant allowing the budgets to reflect the revenue and cost differences associated with changes in soil productivity. The budgets were generated using anticipated average yields associated with each soil productivity class (see Table 5). Crop prices for production year 2008 were based on average new crop farm prices in April of 2008 (South Central Grain 2008). Government payments were excluded in the budgets, and assumed to be the same on land used for crops or switchgrass. Similarly, production expenses excluded land charges.

An establishment budget for switchgrass was based on 2007 input prices and reflected the general assumptions used to produce the 2007 NDSU projected budgets (Swenson and Haugen 2006). Similarly, NDSU projected budgets for the South Central region for 2007, modified to reflect changes in costs tied to soil productivity classes (e.g., fertilization rates), were used to generate an estimate of the opportunity cost of foregone net revenues from traditional crops during the establishment year (Swenson and Haugen 2006). The establishment budget also included a probability-weighted expense for reseeding. The actual expense included in the 2007 establishment budget was a product of an area-wide probability of having to reseed during the establishment year times the additional expenses associated with reseeding (Nyren 2008). The overall net cost of establishing switchgrass (i.e., revenues less costs during the establishment year) was amortized for a 10-year period and included as an expense in the 2008 through 2017 annual production budgets for switchgrass.

Projected future U.S. commodity prices from 2009 through 2017 were obtained from (FAPRI 2008). FAPRI forecasted prices were adjusted to reflect the historic relationship between national prices and actual prices received by producers in North Dakota based on methods developed by Taylor et al. (2004). Forecasted state-level prices were further adjusted to reflect anticipated prices received by producers within the study region.

The annual nominal change in per-acre production expenses for the NDSU projected crop budgets for the South Central region was averaged from 1993 through 2008. The average annual change was estimated for direct and overhead expenses for each crop in the composite acre. The average annual change in expenses, expressed in dollars per acre, was used to provide the level of annual increase in production expenses from 2009 through 2017 for each crop.

Trends in crop yields reported by NDASS from 1992 to 2006 in the study counties were examined. Only corn and soybean yields exhibited statistically significant time trends in yields over the 15-year period. Corn and soybean yields (i.e., yields in 2008) were adjusted annually from 2009 through 2017 using the yield trend from 1992 to 2006. Future yields for the remaining crops were held at the 2008 level for the 2009 through 2017 period.

Annualized Equivalent Values

The result of the budgeting process produced 10 years of budgets for traditional crops and switchgrass (Appendix A). The enterprise budgets were weighted by crop acreage to produce a composite-acre budget. The net returns from the composite-acre budget were then combined with estimated switchgrass production expenses to arrive at a switchgrass price that would provide for projected net returns from switchgrass that equal those of traditional crops over the 10-year study period.

Before switchgrass prices could be calculated, the stream of net returns for the composite acre and annual costs for switchgrass production were adjusted to account for the time value of money. The net present value of production costs and composite-acre net returns are represented by equation (1):

$$(1) \quad NPV = \sum_{n=1}^{10} value_n * (1+d)^{-n}$$

where d = discount rate
n = years 1-10
value = net return from composite acre or switchgrass production cost

The study used an annualized equivalent approach to handle the time value of costs and returns over the 10-year period (Perrin 1972). The annualized equivalent value for switchgrass production costs and the annualized equivalent value for composite-acre net returns are represented in equation (2).

$$(2) \quad AEV = \frac{d}{1-(1+d)^{-n}} * NPV_{net\ returns} + \frac{d}{1-(1+d)^{-n}} * NPV_{production\ costs}$$

where d = discount rate
n = years 1-10

The average annual discounted values of switchgrass costs and composite acre net returns were divided by switchgrass yield to arrive at a breakeven price (equation 3).

(3) Breakeven Price = AEV / average switchgrass yield

Limitations

Although two different approaches were used to provide insights into the breakeven prices required for switchgrass to compete with traditional crops, the study was not without several substantial limitations. The knowledge of how to commercially raise switchgrass in North Dakota is very limited, and as such, little 'ground truthing' is available to formulate enterprise budgets and gauge producer responses to economic incentives to raise switchgrass.

Geographically, the study was limited to a three-county region in south central North Dakota. Crop production varies considerably across North Dakota. It is anticipated that switchgrass yields and production costs will vary across the state. Even though the approach and budget comparisons used in this analysis might be applicable for other regions of North Dakota, general economic relationships and specific findings may not necessarily be representative of other areas in the state.

The definition of marginal soils in this study is subjective. What constitutes marginal soils for other researchers or producers may not equate to the same yields, economic expectations, or physical parameters used in this study. Much of the economic relationships examined in this study with respect to soil productivity hinged on the definition of marginal or low productivity soils. If marginal soils were to be defined as being less productive than used in this study, the likely range of yields on those soils would be less than modeled in this analysis. Conversely, if marginal soils included more productive land, yield ranges on marginal soils would be even greater than modeled in this study. Either way, the definition(s) of soil productivity classes in the study region has implications for the supply and cost of acquiring switchgrass for a processing plant.

Not only is the definition of marginal soils subjective, but the concept is relative. Compared to cropland in the southern Red River Valley, nearly all of the cropland in the study region might be considered marginal. Similarly, nearly all of the cropland in the study region might be considered highly productive land if compared to cropland in the most western portions of the state. The output from marginal lands is always going to be relative to the overall capacity of land in any given region. Thus, the economics of herbaceous energy crops on marginal lands has substantial potential to change as the regional capacities for crop production increase or decrease depending upon location in the state.

While the study's methodology uses techniques to account for the time value of money, essentially the computed breakeven prices can be interpreted as an annualized figure. In reality, pricing contracts could include provisions for switchgrass to remain competitive with other crops. Prices for traditional crops are likely to vary from year to year, and if switchgrass prices are tied to those prices, switchgrass prices could also be adjusted over the life of a contract. For example, switchgrass price might be tied to commodity and/or input price indexes and thus move up and down in relation to the prices of crops raised in an area.

Contracts could also be tied to other criteria, such as past yield output, acreage harvest provisions, or other means to compensate producers for years when weather shortens or increases switchgrass yields. Also possible is that federal farm, conservation, and/or energy policies could influence producers' contract prices through program payments, subsidies, income insurance, or other provisions. Thus, the breakeven prices discussed in this report should be viewed on the basis of an average annualized price, but that switchgrass prices might not remain constant over a 10-year period.

Technology was assumed to be fixed over the 10-year period. However, the likelihood of some technological improvements in agricultural production over the period are almost guaranteed. In general, technological change in traditional crop production will influence future costs, yields, and net revenues. While technological change will continue for existing crops, technology could have substantial impacts on switchgrass production as producers gain experience in raising switchgrass or similar crops, as production-related research improves the understanding of how to raise switchgrass, or as plant breeding influences the yields of available switchgrass cultivars. Technological effects could also come from changes in harvest and handling equipment and techniques/procedures. Specific future improvements in production technologies are difficult to predict, and the effects of those changes on producer net returns would be extremely problematic to include in forecasted budgets.

The analysis does not include price effects on traditional crops that might result from acreage shifts to perennial grass production, either regionally or nationally. It would be expected, all things equal, that as acreage used to raise traditional crops is reduced, that reduction would reduce the supply of those crops and put upward pressure on prices. The overall size of the study region is too small for acreage adjustments within the region to influence national or regional prices. However, a commercialization of cellulosic ethanol would not be limited to the study area, and would likely influence conversion of acreage in sufficient quantity throughout the Upper Midwest or Great Plains to have regional and national price effects on traditional crops. A mitigating factor on the degree of price response from traditional crops would be the extent that those crops were raised on land currently enrolled in the Conservation Reserve Program (CRP). Future conversions of CRP lands to energy crops would potentially lessen the degree of acreage competition between switchgrass and traditional crops, assuming that those CRP lands had not already been converted back to traditional crops.

Another factor associated with the acreage competition between herbaceous energy crops and traditional crops is that price increases from traditional crops will influence the economic attractiveness of energy crops and influence the ability of those crops to provide similar net returns to producers. Ultimately, an equilibrium between energy crops and traditional crops would result, given some assumptions about costs and prices. However, the issues of equilibrium between those crops and the degree of price change for traditional crops resulting from acreage shifting to energy crops is well beyond the goals of this study and represents a completely different type of economic assessment.

Carbon (C) sequestration effects of raising switchgrass were not included. Soil carbon sequestration rates are likely to be higher under switchgrass production than rates associated with traditional crops, regardless of tillage practice used for traditional crops. If C sequestration rates with switchgrass prove to be higher than obtained with traditional crop rotations even under conservative or no-till practices, switchgrass might potentially provide a slightly greater C payment than achievable with traditional crops. Of course, C sequestration rates are subject to a variety of factors, one of which would be land use prior to switchgrass production. Land with depleted soil C would likely generate greater annual rates than land previously held in grass (e.g., CRP). It is difficult to speculate on whether C sequestration rate differences between switchgrass and traditional crops with no-till or conservation tillage would be sufficient to influence land use or substantially influence breakeven prices.

Non-market benefits of switchgrass production were not addressed. The benefits of reduced soil erosion, wildlife habitat, and water quality associated with converting cropland to grass were not included in the analysis. The value of those benefits is not likely to accrue to the landowner, and thus would not likely alter the comparative economics of switchgrass and traditional crops. However, those values could influence or shape future provisions of federal legislation. An additional consideration might be soil fertility improvements for conventional crops upon the retirement of the switchgrass stand.

Net energy returns or life-cycle analysis of comparative emissions between switchgrass and its associated uses versus those related to traditional crop production were not addressed. Again, these measures would provide important information for policymakers, but be of little value to farm-level decision making given the current regulatory environment.

RESULTS

Two approaches to estimating a breakeven switchgrass price were developed. Results from those approaches are presented separately in the following sections. Each approach used a common set of factors and assumptions that represented a baseline condition. Scenarios were then developed to show how switchgrass prices change with adjustments to the baseline conditions.

Baseline Conditions

Net returns from traditional crops were based on a composite acre approach, which represented 32 percent soybeans, 27 percent wheat, 17 percent alfalfa, 10 percent corn, and 7 percent each for barley and sunflowers (see Table 1). Price projections, by crop, from 2008 through 2017, were based on market conditions present in early 2008 and forecasts of prices given current knowledge of futures market activity (Table 6). Discount rate was 5 percent.

Table 6. Baseline Crop Price Projections, South Central North Dakota, 2008 through 2017

Year	Spring Wheat	Soybeans	Corn	Feed Barley	Sunflower	Alfalfa
	---------------------------------- $/bushel --------------------------------				---- $/cwt ----	---- $/ton ----
2008[a]	8.35	10.85	5.15	4.54	23.35	61.00
2009	7.26	7.58	3.45	3.16	14.29	61.00
2010	7.34	7.64	3.36	3.12	14.24	59.00
2011	7.32	7.59	3.41	3.17	14.32	60.00
2012	7.41	7.67	3.44	3.2	14.39	59.00
2013	7.41	7.71	3.48	3.27	14.53	61.00
2014	7.44	7.76	3.48	3.32	14.59	60.00
2015	7.43	7.76	3.50	3.36	14.65	60.00
2016	7.46	7.79	3.47	3.41	14.69	60.00
2017	7.38	7.75	3.47	3.46	14.72	60.00

[a] New crop prices except alfalfa, April 2008, quoted by South Central Grain in Napoleon, ND.
Sources: Haugen et al. (2008), South Central Grain (2008), Taylor and Koo (2008), FAPRI (2008).

Future changes in production expenses were based on past rates of change in those costs. In the analysis using producer profitability classes, the future rate of change in direct and overhead expenses, by crop, from 2008 to 2017 was assumed to be equal to the historic rate of change from 1993 through 2006. Similarly, the future rate of change in direct and overhead expenses in the analysis using soil productivity classes represented the annual average change per acre of crop budgets from the NDSU Extension Service.

Rates of change in future yields for crops in the composite acre were based on trends in yields, or in the absence of a statistically significant yield trend, a 10-year average was used. In the profitability group analysis, yield changes for traditional crops from 2008 through 2017 were based on time trends of producer yields from 1993 through 2006. In the case when yield changes over time were not statistically significant, an average of yields from 1997 through 2006 were used. The soil productivity analysis used the same approach, except that time trends of yields were based on estimated yields used in the published budgets for 1991 through 2006. The estimated yield for each budget year represented a 7-year Olympic average of NDASS published yields.

Soil Productivity Classes

Yields for switchgrass were estimated to average about 2.67 tons per acre in marginal soils to about 3.5 tons per acre in the high productivity soils (Table 7). Switchgrass production costs ranged from just over $40 per ton to $34.80 per ton, depending upon land productivity, but those costs did not include land charges or transportation expenses beyond the field. Net returns on the composite acre represented returns to unpaid labor, management, equity, and land for traditional crops in the region, and were expressed as an average annual equivalent. As might be expected, net returns for traditional crops on the marginal soils were considerably lower (returns were around $18 per acre) than net returns on the most productive lands (returns were around $145 per acre). Breakeven switchgrass prices were estimated as the price required to cover switchgrass production expenses and provide for the same level of net return from traditional crops. Breakeven switchgrass prices across the three soil productivity classes ranged from $47 per ton in the low productivity soils to $76 per ton in the most productive soils (Table 7). Switchgrass was estimated to generate the same level of net returns per acre on average soil productivity with a farm-gate price of $67 per ton (Table 7).

Table 7. Switchgrass Yields, Production Costs, and Breakeven Farm-gate Prices, by Soil Productivity Class, Baseline Conditions, South Central North Dakota, 2008 through 2017

Soil Productivity Class	Switchgrass		Net Return on Composite Acre[a]	Breakeven Switchgrass Price
	Yield	Production Cost[a]		
	--- tons/acre ---	--- $/ton ---	--- $/acre ---	--- $/ton ---
Low	2.67	40.26	18.40	47.14
Average	3.01	38.27	86.40	67.02
High	3.51	34.80	145.27	76.16

[a] Production cost does not include land charges. Net returns are defined as returns to operator labor, management, equity, and land. Values represent an annualized equivalent from 2008-2017. Discount rate was 5 percent.

Producer Profitability Classes

In the analysis that differentiated switchgrass and traditional crop production by producer profitability, methods for estimating switchgrass yields, costs, and composite acre net returns were different. Those methods relied on producer data on the cost and returns from operations in the study area. Further, relationships between average production costs and those associated with different producer profitability were used to estimate production costs for switchgrass. However, despite the differences in methods and approach compared to the soil productivity analysis, this approach still estimated the farm-gate price required to cover switchgrass production costs and provide a level of net return equal to that obtained from traditional crops.

Starting with an average switchgrass yield for the region, and using relationships between producer records and historic yields, switchgrass yields for the farm profitability groups ranged from 2.5 tons per acre for the lowest profitability producers to about 3.9 tons/acre for the most profitable producers. A difference of about 1.4 tons per acre separated the five producer profitability groups (Table 8).

Average switchgrass production expenses were adjusted among the five producer profitability groups based on the historic difference in variable and fixed production expenses among the profitability groups. The results suggest that low-profit producers would have per unit costs that substantially exceed the average cost for the region–$47 per ton compared to the regional average of $37.50 per ton. Switchgrass production costs for the remaining groups ranged from about $33.50 per ton to about $36.75 per ton (Table 8).

Projections of net returns from traditional crops varied considerably among the profitability groups (Table 8). The average annualized net return for the region was estimated to be about $123 per acre from 2008 to 2017, with net returns to unpaid labor, management, equity, and land varying from around $22 per acre for the low-profit producers to nearly over $230 for the most profitable producers. The breakeven switchgrass price ranged from $56 per ton for the two lowest profitability groups to over $94 per ton for the most profitable producers. Generally, as producer profitability increased, switchgrass yields increased, per unit production costs decreased, net returns from traditional crops increased, and breakeven switchgrass prices increased. It appeared that reductions in production cost associated with the higher profitability groups was overshadowed by much higher net returns from traditional crops which equated to considerable differences in breakeven switchgrass prices among the producer groups (Table 8).

Table 8. Switchgrass Yields, Production Costs, and Breakeven Farm-gate Prices, based on Producer Profitability Classes, Baseline Conditions, South Central North Dakota, 2008 through 2017

Profitability Class	Switchgrass		Net Return on Composite Acre[a]	Breakeven Switchgrass Price
	Yield	Production Cost[a]		
	--- tons/acre ---	--- $/ton ---	--- $/acre ---	--- $/ton ---
Average	3.01	37.58	122.81	75.75
Low 20%	2.53	47.25	21.59	55.79
20-40%	2.66	33.47	87.76	66.44
40-60%	2.77	36.26	92.82	69.71
60-80%	3.23	36.73	179.26	92.29
Top 20%	3.86	34.20	232.63	94.50

[a] Production cost does not include land charges. Net returns are defined as returns to operator labor, management, equity, and land. Values represent an annualized equivalent from 2008-2017. Discount rate was 5 percent.

Alternative Scenarios

Several components of the analysis were varied to reveal the sensitivity of breakeven switchgrass prices to changes in default values. Changes in commodity prices, switchgrass yields, and expected costs were examined.

Switchgrass Yields

While the switchgrass yields used in the baseline analysis were based on field trial data, data on switchgrass yields in the region remain sparse. Very little is known about yields across different soil types or alternative management regimes. Switchgrass yields were adjusted in both the soil productivity and income differentiation analyses (Tables 9 and 10). Other parameters were not adjusted.

Switchgrass yields were increased and deceased from the average yield for each soil class. In the marginal soils, yields were reduced and increased from an average of 2.67 tons per acre to 2.5 tons per acre and 2.75 tons per acre, respectively (Table 9). Similar changes in switchgrass yields were also included for the average and high productivity soil classes. Since management of switchgrass production was not changed (i.e., no changes in fertilization, weed control, harvest operations), changes in yields had direct effects on per unit production costs. With the marginal soils, a 0.25 ton per acre yield difference resulted in about a $3 per ton difference in production costs. A 0.50 ton per acre yield difference in the average productivity soils resulted in over a $5 per ton change in production costs. The same 0.50 ton per acre difference in yield on the most productive soils changed production costs by less than $4 per ton.

Production costs, on a per acre basis, did not appear to be overly impacted with the yield changes modeled, at least not over the range of alternative yields used in each soil class. However, relatively minor yield changes had noticeable effects on breakeven prices (Table 9). For example, a 0.17 ton per- acre yield reduction on marginal soils raised the breakeven price by $2.70 per ton. A 0.24 ton per-acre yield difference on the average productivity soils resulted in over a $5 per ton change in breakeven price. A similar decline in yield on the high productivity soils resulted in similar changes in the switchgrass breakeven price. In general, changes in switchgrass prices were inversely related to changes in yields within each soil class.

Table 9. Switchgrass Yields, Production Costs, and Breakeven Farm-gate Prices, by Soil Productivity Class, with Alternative Switchgrass Yields, South Central North Dakota, 2008 through 2017

Soil Productivity Class	Switchgrass Yield	Switchgrass Production Cost[a]	Net Return on Composite Acre[b]	Breakeven Switchgrass Price
	--- tons/acre ---	--- $/ton ---	--- $/acre ---	--- $/ton ---
Low	2.50	42.47	18.40	49.83
Low (default)	2.67	40.26	18.40	47.14
Low	2.75	39.30	18.40	45.99
Average	2.75	41.14	86.40	72.56
Average (default)	3.01	38.27	86.40	67.02
Average	3.25	35.99	86.40	62.57
High	3.25	37.00	145.27	81.70
High (default)	3.51	34.80	145.27	76.16
High	3.75	33.08	145.27	71.82

[a] Production costs among different soil productivity groups will differ even with the same switchgrass yield due to unequal foregone net returns during establishment year. Foregone net returns increased with improvements in soil productivity. Thus, unequal establishment costs produce different per unit production costs across soil classes that have the same yield.

[b] Net returns are defined as returns to operator labor, management, and land. Values represent an annualized equivalent from 2008-2017. Discount rate was 5 percent. Composite acre represents the average crop rotation in the study region expressed on a per-acre basis.

The switchgrass yield for each profitability group was based on each group's historic yield compared to a regional average yield. As a result, to assess the effects of alternative yields on the breakeven switchgrass price in the profitability group analysis, the regional average yield for switchgrass was decreased to 2.75 tons per acre and raised to 3.25 tons per acre.

A decrease in the regional switchgrass yield from 3 tons per acre to 2.75 tons per acre increased breakeven switchgrass prices about $4.50 per ton for the lowest profitability group and over $8 per ton for the highest profitability group (Table 10). An increase in regional switchgrass yield from 3 tons per acre to 3.25 tons per acre decreased breakeven switchgrass price about $3.50 per ton for the lowest profitability group and about $6.50 per ton for the highest profitability group.

Table 10. Switchgrass Yields, Production Costs, and Breakeven Farm-gate Prices, based on Producer Profitability Classes, Alternative Switchgrass Yields, South Central North Dakota, 2008 through 2017

Profitability Class	Switchgrass Yield	Switchgrass Production Cost	Net Return on Composite Acre[a]	Breakeven Switchgrass Price
	--- tons/acre ---	--- $/ton ---	--- $/acre ---	--- $/ton ---
Average (default)	3.01	37.58	122.81	75.75
Low 20%	2.53	47.25	21.59	55.79
20-40%	2.66	33.47	87.76	66.44
40-60%	2.77	36.26	92.82	69.71
60-80%	3.23	36.73	179.26	92.29
Top 20%	3.86	34.20	232.63	94.50
	------------------ decrease in expected switchgrass yields ------------------			
Average	2.75	40.56	122.81	82.33
Low 20%	2.31	51.03	21.59	60.37
20-40%	2.43	36.15	87.76	72.34
40-60%	2.54	39.11	92.82	75.73
60-80%	2.95	39.63	179.26	100.44
Top 20%	3.52	36.88	232.63	102.87
	------------------ increase in expected switchgrass yields ------------------			
Average	3.25	35.26	122.81	70.60
Low 20%	2.73	44.30	21.59	52.21
20-40%	2.87	31.38	87.76	61.92
40-60%	3.00	34.03	92.82	65.01
60-80%	3.48	34.48	179.26	85.93
Top 20%	4.17	32.11	232.63	87.95

[a] Net returns are defined as returns to operator labor, management, equity, and land. Values represent an annualized equivalent from 2008-2017. Discount rate of 5 percent.

Alternative Prices

Forecasting prices is problematic, especially given recent structural changes in domestic demand for corn, which has in turn affected prices for crops that must compete with corn for acreage. Forecasted prices were uniformly increased and decreased to examine how the breakeven price of switchgrass is affected by changes in future commodity prices.

Commodity prices for 2008 were left unchanged from the baseline analysis since forward contracts and other pricing options would allow farmers to lock in prices for the 2008 production year. Annual commodity prices from 2009 through 2017 were increased and decreased by 10 percent (Tables 11 and 12).

The effects of reducing future commodity prices by 10 percent produced lower breakeven prices for switchgrass as net returns from competing crops decreased. The decrease in net returns for traditional crops reduced breakeven prices by $4.80 per ton for low productivity soils to about $7.40 per ton for high productivity soils (Table 11). With commodity price increases of 10 percent, breakeven switchgrass prices increased by the same magnitude, on a per ton basis, as the effects associated with a 10 percent decrease in commodity prices.

The effects of reducing and increasing future commodity prices had similar effects on the breakeven switchgrass price in the farm profitability analysis. Across all profitability groups, a 10 percent decrease in future commodity prices was estimated to reduce the breakeven price of switchgrass from $75.75 per ton to about $68 per ton. A 10 percent increase in future commodity prices raised the regional average breakeven price for switchgrass from $75.75 per ton to about $83.40 per ton (Table 12).

Table 11. Switchgrass Yields, Production Costs, and Breakeven Farm-gate Prices, based on Soil Productivity Classes, Alternative Crop Price Projections, South Central North Dakota, 2008 through 2017

Soil Productivity Class	Switchgrass		Net Return on Composite Acre[b]	Breakeven Switchgrass Price
	Yield	Production Cost[a]		
	--- tons/acre ---	--- $/ton ---	--- $/acre ---	--- $/ton ---
	default crop price projections			
Low	2.67	40.26	18.40	47.14
Average	3.01	38.27	86.40	67.02
High	3.51	34.80	145.27	76.16
	crop price projections -10% lower than default			
Low	2.67	40.26	5.51	42.32
Average	3.01	38.27	66.51	60.40
High	3.51	34.80	119.30	68.76
	crop price projections -10% higher than default			
Low	2.67	40.26	31.29	51.96
Average	3.01	38.27	106.29	73.63
High	3.51	34.80	171.24	83.55

[a] Production cost among different soil productivity groups will differ even with the same switchgrass yield due to differences in foregone net returns during establishment year, which leads to differences in amortized establishment costs.

[b] Net returns are defined as returns to operator labor, management, equity, and land. Values represent an annualized equivalent from 2008-2017. Discount rate at 5 percent. Composite acre represents the average crop rotation in the study region expressed on an acreage basis.

Table 12. Switchgrass Yields, Production Costs, and Breakeven Farm-gate Prices, based on Producer Profitability Classes, Alternative Crop Price Projections, South Central North Dakota, 2008 through 2017

Profitability Class	Switchgrass		Net Return on Composite Acre[a]	Breakeven Switchgrass Price
	Yield	Production Cost		
	--- tons/acre ---	--- $/ton ---	--- $/acre ---	--- $/ton ---
	default crop price projections			
Average	3.01	37.58	122.81	75.75
Low 20%	2.53	47.25	21.59	55.79
20-40%	2.66	33.47	87.76	66.44
40-60%	2.77	36.26	92.82	69.71
60-80%	3.23	36.73	179.26	92.29
Top 20%	3.86	34.20	232.63	94.50
	crop price projections -10% lower than default			
Average	3.01	37.58	98.32	68.14
Low 20%	2.53	47.25	17.29	54.08
20-40%	2.66	33.47	70.26	59.87
40-60%	2.77	36.26	74.31	63.04
60-80%	3.23	36.73	143.52	81.21
Top 20%	3.86	34.20	186.24	82.47
	crop price projections -10% higher than default			
Average	3.01	37.58	147.30	83.36
Low 20%	2.53	47.25	25.90	57.49
20-40%	2.66	33.47	105.26	73.02
40-60%	2.77	36.26	111.33	76.38
60-80%	3.23	36.73	215.01	103.37
Top 20%	3.86	34.20	279.02	106.52

[a] Net returns are defined as returns to operator labor, management, equity, and land. Values represent an annualized equivalent from 2008-2017. Discount rate of 5 percent.

Changes in the Default Rate of Cost Increases

The model captures past cost increases and projects future rates of change in both direct and indirect expenses over the 2008 to 2017 period. However, recent changes in input prices, primarily from 2006 to 2008, have been historically high compared to changes in the previous decade. A number of factors (e.g., petroleum prices, biotechnology) could be presented that might validate claims that average future cost increases over the study period may not be equal to the historical rates of change. Alternatively, past rates of change in variable and fixed expenses may not be a good predictor of future rates of change in those costs.

In the soil productivity analysis, total variable and fixed costs for each crop were increased by an average annual value (dollars per acre). Changes in the quantity, type, and price of inputs are inherently included in the average annual figure. Thus, a change in the rate of increase is not necessarily reflective of only input price changes, but includes a combination of price, quantity, and substitution effects. Overall, the average annual rate of increase in variable and fixed expenses for each crop was adjusted upward by 10 percent.

An increase in the default rate of change for variable and fixed expenses, without adjusting commodity prices or yields, raised production costs for switchgrass and decreased net returns for traditional crops relative to the baseline. The combined changes lowered the breakeven prices for switchgrass across all soil productivity groups by less than $0.50 per ton. Breakeven prices also changed little (less than $1 per ton) when variable and fixed expenses were modeled to increase 10 percent less than default rates.

The effects of increasing and decreasing the rate of change in variable and fixed expenses in the producer profitability analysis also resulted in relatively small changes in breakeven switchgrass prices (Table 14). The magnitude of change in breakeven switchgrass prices were generally less than $1 per ton across all profitability groups.

Table 13. Switchgrass Yields, Production Costs, and Breakeven Farm-gate Prices, based on Soil Productivity Classes, Alternative Rates of Change in Production Costs, South Central North Dakota, 2008 through 2017

Soil Productivity Class	Switchgrass Yield	Switchgrass Production Cost	Net Return on Composite Acre[a]	Breakeven Switchgrass Price
	--- tons/acre ---	--- $/ton ---	--- $/acre ---	--- $/ton ---
	---------- default trend in cost increase ----------			
Low	2.67	40.26	18.40	47.14
Average	3.01	38.27	86.40	67.02
High	3.51	34.80	145.27	76.16
	---------- costs increase 10 percent greater than default values ----------			
Low	2.67	40.43	16.80	46.71
Average	3.01	38.43	84.80	66.64
High	3.51	34.93	143.67	75.83
	---------- costs increase 10 percent less than default values ----------			
Low	2.67	40.07	20.01	47.56
Average	3.01	38.11	88.01	67.39
High	3.51	34.65	146.88	76.47

[a] Net returns are defined as returns to operator labor, management, equity, and land. Values represent an annualized equivalent from 2008-2017. Discount rate at 5 percent. Composite acre represents the average crop rotation in the study region expressed on an acre basis.

Table 14. Switchgrass Yields, Production Costs, and Breakeven Farm-gate Prices, based on Producer Profitability Classes, Alternative Rates of Change in Cost Projections, South Central North Dakota, 2008 through 2017

Profitability Class	Switchgrass Yield	Switchgrass Production Cost	Net Return on Composite Acre[a]	Breakeven Switchgrass Price
	--- tons/acre ---	--- $/ton ---	--- $/acre ---	--- $/ton ---
	---------------------------------- default cost increases ----------------------------------			
Average	3.01	37.58	122.81	75.75
Low 20%	2.53	47.25	21.59	55.79
20-40%	2.66	33.47	87.76	66.44
40-60%	2.77	36.26	92.82	69.71
60-80%	3.23	36.73	179.26	92.29
Top 20%	3.86	34.20	232.63	94.50
	------------------------ cost increase 10% more than default rates ------------------------			
Average	3.01	38.02	120.49	75.46
Low 20%	2.53	47.77	21.18	56.15
20-40%	2.66	33.84	86.10	66.19
40-60%	2.77	36.70	91.06	69.52
60-80%	3.23	37.18	175.87	91.68
Top 20%	3.86	34.63	228.23	93.78
	------------------------ cost increase 10% less than default rates ------------------------			
Average	3.01	37.51	123.03	75.74
Low 20%	2.53	47.17	21.63	55.72
20-40%	2.66	33.41	87.91	66.44
40-60%	2.77	36.19	92.98	69.70
60-80%	3.23	36.67	179.58	92.34
Top 20%	3.86	34.14	233.04	94.54

[a] Net returns are defined as returns to operator labor, management, equity, and land. Values represent an annualized equivalent from 2008-2017. Discount rate of 5 percent.

DISCUSSION

The study results clearly showed that the economic competitiveness of switchgrass will be influenced by several factors. Unlike most of the previous research which has placed emphasis on estimating switchgrass production costs and drawing inferences on how competitive switchgrass might be based on the level of those costs, this study attempted to evaluate the prices required for switchgrass to be competitive with traditional crops by requiring switchgrass to generate the same level of net returns that could be generated by traditional crops.

This study calculated the breakeven price for switchgrass that covered production costs and matched the net returns from traditional crop production. However, farmers may decide to produce switchgrass for a price that does not generate a net return equal to traditional crops. Or, conversely, some producers may require that switchgrass provide a net return above what they could obtain from traditional crops. While economists like to focus on net returns or other measures of profitability when evaluating producers' decisions for which farm enterprises to adopt, decisions on what crops to raise are based on more than just net returns. Factors such as yield and income risk, crop rotations, soil characteristics, personal preference, production knowledge, financial and labor constraints, and other factors (e.g., whether the producer has livestock) often are important determinants in choosing farm enterprises. Currently, much is unknown about how these other factors may influence producers' willingness to raise dedicated energy crops. It is also possible that additional considerations, such as contract terms, land rental arrangements, producer age, and government policies or programs will all affect the decision to add a switchgrass enterprise to an existing farm. While net returns are a strong indicator of producer decisions, net returns will not be the only factor considered in the decision to raise switchgrass.

Assuming producers will want a return from switchgrass that is at a minimum, close to net returns from traditional crop production, the factors influencing future commodity prices will also influence prices farmers are willing to accept to produce switchgrass. Therefore, increases in commodity prices due to starch-based ethanol demand and/or bio-diesel demand have the potential to increase the farm-gate price for switchgrass. The connection between the two is straightforward if switchgrass competes directly for the same acreage (land resource) as corn or soybeans. Those competitions between corn and other crops have already been witnessed as the market has bid up corn prices to secure the acreage necessary to meet expected demand. However, as corn prices have risen, and as acreage has shifted to corn production, corresponding price increases have occurred in other crops–even crops that are not necessarily in direct competition for the same land resource as corn. Generally, as prices continue to escalate, so does the opportunity cost of growing traditional crops on all lands, even marginally productive lands. As the opportunity cost increases, so does the price needed for switchgrass to provide a competitive net return.

A better understanding of fertilization management would greatly improve the budgeting process for switchgrass. Fertilizer has increased in cost considerably in recent years, and represented the largest single variable input cost in the switchgrass budgets. However, the same rate was applied across all three soil productivity classes, largely because current knowledge is insufficient to prescribe the optimum level based on yield expectation associated with different soil productivity factors. Fertilization influences costs, but also has the ability to influence yields. Hopefully, future research will provide insights on the trade-offs associated with fertilization cost and yield response.

It could be argued that what the average switchgrass yield would be in the study region is not well understood. Further, what the average production cost might be for switchgrass is also not well understood. Much of the analysis for the profitability groups was based on generating differences in costs, yields, and returns within those groups based on percentages of the regional average for various crops. Thus, if the analysis uses a different regional average or the regional average is considerably different than modeled, the prices among those profitability segments will similarly change. However, analysis of producer records does show a very identifiable relationship indicating that production costs, yields, and prices received for traditional crops vary among those groups. The idea that breakeven switchgrass prices will vary depending upon the profitability of producers is valid, but the question of how much acreage is affected is problematic because the data used in the profitability analysis could not account for soil productivity. High profit producers might simply have better land or be better producers, or both. Similarly, the influence of soil productivity cannot be removed from the data on the low producer profitability groups–how much of those producers' position in the profitability stratification is due to the extent of low quality farm land? Ideally, some combination of soil assessment and management or profitability considerations would be required to answer those questions in the future.

The breakeven prices presented in this study should be considered preliminary given the paucity of switchgrass yield data, the unknowns with fertilization and yield response, recent and potential future changes in input prices, and the extent of future commodity price shocks linked to bio-fuels demand. The time frame for when commercial cellulosic ethanol production from herbaceous energy crops might become mainstream or widespread is unknown, but given current knowledge and activity levels in the bio-fuels industry, the time frame is certain to be sufficiently long to require re-examining the economics of herbaceous energy crops. Actually, it is quite likely that the economics of herbaceous energy crops will continually undergo evaluation as new information becomes available, or as prices, costs, and net returns from traditional crops change. While the breakeven switchgrass prices presented in this study are likely to change in the future, the value of this research lies less with the specific prices presented as it does with fostering an understanding of the factors that will influence the economic competitiveness of herbaceous energy crops with traditional crops. Further, energy industry leaders, policy makers, and researchers now have additional information with which to continue evaluations of the economic viability of cellulosic ethanol.

Some insights can be gained on the potential supply of switchgrass by considering the acreage of marginal soils in the study region. Soils that met the definition of marginal productivity in this study represented about 30 percent or about 567,000 acres in the study region. By comparison, as of September of 2007, the study region had 354,800 acres of land in the CRP (Farm Service Agency 2007). At an average yield of 2.67 tons per acre, assuming all marginal soils were converted to switchgrass, those lands could generate about 1.5 million tons of switchgrass annually with a farm-gate value of $71.2 million. However, it would be unlikely that all marginal land in the study region would be devoted to switchgrass over the range of prices evaluated in this study. Also, it is possible that at prices near the breakeven switchgrass price on marginal lands, some producers may choose to raise switchgrass on other, more productive soils. It is difficult to speculate on what a true supply function for switchgrass might look like given current data limitations. As mentioned earlier, as greater amounts of acreage are removed from traditional crop production, prices for those crops will react, which would also create a price increase for switchgrass as it would need to compete with ever increasing net returns from traditional crops.

CONCLUSIONS

Switchgrass yields and production costs are likely to vary considerably based on soil productivity. However, perhaps one of the greatest economic criteria influencing the breakeven price for switchgrass would be the opportunity cost or lost revenue from not producing traditional crops on the same acreage. The magnitude swing in net returns from traditional crops appears to be a substantial and critically important part of determining switchgrass prices. For example, on marginal lands, just under one-third of the breakeven switchgrass price is derived from the level of foregone net returns from traditional crops; the remaining two-thirds of the price covers production expenses. However, on the most productive lands, over 80 percent of the breakeven price of switchgrass is derived from the level of foregone net returns from traditional crops, while the remainder of the price covers production expenses. Essentially, the lower the net returns from traditional crops the more that breakeven switchgrass prices will approach the production cost for switchgrass. And, if switchgrass is going to compete against traditional crops on more productive lands, breakeven prices will be more heavily influenced by net returns from the displaced crops.

Regardless of methodology or scope, previous research on estimating switchgrass production costs revealed fairly consistent production costs for switchgrass, albeit with differences that were attributable to regional productivity or land values. Those assessments indicated that production expenses for switchgrass would be modest, and compete favorably with traditional crops at an economic level that would provide cellulosic ethanol plants with a relatively cheap feedstock. Those studies were conducted prior to the substantial increases in input prices and prior to the recent commodity price increases. Under current conditions of high input costs, escalating transportation costs, and given the increases in net returns from traditional crops, switchgrass, as a feedstock to a cellulosic ethanol plant, will be more expensive than previously estimated. Even if switchgrass production is targeted for marginal or low productivity soils, farm-gate switchgrass prices on those lands are still likely to be higher than previously thought. Of course, the future is uncertain, and much will change before the economic competitiveness of switchgrass as an energy crop is more fully understood.

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APPENDIX A

Forecasted Crop Budgets, 2008 through 2017

Appendix Table A1. Forecasted Crop Budgets for Producer Profitability Analysis, Kidder, Logan, and Stutsman Counties, North Dakota, 2008 through 2017

Budget Item	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	---------- wheat ----------									
Yield	46.51	47.83	49.14	50.45	51.77	53.08	54.40	55.71	57.02	58.34
Price	8.35	7.26	7.34	7.32	7.41	7.41	7.44	7.43	7.46	7.38
Other Product	0.16	0.15	0.15	0.16	0.16	0.17	0.17	0.17	0.18	0.18
Miscellaneous	17.91	16.02	16.64	17.04	17.69	18.14	18.67	19.09	19.62	19.86
Gov. Payments	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24
Gross Revenue	417.68	374.61	388.71	397.75	412.69	422.88	434.78	444.43	456.44	461.81
Direct Expenses	132.29	136.07	139.84	143.62	147.4	151.18	154.96	158.74	162.52	166.30
Overhead Expenses	37.11	37.84	38.57	39.29	40.02	40.75	41.48	42.20	42.93	43.66
Net Return	248.29	200.71	210.30	214.83	225.27	230.95	238.34	243.49	250.99	251.86
	---------- soybeans ----------									
Yield	30.12	30.12	30.12	30.12	30.12	30.12	30.12	30.12	30.12	30.12
Price	10.85	7.58	7.64	7.59	7.67	7.71	7.76	7.76	7.79	7.75
Other Product	0	0	0	0	0	0	0	0	0	0
Miscellaneous	15.79	11.03	11.13	11.05	11.17	11.22	11.30	11.30	11.34	11.28
Gov. Payments	11.61	11.61	11.61	11.61	11.61	11.61	11.61	11.61	11.61	11.61
Gross Revenue	354.19	250.90	252.97	251.32	253.79	255.03	256.68	256.68	257.51	256.27
Direct Expenses	136.69	138.48	140.27	142.05	143.84	145.63	147.42	149.21	151.00	152.79
Overhead Expenses	40.77	39.84	38.90	37.97	37.03	36.10	35.16	34.23	33.29	32.36
Net Return	176.73	72.59	73.80	71.30	72.92	73.30	74.10	73.25	73.22	71.13

Appendix Table A1. Continued

Budget Item	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	---------- corn ----------									
Yield	96.38	96.38	96.38	96.38	96.38	96.38	96.38	96.38	96.38	96.38
Price	5.15	3.45	3.36	3.41	3.44	3.48	3.48	3.50	3.47	3.47
Other Product	4.64	3.11	3.03	3.07	3.10	3.14	3.14	3.15	3.13	3.13
Miscellaneous	62.73	42.07	40.93	41.50	41.88	42.45	42.45	42.64	42.26	42.26
Gov. Payments	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31
Gross Revenue	576.04	390.37	380.17	385.27	388.67	393.78	393.78	395.48	392.08	392.08
Direct Expenses	213.81	219.34	224.86	230.38	235.90	241.42	246.95	252.47	257.99	263.51
Overhead Expenses	53.22	53.82	54.41	55.01	55.61	56.21	56.81	57.41	58.00	58.60
Net Return	309.01	117.22	100.90	99.88	97.16	96.14	90.02	85.60	76.08	69.96
	---------- barley ----------									
Yield	67.54	68.61	69.69	70.77	71.85	72.92	74.00	75.08	76.16	77.24
Price	5.33	3.16	3.12	3.17	3.20	3.27	3.32	3.36	3.41	3.46
Other Product	0.30	0.18	0.18	0.19	0.19	0.20	0.21	0.21	0.22	0.23
Miscellaneous	19.72	11.86	11.93	12.30	12.61	13.05	13.44	13.83	14.22	14.63
Gov. Payments	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
Gross Revenue	390.98	239.62	240.88	247.99	254.00	262.53	269.96	277.49	285.14	292.90
Direct Expenses	118.80	122.05	125.31	128.56	131.82	135.07	138.33	141.58	144.84	148.09
Overhead Expenses	42.43	43.62	44.80	45.99	47.18	48.36	49.55	50.73	51.92	53.11
Net Return	229.75	73.95	70.77	73.44	75.01	79.09	82.08	85.18	88.38	91.70

Appendix Table A1. Continued

Budget Item	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
					----- sunflowers -----					
Yield	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86	13.86
Price	23.35	14.29	14.24	14.32	14.39	14.53	14.59	14.65	14.69	14.72
Other Product	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Miscellaneous	19.32	11.82	11.79	11.85	11.91	12.02	12.07	12.12	12.15	12.18
Gov. Payments	11.43	11.43	11.43	11.43	11.43	11.43	11.43	11.43	11.43	11.43
Gross Revenue	354.32	221.22	220.59	221.77	222.72	224.76	225.65	226.58	227.13	227.66
Direct Expenses	143.72	147.44	151.15	154.87	158.59	162.30	166.02	169.73	173.45	177.17
Overhead Expenses	42.20	42.20	42.20	42.20	42.20	42.20	42.20	42.20	42.20	42.20
Net Return	168.40	31.59	27.24	24.70	21.93	20.26	17.43	14.64	11.48	8.29
					----- alfalfa -----					
Yield	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94
Price	61.00	61.00	59.00	60.00	59.00	61.00	60.00	60.00	60.00	60.00
Other Product	0.95	0.95	0.92	0.94	0.92	0.95	0.94	0.94	0.94	0.94
Miscellaneous	4.78	4.78	4.62	4.70	4.62	4.78	4.70	4.70	4.70	4.70
Gov. Payments	8.18	8.18	8.18	8.18	8.18	8.18	8.18	8.18	8.18	8.18
Gross Revenue	131.94	131.94	127.88	129.91	127.88	131.94	129.91	129.91	129.91	129.91
Direct Expenses	35.42	35.42	35.42	35.42	35.42	35.42	35.42	35.42	35.42	35.42
Overhead Expenses	27.36	27.36	27.36	27.36	27.36	27.36	27.36	27.36	27.36	27.36
Net Return	69.15	69.15	65.09	67.12	65.09	69.15	67.12	67.12	67.12	67.12

Appendix Table A2. Switchgrass Establishment and Production Inputs, Farm Profitability and Soil Productivity Analyses, Kidder, Logan, and Stutsman Counties, North Dakota

Input Item and Description	Establishment	Production
Switchgrass seed planting rate (lbs of pls/acre)	7.0	na
Switchgrass seed cost (per pound of pls)	$7.00	na
Cover crop seed planting rate (bu/acre of oats)	1.5	na
Cover crop seed cost (per bushel)	$2.00	na
Cover crop yield (tons/acre) (low, average, high productivity soils)	0.77, 1.29, 1.69	na
Cover crop price ($/ton)	$25.00	na
Reseed probability	10%	na
Nitrogen cost ($/lb of 46% Urea)	0.181	0.607
Phosphorus ($/lb)	0.250	0.642
Nitrogen application rate (lbs/acre)	0	60
Phosphorus application (lbs/acre)	0	6
Broadleaf control ($/acre) (cost in production year represented an average annual cost based on 1 broadleaf treatment over the 10-year production period)	$19.22	$1.92
Grass control ($/acre) (cost in production year represented an average annual cost based on 2 grass control treatments over the 10-year production period)	na	$6.00
Weight per round bale harvested (lbs/bale)	na	1,000
Planting sequence: one pass field cultivator, grain drill		
Harvesting sequence: single fall harvest, swather, round baler		

Appendix Table A3. Switchgrass Establishment Budget, Average Profitability, Kidder, Logan, and Stutsman Counties, North Dakota, 2007

Item		Values
Gross revenue		
Switchgrass yield	tons/ac	0.0
Price	$/ton	$0.00
Cover crop (oats hay)	tons/ac	1.25
Price (cover crop)	$/ton	$25.00
Government payment		$12.64
Total revenue		$43.89
Direct expenses		
Seed		$52.00
Chemical		$19.22
Custom hire		$31.11
Seed bed preparation (field cultivator)	$5.64	
Planting (grain drill)	$8.43	
Spraying	$7.86	
Swathing	$2.45	
Baling	$6.73	
Reseeding charges		$6.61
Interest		$3.46
Miscellaneous		$0.74
Total direct		$113.13
Overhead expenses		$17.05
Net returns to unpaid labor, management, equity, and land		($86.28)
Foregone net returns from composite acre		$60.91
Total cost of establishment		($147.19)
Amortization of establishment costs		$19.06

Appendix Table A4. Switchgrass Production Budget, Average Profitability, Kidder, Logan, and Stutsman Counties, North Dakota, 2008

Item		Values
Gross revenue		
Yield	tons/ac	3.01
Price (intentionally put to zero for computation of breakeven value)	$/ton	$0.00
Government payment		$10.96
Total revenue		$10.96
Direct expenses		
Fertilizer		$40.24
Chemical		$7.42
Custom hire		$23.75
Fertilizer application	$4.24	
Spraying	$1.27	
Swathing	$2.69	
Baling	$18.09	
Interest		$2.27
Miscellaneous		$0.49
Total direct		$74.17
Overhead expenses		$23.01
Amortization of establishment costs		$19.06
Net Returns to unpaid labor, management, equity, and land		($105.29)

Appendix Table A5. Switchgrass Establishment Budget, Low Productivity Soils, Kidder, Logan, and Stutsman Counties, North Dakota, 2007

Item		Values
Gross revenue		
Switchgrass yield	tons/ac	0.0
Price	$/ton	$0.00
Cover crop (oats hay)	tons/ac	0.77
Price (cover crop)	$/ton	$25.00
Total revenue		$19.33
Direct expenses		
Seed		$61.40
Chemical		$19.20
Fuel and Lubrication		$10.99
Repairs		$12.16
Reseeding charges		$8.28
Interest		$4.31
Miscellaneous		$0.84
Total direct		$117.18
Indirect expenses		
Miscellaneous overhead		$3.50
Machinery depreciation		$10.12
Machinery investment		$7.31
Indirect expenses		$20.95
Net returns to unpaid labor, management, and land		($118.80)
Foregone net returns from composite acre		($4.69)
Total cost of establishment		($123.49)
Amortization of establishment costs		$15.99

Appendix Table A6. Switchgrass Establishment Budget, Average Productivity Soils, Kidder, Logan, and Stutsman Counties, North Dakota, 2007

Item		Values
Gross revenue		
Switchgrass yield	tons/ac	0.0
Price	$/ton	$0.00
Cover crop (oats hay)	tons/ac	1.29
Price (cover crop)	$/ton	$25.00
Total revenue		$32.14
Direct expenses		
Seed		$61.40
Chemical		$19.20
Fuel and Lubrication		$12.04
Repairs		$12.56
Reseeding charges		$8.35
Interest		$4.40
Miscellaneous		$1.37
Total direct		$119.32
Indirect expenses		
Miscellaneous overhead		$3.87
Machinery depreciation		$10.80
Machinery investment		$7.77
Indirect expenses		$22.44
Net returns to unpaid labor, management, and land		($109.62)
Foregone net returns from composite acre		($52.95)
Total cost of establishment		($162.57)
Amortization of establishment costs		$21.05

Appendix Table A7. Switchgrass Establishment Budget, High Productivity Soils, Kidder, Logan, and Stutsman Counties, North Dakota, 2007

Item		Values
Gross revenue		
Switchgrass yield	tons/ac	0.0
Price	$/ton	$0.00
Cover crop (oats hay)	tons/ac	1.69
Price (cover crop)	$/ton	$25.00
Total revenue		$42.35
Direct expenses		
Seed		$61.40
Chemical		$19.20
Fuel and Lubrication		$12.88
Repairs		$12.89
Reseeding charges		$8.40
Interest		$4.46
Miscellaneous		$1.79
Total direct		$121.02
Indirect expenses		
Miscellaneous overhead		$4.14
Machinery depreciation		$11.34
Machinery investment		$8.13
Indirect expenses		$23.61
Net returns to unpaid labor, management, and land		($102.28)
Foregone net returns from composite acre		($94.13)
Total cost of establishment		($188.00)
Amortization of establishment costs		$24.35

Appendix Table A8. Switchgrass Production Budget, Low Productivity Soils, Kidder, Logan, and Stutsman Counties, North Dakota, 2008

Item		Values
Gross revenue		
Yield	tons/ac	2.67
Price (intentionally put to zero for computation of breakeven value)	$/ton	$0.00
Total revenue		$0.00
Direct expenses		
Herbicides		$7.69
Fertilizer		$28.80
Fuel and Lubrication		$13.68
Repairs		$7.93
Miscellaneous		$7.47
Operating Interest		$2.46
Total Direct		$68.03
Indirect expenses		
Miscellaneous overhead		$4.03
Machinery depreciation		$8.72
Machinery investment		$6.24
Total Indirect		$18.99
Amortization of establishment costs		$15.99
Net Returns to unpaid labor, management, and land		($103.08)

Appendix Table A9. Switchgrass Production Budget, Average Productivity Soils, Kidder, Logan, and Stutsman Counties, North Dakota, 2008

Item		Values
Gross revenue		
Yield	tons/ac	3.01
Price (intentionally put to zero for computation of breakeven value)	$/ton	$0.00
Total revenue		$0.00
Direct expenses		
Herbicides		$7.69
Fertilizer		$28.80
Fuel and Lubrication		$14.47
Repairs		$8.19
Miscellaneous		$7.80
Operating Interest		$2.51
Total Direct		$69.46
Indirect expenses		
Miscellaneous overhead		$4.24
Machinery depreciation		$9.13
Machinery investment		$6.52
Total Indirect		$20.63
Amortization of establishment costs		$21.05
Net Returns to unpaid labor, management, and land		($112.33)

Appendix Table A10. Switchgrass Production Budget, High Productivity Soils, Kidder, Logan, and Stutsman Counties, North Dakota, 2008

Item		Values
Gross revenue		
Yield	tons/ac	3.50
Price (intentionally put to zero for computation of breakeven value)	$/ton	$0.00
Total revenue		$0.00
Direct expenses		
Herbicides		$7.69
Fertilizer		$28.80
Fuel and Lubrication		$15.79
Repairs		$8.61
Miscellaneous		$8.35
Operating Interest		$2.60
Total Direct		$71.84
Indirect expenses		
Miscellaneous overhead		$4.60
Machinery depreciation		$9.81
Machinery investment		$6.98
Total Indirect		$21.39
Establishment of establishment costs		$24.35
Net Returns to unpaid labor, management, and land		($117.58)