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Economic analysis of private and public benefits of corn, switchgrass and mixed grass systems in Eastern South Dakota

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Abstract

The objective of this research is to develop an economic analysis of different crop mix biofuels programs for meeting ethanol and sustainability demands. Primary data are from South Dakota State University field experiments on farms located in east-central South Dakota. The data include 4 years of field data, three crop systems (mixed grass, switchgrass and corn), two residue treatments (no removal, removal of biomass), and three landscape positions (back slope, crest and foot slope). A representative farm model and five scenarios are developed to conduct a full budget analysis over a 12-year period. Public benefits are evaluated, using the benefit transfer method to value ecosystem services, by allocating a dollar value to three environmental variables; carbon sequestration, reduction of sedimentation and pheasant production. Stochastic simulation results are compared for each of the five scenarios, one with only annualized net private returns, and one including the value of environmental benefits. Results indicate that: (1) the conventional continuous corn scenario has the highest net returns over the 12-year budget, (2) carbon sequestration represents 80% of the environmental benefits, and (3) the added economic value of ecosystem services does not provide enough incentives for farmers to convert from corn production to grass production.

Key words: biofuels, switchgrass, crop budgets, environmental benefits, South Dakota

Introduction

Energy production from biofuels feedstock is often viewed as a potential approach to reduce reliance on oil, stabilize energy prices, mitigate climate change and improve rural economic development[1–3]. Controversies about how sustainable corn-based ethanol can be used to replace fossil fuels include the large amount of arable lands required for the crops, the impact on grain supply, the land use change effects, the carbon emission balance, the subsidies, and the protective trade measures that were provided to the ethanol industry for many years. While additional acreage for the production of biofuels feedstock can be found from utilizing previously uncropped lands and by converting production from the growing of other crops, corn grain-based ethanol development will still be limited by land availability[4,5]. Devoting all US corn and soybean acreage to ethanol and biodiesel production would offset only 12 and 6%, respectively, of gasoline and diesel consumption for transportation fuel[6]. The Northern Plains region, one of the major corn growing areas of the nation, is expected to experience a shift in crop production from providing food and fiber to an emphasis on energy farming.

Recent attention has been focused on second-generation biofuels from cellulosic feedstock, such as perennial grasses and crop residues. However, the increase in corn stover supply is associated with reductions in soil organic carbon, increases in nitrogen application and increases in corn prices[7]. Switchgrass is identified as a promising crop because of its high yield compared with other perennial grasses, its efficiency in using nutrients, and its growing conditions and equipment use are similar to those for corn[8]. Cellulosic grasses for biofuels production play an important role for the environment in controlling nutrient loss, reducing erosion, maintaining soil carbon level, extending habitat for wildlife, reducing input requirements and so forth[5]. However, perennial grasses that would produce cellulosic ethanol are not yet grown on a commercial scale.

The overall objective of this research is to develop an economic analysis of different crop mixing biofuels

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programs to meet ethanol and sustainability demands. This analysis is separated into two parts: the private profitability and the environmental benefits. The specific objectives of this paper are to (1) identify which systems (mixed grass, switchgrass and corn) on which landscape positions are the most profitable for farmers; (2) determine the variability of net-returns depending on the expected yields and prices; and (3) evaluate the environmental benefits of these practices.

This study is part of a research project conducted at South Dakota State University. The paper intends to establish which system provides sufficient economic incentives for farmers in response to the increasing demand for ethanol. Because profitability is one of the main goals of farmers, farmers will produce cellulosic feedstock only if the expected economic return from including it in their production system is equivalent or higher than the returns from the most profitable conventional crops.

Literature Review

The Energy Independence and Security Act (EISA), signed into law in 2007, is the most important legislation concerning biofuels production[1]. EISA requires a minimum of 15 billion gallons of corn-based ethanol by 2015 and the use of 21 billion gallons of advanced biofuels by 2022.

Profitability of ethanol production for farmers

Biofuels production is planned to drastically increase over the next several years and to significantly impact the commodity markets[9,10]. Corn has been the preferred source of ethanol feedstock in the USA since the Energy Policy Act of 1978 provided a 40-cent tax exemption per gallon of ethanol to blenders of gasoline and ethanol[11]. Since that time, the corn-based ethanol industry has successfully fought for a variety of subsidies, tariffs and mandates that support corn's use as the predominant ethanol feedsource[12]. However, the use of corn as the main input for ethanol production raises concerns about the negative environmental impacts associated with its production. An alternative to this production is cellulosic ethanol which relies on non-food feedstock; crop residues or perennial grasses. The economic potential of cellulosic crops depends on yields, cost of production, input requirements, technology and also on energy market substitutes such as natural gas.

Khanna estimated the breakeven total costs of switchgrass to be between US$277.8 and 264.2 per metric ton of dry matter, while it was between US$111.3 and 93.1 per metric ton of dry matter for corn stover[13]. Mooney et al. completed a study focused on management practices and production costs of switchgrass varying across different production environments[14]. The authors found that switchgrass production costs range from US$49 per metric ton in the well-drained level upland environment to US$77 per metric ton in the marginal environment poorly drained flood plain. Another study completed by Bangsund et al. in south-central North Dakota generated costs of producing switchgrass over a range of soil productivity and farm profitability scenarios[15]. Production costs were US$44 per metric ton on marginal soil and US $38 per metric ton on highly productive soil. They found that the opportunity cost from not producing traditional crops on the same acreage is the major economic criterion influencing the switchgrass breakeven price.

Given the high initial investment and the multi-year production process, market risk is a crucial subject to understand farmers' willingness to adopt bioenergy crops. Farmers face two main sources of uncertainty; production and prices. Major cellulosic energy crops are perennial and need several years to reach their maximum yield potential. Therefore, it represents a long-term commitment and investment for farmers. Song et al. found that if the land is currently in a corn–soybean rotation, the minimum switchgrass return from converting the land to switchgrass should be between US$259 and US$778 ha^{-1} depending on the risk assumptions[16].

Environmental, social and economic welfare of biofuels production

These new crop mixing systems have been introduced in the EISA legislation for the purpose of improving sustainability and protecting the environment[1]. Biofuels not only provide a renewable source of energy, but also have the potential to produce a wide range of environmental benefits; fertilizer and chemical input requirements are fairly low relative to conventional crops, switchgrass provides better habitat for wildlife, native mixed prairie grass enhances biodiversity in the landscape, and so forth[13,17].

The major limitation of studying ecosystem services is the method used to attach a dollar value to these services. The method most often used is the benefit transfer method that 'estimates economic values by transferring existing benefit estimates from studies already completed for another location or issue'[18]. Babcock et al. provide estimates of the costs associated with inducing conversion of land from traditional crops to switchgrass[19]. They also examine the potential environmental consequences of conversion and studied three land-use scenarios. The first scenario, entirely switchgrass, is predicted to reduce sediment by 84%. The second scenario, continuous corn, is predicted to increase sediment yield by 23%. The third scenario, a combination of switchgrass and continuous corn, gives mixed results with a reduction in sediments of 19%. This study is very useful for quantifying the effects of growing switchgrass compared with corn on sedimentation; however, it does not monetize these changes.

A study published by Gascoigne et al. (p. 1715) 'uses biophysical values derived for the Prairie Pothole Region of North and South Dakota, in conjunction with value transfer methods, to assess environmental and economic

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tradeoffs under different policy relevant land use scenarios over a 20 year period'[20]. The authors valued and compared three indicators; carbon sequestration, reduction in sedimentation and waterfowl production, across four land-use scenarios, each involving different combinations of Conservation Reserve Program (CRP), native prairie and cropland hectares. They identified the ecosystems services by land use, quantified them with a biological value, and monetized these values using benefit transfer methods. Finally, the authors standardized these values to a per-hectare basis to compare them with other land incomes. The method developed by Gascoigne et al. is used in this paper[20]. Gascoigne et al. found that the aggressive conservation scenario, in which all remaining native prairie in the study area is preserved and there is a 50% increase in CRP/Wetland Reserve Program (WRP) lands in the region that are substituted away from overall cropland, increases all ecological measures. When native prairie loss is minimized and CRP lands increased, the societal benefits are the highest. All other scenarios reduced all ecological measures modeled. The scenario converting the native prairie land into cropland results in a social welfare loss of more than US$4 billion.

Concerns about energy security and environmental sustainability are creating interest in new practices, such as second-generation biofuels, and legislation that help reach independence from fuel imports and protects the environment. Greater emphasis on perennial grasses in cropping systems could lead to changes in environmental, social and economic welfare. Several studies have shown environmental improvements of this renewable energy source on greenhouse gas emissions, soil erosion and so forth[1,4,13]. However, none of these studies are focused on farm-level analysis, which is the main focus of this study.

Research Design

Main sources of data

Primary data for this research come from South Dakota State University field experiments on farms located in east-central South Dakota[21]. It is part of a larger project called Eco Sun Prairie farm. This information includes 4 years of field data from 2008 to 2011. Each year contains data collected from three cropping systems (mixed grass, switchgrass and corn), with each system subject to two residue treatments (no removal, and excess removal of biomass), and three landscape positions (back slope, crest and foot slope). To facilitate the analysis, each rotation is split depending on its landscape position and residue treatment. The field experiments include two sites; Colman (no-till system) and Flandreau (conventional tillage). There is no mixed grass in Flandreau. Each of the 30 combinations is analyzed in a full capital budget.

Farming practices on these lands are similar to local farming practices. Biomass and grain yields are measured; erosion potential is estimated; nitrogen, phosphate and potassium distribution within the landscape is determined as well as basic soil quality (aggregate stability, soil texture, bulk density and organic carbon distribution).

Conceptual model: methods of analysis for private benefits

A full capital budget analysis is developed for each of the 30 management options to determine the breakeven price and the profitability of each system at the simulation farm level. It is focused not only on net returns, but also on gross returns, total direct costs and total costs. Cellulosic feedstock are perennial crops and, according to experts, a normal switchgrass and mixed grass stand can be harvested and produce to their full potential for up to 10–15 years. Therefore, the capital budget is based on price, cost and management scenarios for a 12-year period, and includes the annualized costs of establishing switchgrass and mixed grass.

A continuous corn rotation is introduced in the analysis as comparison. Several types of data are needed to develop the budget analysis: yields, hectares, input prices, output prices, government payments, crop insurance, machinery costs, land charge and drying costs.

The bioenergy farm model. Because these data need to be applied to a commercial scale farm model for analysis, a 404.7 ha (1000 acres) energy farm model is developed for nine counties in east-central and southeast South Dakota (Brookings, Clay, Lake, Lincoln, McCook, Minnehaha, Moody, Turner and Union)[22]. This model is standardized for natural resource, land use, policy program and management characteristics[23].

Different scenarios based on soil properties and yields. Five different scenarios are established based on the yields of the experimental fields and on the soil properties described by Web Soil Survey (Table 1). The results of profitability and net returns are generalized to each scenario for the farm model.

Budget generalization to a 12-year period. Switchgrass and mixed grass are perennial grasses and are not harvested during the first year of implementation; therefore, the budgets are generalized over a 12-year period. The method used is the net present value of a stream of net benefits (B_0,…, B_{11}) received over a period of 12 years:

$$\mathrm{PV}\ [B_0, \ldots, B_{11}] = \sum\nolimits_0^{11} Bi/(1+0.03)^i.$$

A 3% discount rate is used, as this is the central rate presented in the US government assessment[24]. Compared to recent literature, our data show that the first 3 years of grass yields recorded are very low compared to what a farmer should expect. The fourth year of grass yields from the experimental plots is closer to yield estimates in the literature, around 9 metric tons ha^{-1}[13,14,20]. Therefore, the net return of the fourth year is used as if each year a farmer could generate this net return. The net return is then discounted at a 3% rate. For corn, from the first year

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Table 1. Description and justification of the five scenarios.

Scenario	Corn (%)	Switchgrass	Mixed grass (%)	Landscape position	Justification
1	100	0	0	Not considered	
2	0	50	50	Not considered	Ensure the diversity of revenues and limit the risks
3	80	10	10	Not considered	Agricultural land use average grass yield of 9 metric tons ha^{-1} necessary
4	50	25	25	Not considered	Crop productivity index, corn grown on soils with index >80
5	25	37.5	37.5	Corn on slope <2% grass on slope >2%	

Table 2. Annual average crop prices for South Dakota. Source: NASS.

	2008	2009	2010	2011
Corn for grain (US$ per metric ton)	148.8	127.2	200.8	238.2
Grass 1. Hay other w/o alfalfa (US$ per metric ton)	86.0	77.2	76.1	100.3
Grass 2. All hay (US$ per metric ton)	102.5	88.2	85.4	130.1

of our data record, the yields correspond to the average yield estimated in the literature. Therefore, the average annual net returns for the first 4 years of data is calculated and then this average is considered as the net return a farmer could get every subsequent year. This is also discounted at a 3% rate. This method allows for making the comparison between budgets and scenarios without trying to project any future prices or yields that are uncertain, especially for switchgrass and mixed grass.

Input prices. Input prices are determined based on the management schedules given by the researchers of the EcoSun Prairie farm experimental fields[23]. Seed prices for corn, as well as fertilizer and herbicides prices, are established using data from the National Agricultural Statistics Service (NASS) and the South Dakota Agriculture bulletins for 2008, 2009, 2010 and 2011. Seed prices for switchgrass and mixed grass are determined from interviews with experts from Millborn Seed and data generated from the experimental fields. In this model, only corn is considered to be a farm program crop eligible for farm program subsidy payments and crop insurance. Machinery costs and corn drying costs are estimated using the Iowa Custom Rate of the appropriate years[25]. Land charge is established with the average cash rental rates of the nine counties in the study area found through the South Dakota Agricultural Land Market Trends[26].

Output prices. South Dakota annual average corn prices are used, and are collected from the NASS website[27]. Perennial grass production is not yet well-established; therefore, prices are difficult to find. Two price scenarios are considered; the first one is based on 'all hay' prices and the second one based on the 'other hay (non-alfalfa hay)' prices, both specific to the state of South Dakota. Experts at Millborn Seed were also interviewed and confirmed the price range (Table 2).

Conceptual model: methods of analysis for public benefits

Another study was conducted to estimate the public benefits of the bioenergy crops systems. To do so, a dollar value was allocated to environmental variables that impact sustainability and welfare. The valuation method uses biophysical values from the experimental fields of Eco Sun Prairie Farm, as well as value transfer methods to assess environmental tradeoffs under different land-use scenarios. The valuation method is composed of three essential steps: (1) identify ecosystem services by land use; (2) quantify the biological values associated with those services and annualize them to a per hectare value; and (3) monetize those values using economic methods. By standardizing measurement to a per hectare value, ecosystem services can be compared with other land incomes.

In this paper, the benefit transfer method is used to monetize three non-market ecosystem services; carbon sequestration, reduction of sedimentation and pheasant production. The data for the first two services come from the EcoSun Prairie farm experiment, and the pheasant production data come from the South Dakota Department of Game, Fish and Parks[28]. Previous research completed in other regions in the Northern Plains shows that these three services are the most valuable in our study area[20]. These three ecosystem services are analyzed and valued for two specific land covers; switchgrass and mixed grass scenarios are compared with a conventional continuous corn system. Results from each ecosystem service are generalized to the simulation farm and five different scenarios. It should be noted that this study measures only the individual contributions of the indicators and makes no attempt to combine the indicators in any fashion. In particular, the ability to capture and sequester carbon may be significantly reduced when soil is lost through erosion and, thus, lead to greater environmental damage and long-term profit losses than are derived in this work.

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Carbon sequestration data. Soil organic matter is estimated separately for upland and wetland zones. For each zone, data are collected for summit, shoulder, upper back slope, lower back slope and foot slope positions[29]. To estimate potential carbon gains or losses from changing land cover, soil organic matter data are converted into soil organic carbon using a conversion factor of 1.724[30]. Then soil organic carbon is converted to a per hectare basis following the equation: C (Mg ha^{-1}) = C (g kg^{-1}) $de \times 10^{-2}$, where $d = 1.30$ g cm^{-3} and $e = 15$ cm are the bulk density and thickness, respectively, representative for agricultural surface soil (EcoSun Prairie farm experts). To calculate the carbon sequestration change of converting cropland to grasslands, the sequestration potential of cropland is found in the literature. The value used is 4% by weight[31]. This means that in 1 kg of soil there are 40 g of soil organic matter. This value was confirmed by Douglas Malo, professor in soil sciences Department at South Dakota State University. The mean estimate for cropland is then subtracted from those of grassland to arrive at the potential net gain from conversion of cropland to grassland. The soil data of the EcoSun Prairie farm are collected 4 years after the conversion of cropland to grasslands. Therefore, the net differences in mean estimates between cropland and grassland are divided by four to find the sequestration rate of Soil Organic Carbon. Once carbon flux has been determined, it is converted into units of carbon dioxide equivalents (CO_2e) by multiplying by the conversion factor of 3.67.

The annualized carbon sequestration output can be converted to a dollar value by using estimates of the social cost of carbon, carbon market prices or estimates of the cost of carbon capture and storage[32]. In 2009, a US government interagency working group calculated the social cost of carbon estimates to be used in regulatory impact analysis[24]. The four social costs of carbon estimates chosen by the group were US$5 per ton of CO_2e, US$21per ton of CO_2e, US$35 per ton of CO_2e and US$65 per ton of CO_2e (2007, US$). The first three estimates are based on the average social costs of carbon across models and socio-economic and emissions scenarios at the 5, 3 and 2.5% discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the social costs of carbon distribution. For more information on these estimates see the technical support document realized by the US Working Group under Executive Order 12866[24].

The amount of CO_2 sequestered/emitted is multiplied by the social cost of carbon price for each year. The monetary values are discounted back to the present with a 3% real discount rate. Since the first part on private profitability is calculated on a 12-year scale, the timeline applied here is 12 years using the formula of the present value of a stream of net benefit ($B_0, \ldots, B_{11}$) received over a period of 12 years: PV $[B_0, \ldots, B_{11}] = \sum_0^{11} Bi/(1 + 0.03)^i$.

Reduction of sedimentation. Numerical data on erosion estimates are based on tillage erosion and water erosion models for specific management systems, the main causes of erosion on the farm, and the climate from the county. Sedimentation is more difficult to estimate as most of the eroded soil is translocated and deposited in the fields. However, the typical range for a sediment delivery ratio in agricultural systems is around $25 \pm 15\%$.

Per ton benefit values for reduced soil erosion are derived from Hansen and Ribaudo[33]. This study estimates the economic values that both the public and private sectors place on fluctuations of soil quality. In the study area defined earlier the average value is US$0.455 per metric ton. The total benefit is calculated by multiplying the economic soil loss values by the changes in erosion (from cropland to grassland). These results are summed across the 12-year period and a 3% discount rate is used to calculate the net present value.

Pheasant habitat sustainability. The experimental fields at the EcoSun Prairie farm did not allow for the collection of unbiased information on wildlife in the area as the medium-sized plots under study were insufficient in size to provide the necessary habitat for some species and necessitated the use of benefit transfer methodology. For this benefit transfer estimate, the value of one pheasant of US$57.15 is found by dividing the total expenditures by the total number of pheasant harvested[28]. The average number of pheasants present on the fields in the study area is found by dividing the number of pheasants harvested by the number of hectares operated in farms. The number of additional pheasants in a grass field compared with a corn field has not been estimated; therefore, we use data from CRP grass fields. Nielson et al. found an estimated 22% increase in ring-necked pheasant counts for every increase of 318 ha of CRP vegetation[34]. In reality, the relationship between the size increase of CRP fields and the number of pheasants is not linear. However, to simplify this analysis we consider it linear.

Conceptual model: methods of analysis for the simulation of risky scenarios

Capital budgets are important for farmers, but it is also essential to understand the variation in crop rotation preferences under different risk preferences. Variability of prices and yields are major sources of risk in agriculture. In this study, a stochastic dominance and a stochastic efficiency is used to order risky alternatives. Simetar©, a simulation Excel add-in, provides a method for analyzing data and simulating the effects of risk[35]. It is used to stochastically simulate prices and yields of all five scenarios.

Two simulations are realized into Simetar©. The first includes only private profitability, and the second one includes private profitability and environmental variables. Both of the simulations are based on the net returns calculated in the capital budget. This approach allows the

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evaluation of the effects of environmental benefits on profitability.

Output prices are simulated using a normal distribution. This requires using the average yearly price and the standard deviation calculated from the monthly prices for each year. The 4 years of corn prices are used, as well as the two different levels of grass prices. Yields of corn and grass from each of the 30 rotations are simulated using an empirical distribution.

In the second simulation, environmental variables are also simulated. Social costs of carbon are simulated using a truncated normal distribution centered on the value of US$21 per ton of CO_2e. The four social costs of carbon estimated by the US government interagency working group are used to calculate the standard deviation. The amount of carbon sequestered is simulated with an empirical distribution using the data found for the different types of land and landscape position. The amount of erosion is simulated with an empirical distribution using the low, high and mean values from the EcoSun Prairie farm data. The value for every additional pheasant is simulated with a normal distribution centered on the price used of US$57.15. The standard deviation is calculated from the price for each different county of the study area. The pheasant number is simulated with an empirical distribution using the data for each county in the study area.

These environmental values and other variables of interest (indemnity payment, gross return, total cost and net return) are entered in the simulation engine of Simetar© and run through 500 iterations for each year, each scenario and each variable. The 6000 samples of net returns from each scenario are compared with each other using stochastic dominance and probability analysis.

Empirical Results and Discussion

Private profitability budgets

The budget analysis is conducted for the years 2008, 2009, 2010 and 2011. Results for returns to management and labor, gross returns and total costs are discussed in the following section. Using these results, the five risky scenarios can be ranked from best to worst. However, the stochastic simulation and the level of risk are not included in this part and are analyzed in a later section.

Returns to management and labor for the 4 years of field experiments. For the first 2 years of data, switchgrass and mixed grass have negative net returns due to low or no yields during the establishment period. For the last 2 years, switchgrass and mixed grass net returns are positive, yields are high enough and costs are low after the years of establishment. Over the entire period, mixed grass seems to have lower net returns than switchgrass, mainly due to lower yields.

The year 2008 has positive net returns for corn, but lower than for the subsequent years and the yields were high but the price was low. In 2009, the net returns were negative. This is due to the extremely high drying costs and low yields. As a result of high corn prices in the final 2 years, net returns increase to their highest values. For the overall period, corn has much higher net returns per acre than either grass.

Switchgrass and mixed grass are reputed to have high yields and are well adapted on marginal lands. Numerous studies have expectations on replacing corn on these lands by switchgrass or mixed grass. However, the 4 years of field plot data do not allow us to confirm these expectations. For the rest of the study the average yield for all positions is used.

Net returns, total costs and gross returns for the simulation farm. The previous per acre results are generalized to a 404.7 ha (1000 acre) simulation farm and to a 12-year budget to take into consideration the year of establishment needed for switchgrass and mixed grass. Five scenarios are compared for gross returns, net returns and total costs (Table 3).

Gross returns are the highest for scenario 1, followed by scenario 3, scenario 4, scenario 5, and finally scenario 2. Overall, this pattern exists for net returns and costs as well, with the rotation with the larger amount of corn ranking the highest. For the 12-year period, the scenario with continuous corn has a cumulative net return of US$2,336,240, while the scenario with only switchgrass and mixed grass has a net return of US$317,500 or US$941,320 depending on the grass price level considered. Corn is highly profitable especially in the first years when switchgrass and mixed grass are being established and production output is low. However, direct costs per acre for corn are much higher than establishment costs and harvesting costs for switchgrass and mixed grass.

Environmental benefits results

Environmental benefits on a per hectare basis. The biophysical results for ecosystem services increase with the amount of grass considered in each scenario. For each ecosystem service, soil organic carbon sequestration, soil erosion and pheasant production, the total stock values for the 12-year period are calculated, as well as the annual flow.

The net present value of soil organic carbon varies across landscape positions and, of course, across the social cost of carbon chosen. The parameters used are therefore very important because these values are extremely variable; from US$7.8 ha^{-1} yr^{-1} in the uplands back slope positions with the social costs of carbon of US$5 per ton of CO_2e to US$303.5 ha^{-1} yr^{-1} in the uplands foot slope with the social costs of carbon of US$65 CO_2e. These estimates could be potentially very important for a decision maker to choose between grass and corn production.

The soil erosion net present values are much lower than for soil organic carbon. Over a 12-year period, soil erosion

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Table 3. Net present value of the simulation farm production over a 12-year period for the five scenarios and the two grass price levels (thousands US$).

	Hectares			Grass price level 1 (in thousand US$)			Grass price level 2 (in thousand US$)		
	Corn	**SWG**	**MXG**	**Gross returns**	**Total costs**	**Net returns**	**Gross returns**	**Total costs**	**Net returns**
Scenario 1	404.7	0.0	0.0	8252	5916	2336	8252	5916	2336
Scenario 2	0.0	202.3	202.3	2235	1918	317	2859	1918	941
Scenario 3	323.7	40.5	40.5	7049	5116	1932	7173	5116	2057
Scenario 4	202.3	101.2	101.2	5244	3917	1326	5556	3917	1638
Scenario 5	101.2	151.8	151.8	3632	2722	910	4075	2722	1352

Grass price level 1: hay other w/o alfalfa (US$ per metric ton) 2008: 86; 2009: 77; 2010: 76; 2011: 100.
Grass price level 2: all hay (US$ per metric ton) 2008: 103; 2009: 88; 2010: 85; 2011: 130.

Table 4. Net present value [NPV US$] of annual flow and total stock by ecosystem services and simulation farm scenarios.

Parameters	
Simulation farm	404.7 ha
Social cost of carbon	US$21 per ton of CO_2e
Erosion value	Mean

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Corn (ha)	404.7	0.0	323.7	202.3	101.2
Grasslands (ha)	0.0	404.7	80.9	202.3	303.5
Annual flow (US$)					
Soil organic carbon, US$	0.00	22,049	4410	11,024	16,536
Erosion, US$	0.00	4951	99	2476	3713
Pheasant, US$	0.00	425	85	213	319
Total, US$	0.00	27,425	5485	13,712	20,569
NPV of total stock (US$) over 12-year period					
Soil organic carbon, US$	0.00	226,056	45,211	113,028	169,542
Erosion, US$	0.00	50,761	10,152	25,381	38,071
Pheasant, US$	0.00	4358	872	2179	3268
Total, US$	0.00	281,175	56,235	140,588	210,882

Values for scenarios 2–5 are calculated considering scenario 1 as the baseline.

on average could bring to a farmer US$125.48 ha^{-1}, while carbon sequestration could bring US$558.50 ha^{-1}. Therefore, in the decision-making process, soil erosion seems less important than carbon sequestration.

Pheasant production can also be a potential factor for a decision maker. By growing more grass, a farmer could potentially attract more pheasants and therefore, have another source of revenue. However, after calculations, this potential revenue is very low. On a 12-year period, from the additional pheasant attracted by grass production, a farmer would only make an additional US$10.80 ha^{-1}. Therefore, for a decision maker, carbon sequestration would be a preferred factor of decision.

Public benefits generalized to the simulation farm. The first scenario used as a reference for comparison considers only corn, and therefore, no additional value from ecosystem services is added. The second scenario, which considers only grass, is the one with the highest additional value from ecosystem services. It would generate overall US$281,175 over the 12-year period, or an annual flow of US$27,425. Nearly 80% of the ecosystem service value is from soil organic carbon (Table 4).

The three other scenarios are a mix of corn and grass. The third scenario would generate an overall value of US$56,235 over the 12-year period, and an annual flow of US$5,485. Soil organic carbon sequestration is once again the ecosystem service with the highest value. The fourth scenario generates an annual flow of US$13,712 and a total stock of US$140,588 over the 12-year period. The fifth scenario generates an annual flow of US$20,569 and a total stock over the 12-year period of US$210,882.

These estimates are largely influenced by the increase in soil organic carbon due to growing grass. Soil organic carbon sequestration generates more than 80% of the total net present value of the environmental services in each scenario. The soil erosion generates 18% of the total stock value while the pheasant production generates only 2%. Obviously, these ratios would be greatly modified if the price of a ton of CO_2e was different. In this analysis

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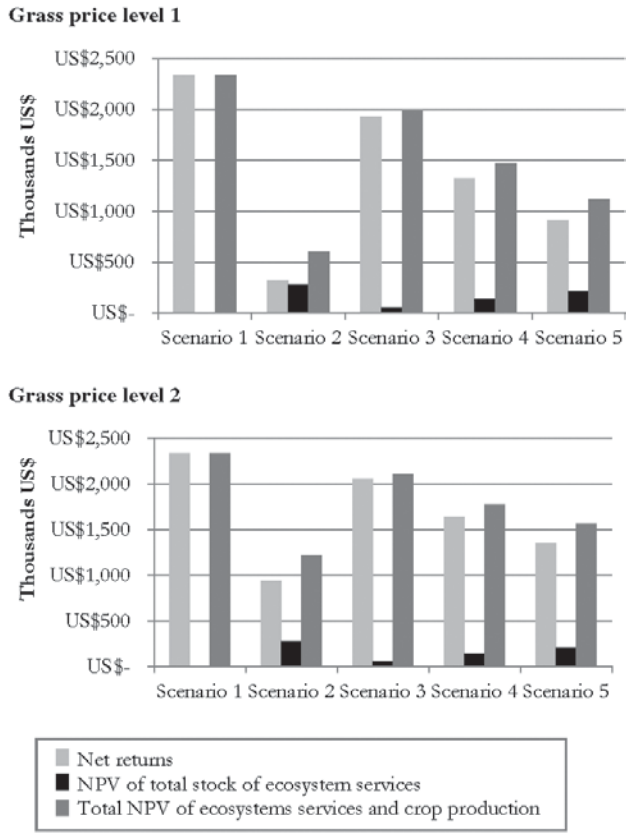

Figure 1. Net present value (thousand $) of the total stock of ecosystem services and of crop production for the simulation farm over a 12-year period, with a social cost of carbon of US$21 per ton of CO_2e.

the social cost of carbon of US$21 per ton of CO_2e is used since it is the central value suggested by the US government interagency group[24]. However, given its considerable dominance in the study, if we look at the lowest price of US$5 per ton of CO_2e, soil organic carbon sequestration has less impact on the overall net present value of total stock. It only represents 49% of the total stock, while soil erosion represents 47%, and pheasant production 4%. This result is also found by Gascoigne et al. who showed that a large investment in native prairie conservation programs would provide a net benefit to society of over US$1 billion over the 20-year policy time period, and that most of these benefits would come from carbon sequestration increases[20]. However, the increase in net benefits to society with the increase of grass proportion remains the same across land use scenarios.

Environmental benefits coupled with private profitability for the simulation farm. When environmental results are coupled with the capital budget analysis, the ranking in scenario based on net returns does not change (Fig. 1). The scenario with only switchgrass and mixed grass is the one with the highest additional value from ecosystem services, generating an increase of US$281,175 over the 12-year period. However, the additional value added by the ecosystem services does not overcome the lost returns

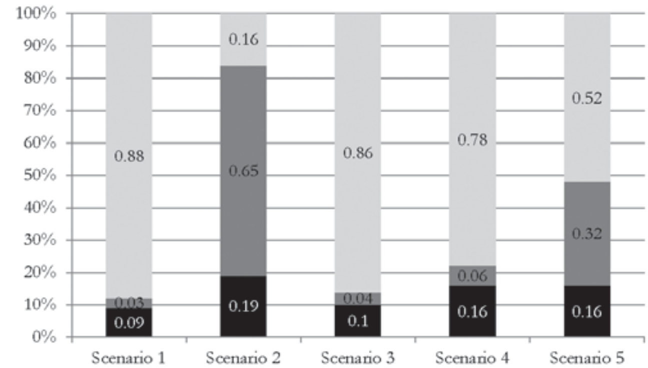

Figure 2. Probabilities of net returns to management and labor < US$0 and > US$100,000 for the simulation farm per year: environmental benefits *are not* included into percentages.

from not growing and selling corn. If the scenarios had to be ranked on the basis of total net returns, scenario 1 would be the highest ranked, even if it does not consider any additional benefits from environmental values. The ecosystem services value is therefore not high enough to influence farmers' decisions to convert their land from corn to grass. Hence, incentives for environmental benefits must be much higher to be competitive with the net returns of crop production.

Stochastic analysis

Stochastic Dominance with Respect to a Function (SDRF) and Stochastic Efficiency with Respect to a Function (SERF) are performed through Simetar©. These analyses evaluate the five scenarios based on alternative risk preferences. SDRF and SERF are performed using 6000 samples for each scenario. The results are presented through probabilities of net return and stochastic efficiency ranking schedule.

StopLight analysis. The StopLight chart, or probabilities of net returns, represents the probabilities of target values. Simetar© calculates and reports the probability of achieving a preferred target (US$100,000) and probability of failing to achieve a minimum target (US$0). A value of $100,000 is chosen to represent an overall net return of US$247 ha^{-1} yr^{-1} (US$100/acre yr^{-1}), and US$0 is chosen as the lower target to represent the probability of loss.

Without the environmental benefits included in the analysis, scenario 1 and scenario 3 have the lowest probability of losses with 9 and 10%, respectively (Fig. 2). The worst performing scenario is scenario 2 with 19% probability of losses. The more grass is grown in the scenario the worse is the probability of positive net returns. Scenario 2, which considers grass only, has a probability of net returns higher than US$100,000 per year of 16% while the scenario 1 has a probability of 88%.

With the environmental benefits included in the analysis, the probabilities change slightly. The probability

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Table 5. Stochastic efficiency analysis of scenario without environmental benefits.

	Slightly risk averse →				Extremely risk averse
Rank	0.00–0.0000082	0.0000083–0.0000166	0.0000167–0.0000666	0.0000667–0.0001332	> 0.0002
1st	Scenario 1	Scenario 1	Scenario 3	Scenario 3	Scenario 3
2nd	Scenario 3	Scenario 3	Scenario 1	Scenario 1	Scenario 2
3rd	Scenario 4	Scenario 5	Scenario 5	Scenario 2	Scenario 1
4th	Scenario 5	Scenario 4	Scenario 2	Scenario 5	Scenario 5
5th	Scenario 2	Scenario 2	Scenario 4	Scenario 4	Scenario 4

Table 6. Stochastic efficiency analysis of scenarios with environmental benefits.

	Slightly risk averse →					Extremely risk averse
Rank	0.00–0.0000082	0.0000083–0.0000166	0.0000167–0.0000249	0.0000250–0.0001166	0.0001167–0.0001666	> 0.0001667
1st	Scenario 1	Scenario 3	Scenario 3	Scenario 3	Scenario 3	Scenario 3
2nd	Scenario 3	Scenario 1	Scenario 1	Scenario 5	Scenario 5	Scenario 2
3rd	Scenario 4	Scenario 5	Scenario 5	Scenario 1	Scenario 2	Scenario 5
4th	Scenario 5	Scenario 4	Scenario 2	Scenario 2	Scenario 1	Scenario 1
5th	Scenario 2	Scenario 2	Scenario 4	Scenario 4	Scenario 4	Scenario 4

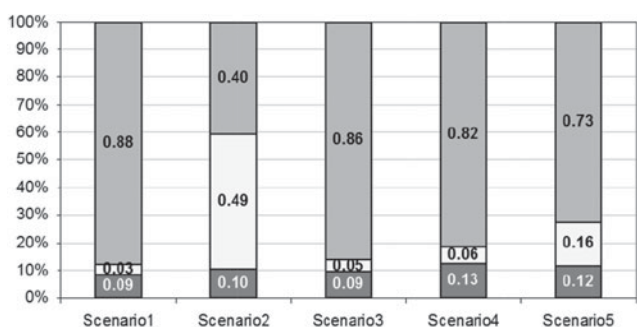

Figure 3. Probabilities of net returns to management and labor < US$0 and > US$100,000 for the simulation farm per year: environmental benefits are included into percentages.

of losses goes to 10% for scenario 2, 13 and 12% for scenario 4 and 5, respectively (Fig. 3). The probability of net returns higher than $100,000 goes to 40% for scenario 2, and 73% for scenario 5. For the other scenarios, the environmental benefits only slightly improved the probabilities of net returns higher than US$100,000.

In this analysis, the scenarios with the higher proportion of corn would be preferred over the scenarios with the higher proportion of grass. The environmental benefits slightly change the probabilities of net returns but not enough to change the ranking of preferred scenario.

Risk aversion. Simetar© allows the user to input different risk aversion coefficients (RAC) to analyze decision makers' choices under any level of risk. The interval is determined to be between an RAC of 0 when a producer is risk neutral, and an RAC of 0.0002 when a producer is risk averse (Table 5). When a producer is risk neutral, the preferred scenario is scenario 1. The remaining scenarios are ranked based on the corn proportion. As the RAC value increases to 0.0002 (risk averse), scenario 1 moves to the third preferred scenario and is replaced by scenario 3 (80% corn and 20% grass). Although the continuous corn scenario ranks high in most of the RAC categories, a high standard deviation causes it to drop in ranking when a decision maker becomes more risk averse. However, as producer risk aversion increases, the ranking increases for the two scenarios (2 and 5) with the highest proportion of grass.

When environmental benefits are included in the analysis, the ranking of scenarios for a risk neutral producer is the same as if the environmental benefits were not included. When a producer is risk averse, the ranking is almost similar, except for scenarios 1 and 5, which switch positions between third place and fourth place (Table 6). This means that, even if environmental benefits as calculated in this study are materialized and paid to farmers, the preferred scenarios would not change. The incentives from ecosystem services are not high enough to influence farmers' decisions.

The difference between continuous corn and all other scenarios is the risk premium that would be needed at the RAC to be indifferent between the two scenarios. When no environmental benefits are included in the analysis, scenarios 3 and 2 move above the continuous corn scenario as RAC increases, while scenarios 4 and 5 continue to rank below the continuous corn scenario. When the environmental benefits are included in the analysis, only scenario 4 never moves above the continuous corn scenario (Table 6).

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These results also show that as producers become more risk averse, scenario 3 (80% corn and 20% grass) becomes the most preferred. A more risk-averse producer prefers minimal variation in net returns compared with fluctuating gains or losses and thus may prefer a mixture of corn and grass compared to continuous corn.

Discussion and conclusion

Switchgrass and mixed grass are starting to become a part of South Dakota agriculture, but as this study shows, it is far from producing the same net returns as corn production. The availability of better, more drought tolerant hybrids allowed corn to be preferred over perennial grass production. As corn hybrids become more advanced, and if corn prices and yields stay at the current level or higher, the conversion from corn production to prairie grasslands production is not expected to occur.

The future of grassland prairie production depends on potential commercial uses of grass. If switchgrass or mixed grasses are used as feedstock for ethanol, further research will be needed to increase yields and reduce costs. For switchgrass or mixed grass to be commercially viable, there must be available markets, and for producers to change their practices there must be a sufficient financial incentive. If the incentives have to be done on the environmental friendly characteristic of growing grasses, the main environmental attribute that policy makers should be focused on is carbon sequestration. In the United States, carbon trade was taking place on a voluntary basis; however, in some other global regions such as Europe, carbon trading is mandatory. This system could be developed in the US and may convince farmers to switch from conventional corn production to prairie grasslands. A green market could also be developed for the reduction in soil erosion and sedimentation in the rivers due to growing grasses. Also, increased grass production favors increases pheasant production and hunting, which may be another revenue source for landowners and producers.

Conducting similar studies in other regions of the USA would help to investigate and understand the incentive levels needed to convert cropland to grassland. If similar studies were to be conducted, a corn–soybean scenario should be introduced for a more realistic cropping pattern comparison in eastern South Dakota. Experimental data should also span a longer period. The first years of the conversion are the establishment period, and some experts think that switchgrass and mixed grass can easily reach a yield of 9–12 metric tons ha^{-1}. However, in the field plot data evaluated here the maximum yield is 6.9 metric tons ha^{-1}. Moreover, other output possibilities could be studied. Switchgrass and mixed grass do not yet have a commercial market; therefore, they are sold as valued hay for feeding. However in the future, they have potential to become one of the main sources of supply for second generation biofuels, and the value of a ton of switchgrass or mixed grass has the potential to increase compared to a ton of conventional hay. On the EcoSun Prairie farm, the main revenue comes from selling grass seed. Therefore, seed yields should be recorded and studied, and if the price of seed could be introduced, the net returns from grass are likely to increase. Grass can also be used as prairie to raise cattle, which can be sold as a high value product. For grass to be viable all these streams of revenue should be studied and a mix of all of them could be economically compared to corn and hay productions.

On the other hand, corn stover can be grazed or used as feedstock for ethanol production. Therefore, this could increase the corn dominance over grass production. The use of corn stover for ethanol production would increase the costs of growing corn because it would require special harvesting and handling methods. For now, no price is clearly determined; the value of corn stover depends on the costs of operating the ethanol plant, and the price of substitute products.

The result of this study provides some initial insight for ecosystem services valuation in east central and southeast South Dakota. Only three ecosystem services are considered in this study. Even if they are perceived as top priorities, other ecosystem services could be included. Moreover, with the uncertainty of the price and value of each ecosystem service, it may be useful to evaluate grass production with higher social cost of carbon, higher price for soil erosion, or pheasant harvest.

The overall conclusion of this paper is that the conventional continuous corn production consistently performs better than any of the other scenarios including grass production alone, in terms of profitability. The addition of ecosystem services values does not seem to provide enough incentives to convince farmers to convert their corn production to grass production. Higher payments from federal or state government for ecosystem conservation, and more competitive prices for all streams of grass production might provide incentives sufficiently high for farmers to switch from conventional cropland to grassland.

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